45/- net

MORRIS'

HUMAN ANATOMY

NINTH EDITION

PUBLISHER'S NOTE

MORRIS' ANATOMY—NINTH EDITION

This edition has been very carefully and thoroughly revised. Some parts have been almost entirely rewritten, this applying especially to the following sections:—Special Sense Organs, Urogenital System, Glands of Internal Secretion, Osteology, and Articulations. The section on Clinical and Typographical Anatomy has been distributed among the other sections. The changes recommended by the Nomenklatur-Kommission (NK) are indicated in parenthesis, immediately after the BNA terms. The illustrations have received special attention—a considerable number of those used in the previous edition have been improved and 253 new pictures, of which 92 are in color, have been included to take the place of those deleted.

MORRIS'

HUMAN ANATOMY

A COMPLETE SYSTEMATIC TREATISE

EDITED BY

C. M. JACKSON, M. S., M. D., LL. D.

PROFESSOR AND DIRECTOR OF THE DEPARTMENT OF ANATOMY, UNIVERSITY OF MINNESOTA

THE CONTRIBUTORS

LESLIE B. AREY, Northwestern University.

CHARLES R. BARDEEN, University of Wisconsin.

ELIOT R. CLARK, University of Pennsylvania.

J. F. GUDERNATSCH, Formerly Cornell University Medical College.

IRVING HARDESTY, Tulane University of Louisiana.

C. M. JACKSON, (Editor) University of Minnesota.

FRANKLIN P. JOHNSON, University of Oregon.

RICHARD E. SCAMMON, University of Minnesota.

J. PARSONS SCHAEFFER, Jefferson Medical College.

H. D. SENIOR, University and Bellevue Hospital Medical College, N. Y.

CHARLES R. STOCKARD, Cornell University Medical College.

R. J. TERRY, Washington University, St. Louis.

NINTH EDITION

ELEVEN HUNDRED AND SIXTY-SIX ILLUSTRATIONS
FIVE HUNDRED AND FOURTEEN PRINTED IN COLORS

PHILADELPHIA

P. BLAKISTON'S SON & CO., Inc.

1012 WALNUT STREET

PRINTED IN U. S. A.
BY THE MAPLE PRESS COMPANY, YORK, PA.

CONTRIBUTORS TO NINTH EDITION

LESLIE B. AREY, Northwestern University.

CHARLES R. BARDEEN, University of Wisconsin.

ELIOT R. CLARK, University of Pennsylvania.

J. F. GUDERNATSCH, Formerly Cornell University Medical College.

IRVING HARDESTY, Tulane University of Louisiana.

C. M. JACKSON, University of Minnesota.

FRANKLIN P. JOHNSON, University of Oregon.

RICHARD E. SCAMMON, University of Minnesota.

J. PARSONS SCHAEFFER, Jefferson Medical College.

H. D. SENIOR, University and Bellevue Hospital Medical College, N. Y.

CHARLES R. STOCKARD, Cornell University Medical College.

R. J. TERRY, Washington University, St. Louis.

For arrangement of subjects and authors see page ix

EDITOR'S PREFACE TO THE NINTH EDITION

The present edition has continued the plan of systematic discrimination in the use of sizes of type. The larger type is used for the more fundamental facts, and the smaller type for details. This plan has been found useful for the orientation of the beginner. While emphasizing the more important aspects it makes conveniently accessible the related details which from time to time will be needed for reference in connection with the student's later work.

For those who desire more information, bibliographic references are scattered throughout the text, and in addition, a special list is given at the close of each section. These brief lists are intended merely as a guide to put the student 'on track' of the original literature.

Each of the various sections has been carefully revised, and some of them almost entirely rewritten. This applies especially to the section on the Sense Organs by Professor Arey, the section on the Urogenital System by Professor Johnson, the section on the Glands of Internal Secretion by Professor Gudernatsch, and the sections on Osteology and Articulations by Professor Terry. The section on Clinical and Topographical Anatomy has been discontinued, the material being distributed among the other sections where it more properly belongs. While each author is responsible for the subject matter of the corresponding section, the editor has endeavored to make the whole work as uniform and complete as possible.

As to nomenclature, the BNA (in Anglicized form) has been continued. This system has received general recognition throughout the world. In the present work, the BNA Latin form as heretofore is indicated *in brackets*, except where it differs but slightly from, or is identical with, the Anglicized term. A revision of the BNA system by the Nomenklatur-Kommission (NK) is now in progress, and some of the more important changes are also indicated as synonyms in the present edition. Another change recommended by the NK, but not indicated in the present edition, is the replacement of the terms anterior, posterior, superior and inferior, by the morphologically preferable terms ventral, dorsal, cephalic and caudal, respectively.

In the illustrations representing muscular attachments, the origins are colored red and the insertions blue, as in previous editions. Ligamentous attachments are shown by dotted black lines.

In the present edition, many new figures have been added and a large number of the older figures have been improved. Due credit has been given for borrowed illustrations. Special acknowledgment is made of our indebtedness to the works of Toldt, Spalteholz, Rauber-Kopsch, Poirier and Charpy, Braus, and Fick. For the generosity of the publishers in this connection, and for the hearty coöperation of the contributors in the revision of the various sections, the editor desires to express his grateful appreciation.

C. M. JACKSON.

MINNEAPOLIS.

CONTENTS

SECTION IV

THE ARTICULATIONS

By Robert J. Terry A.B., M.D.

SECTION V

THE MUSCULATURE

By C. R. Bardeen, A.B., M.D.

SECTION VI

THE BLOOD-VASCULAR SYSTEM

By Harold D. Senior, M.D., F.R.C.S.

SECTION VII

THE LYMPHATIC SYSTEM

By Eliot R. Clark, A.B., M.D.

SECTION VIII

THE NERVOUS SYSTEM

BY IRVING HARDESTY, A.B., PH.D.

SECTION IX

THE SPECIAL SENSE-ORGANS

BY LESLIE B. AREY, PH.D.

SECTION X

THE DIGESTIVE SYSTEM

BY C. M. JACKSON, M.S., M.D., LL.D.

SECTION XI

THE RESPIRATORY SYSTEM

BY J. PARSONS SCHAEFFER, PH.D., M.D.

SECTION XII

THE UROGENITAL SYSTEM

BY FRANKLIN P. JOHNSON, PH.D., M.D.

SECTION XIII

THE GLANDS OF INTERNAL SECRETION

By J. F. Gudernatsch, Ph.D.

INTRODUCTION

By C. M. JACKSON, M.S., M.D., LL.D.

PROFESSOR OF ANATOMY, UNIVERSITY OF MINNESOTA

ANATOMY, as the term is usually employed, denotes the study of the structure of the human body. Properly, however, it has a much wider significance, including within its scope not man alone, but all animal forms, and, indeed, plant forms as well; so that, when its application is limited to man, it should be termed human anatomy. *Human anatomy*, then, is the study of the structure of the human body, and stands in contrast to, or rather in correlation with, *human physiology*, which treats of the functions of the human body. The two sciences, anatomy and physiology, include the complete study of man's physical organization and functional activities.

In the early history of the sciences these terms sufficed for all practical needs, but as knowledge grew, specialization of necessity resulted and new terms were from time to time introduced to designate special lines of anatomical inquiry. With the improvement of the microscope a new field of anatomy was opened up and the science of *histology* came into existence, including the portion of anatomy which deals with the minuter details of structure. So, too, the study of the development of the body gradually assumed the dignity of a more or less independent study known as *embryology* or developmental anatomy. The study of the structural changes due to disease is included in the science of *pathology;* so that the term anatomy is sometimes limited to the study of the macroscopic structure of normal adult organisms.

It is clear, however, that the lines of separation between anatomy, histology, embryology, and pathology are largely arbitrary. Microscopic anatomy necessarily grades off into macroscopic anatomy; the development of an organism is a progressive process and the later embryonic or fetal stages shade gradually into the adult; and structural anomalies lead insensibly from the normal to the pathological domains. Furthermore it is found that in its individual development the organism passes through stages corresponding in part to those of its ancestry in evolution; in other words, ontogeny repeats phylogeny. A comprehensive study of anatomy must therefore include more or less of the other sciences. Since an appreciation of the significance of structural details can be obtained only by combining the studies of anatomy (including histology) and embryology, and since, further, much light may be thrown on the significance of embryological stages by comparative studies, anatomy, embryology, and comparative anatomy form a combination of sciences by which the structure of an organism, the significance of that structure, and the laws which determine it are elucidated. For this combination it is convenient to have a single term, *morphology*, a word meaning literally the science of form.

In morphological comparisons the term *homology* denotes similarity of structure, due to a common origin in the evolution of organs or parts; while *analogy* denotes merely physiological correspondence in function. Thus the arm of man and the wing of a bird are homologous, but not analogous, structures; on the other hand, the wing of a bird and the wing of an insect are analogous, but not homologous. *Serial homology* refers to corresponding parts in successive segments of the body.

Nomenclature.—Formerly there was much confusion in the anatomical nomenclature, due to the multiplicity of names and the lack of uniformity in using them. Various names were applied to the same organs and great diversity of usage prevailed, not only between various countries, but also even among authors of the same country. Recently, however, a great improvement has been made by the general adoption of an international system of anatomical nomenclature. This system was first adopted by the German Anatomical Society at a meeting in Basel, in 1895, and is hence called the Basel Nomina Anatomica, or briefly, the BNA. The BNA provides each term in Latin form, which is especially desirable for international usage. Each nation, however, is expected to

translate the terms into its own language, wherever it is deemed preferable for everyday usage. Thus in the present work the Anglicised form of the BNA is generally used. Where not identical, however, the Latin form is added once for each term in a place convenient for reference, and is designated by enclosure in brackets[ ]. Where necessary the older terms have also been added as synonyms.

The Commission by whom the BNA was prepared for the German Anatomical Society included eminent anatomists representing various European nations. The work of the Commission was very thorough and careful, and extended through a period of six years. Among the guiding principles in the difficult task of selecting the most suitable terms were the following: (1) Each part should have one name only. (2) The names should be as short and simple as possible. (3) Related structures should have similar names. (4) Adjectives should be in opposing pairs. A few exceptions were found necessary, however.

On account of its obvious merits, the BNA system has been generally adopted throughout the civilized world, and the results are very satisfactory. Comparatively few new terms have been thereby introduced, over 4000 of the 4500 names in the BNA corresponding almost exactly to older terms already in use by the English-speaking nations. Certain minor defects have been criticized; but most of these are removed by a revision that is now (1932) in progress. In accordance with vertebrate morphology, the terms *anterior* and *posterior* are to be replaced by *ventral* and *dorsal;* and the terms *superior* and *inferior* by *cranial* and *caudal*, respectively. In the head region, where these terms become ambiguous, special adjectives have been used. These latter, together with the more important of the other changes recommended, are indicated in the present edition in parenthesis, following the BNA terms, and are designated in each case by 'NK' (Nomenklatur-Kommission).

Abbreviations.—Certain frequently used words in the BNA are abbreviated as follows: a., arteria (plural, aa., arteriæ); b., bursa; g., ganglion; gl., glandula; lig., ligamentum (plural, ligg., ligamenta); m., musculus (plural, mm., musculi); n., nervus (plural, nn., nervi); oss., ossis (or ossium); proc., processus; r., ramus (plural, rr., rami); v., vena (plural, vv., venæ).

Terms of position and direction.—The exact meaning of certain fundamental terms used in anatomical description must be clearly understood and kept in mind. In defining these terms, it is supposed that the human body is in an upright position, with arms at the sides and palms to the front.

The three **fundamental planes** of the body are the sagittal, the transverse and the frontal. The vertical plane through the longitudinal axis of the trunk, dividing the body into right and left halves, is the *median* or *midsagittal* plane; and any plane parallel to this is a *sagittal* plane. Any vertical plane at right angles to a sagittal plane, and dividing the body into front and rear portions is a *frontal* (or coronal) plane. A plane across the body at right angles to sagittal and coronal planes is a *transverse* (*horizontal*) plane.

Terms pertaining to the front of the body are *ventral* (*anterior*); to the rear, *dorsal* (*posterior*); upper is designated as *cranial* (*superior*); and lower as *caudal* (*inferior*).

The term *medial* means nearer the midsagittal plane, and *lateral*, further from that plane. These terms should be carefully distinguished from internal (inner) and external (outer), which were formerly synonymous with them. *Internal*, as now used (BNA), means deeper i. e., nearer the central axis of the body or part; while *external* refers to structures more superficial in position. *Proximal*, in describing a limb, refers to position nearer the trunk; while *distal* refers to a more peripheral position.

Adverbial forms are also employed, e. g., anteriorly or ventrally (forward, before); posteriorly or dorsally (backward, behind); superiorly or cranially (upward, above); and inferiorly or caudally (downward, below).

It should also be noted that the terms ventral, dorsal, cranial and caudal are independent of the body posture, and therefore apply equally well to corresponding surfaces of vertebrates in general with horizontal body axis. On this account these terms are preferable, and will doubtless ultimately supplant the terms anterior, posterior, superior and inferior, as recommended by the NK revision.

The discrimination in the use of several similar terms of the BNA should also receive attention. Thus *medianus* (median) refers to the median plane. *Medialis* (medial) means nearer the median plane and is opposed to lateral, as above stated. *Medius* (middle) is used to designate a position between anterior and posterior, or between internal and external. Between medialis and lateralis, however, the term *intermedius* has been used (but it is dropped by the NK). Finally, *transversalis* means transverse to the body axis; *transversus*, transverse to an organ or part; and *transversarius*, pertaining to some other structure which is transverse.

Parts of the body.—The primary divisions of the human body (fig. 1) are the head, neck, trunk and extremities. The *head* [caput] includes *cranium* and *face* [facies]. The *neck* [collum] connects head and trunk. The *trunk* [truncus] includes *thorax*, *abdomen*, and *pelvis*. The *upper extremity* [extremitas superior]

includes *arm* [brachium], *forearm* [antibrachium], and *hand* [manus]. The *lower extremity* [extremitas inferior] includes *thigh* [femur], *leg* [crus], and *foot* [pes].

Each of the parts mentioned has further subdivisions, as indicated in fig. 1. The cranium includes: *crown* [vertex]; *back* of the head [occiput]; *frontal* region

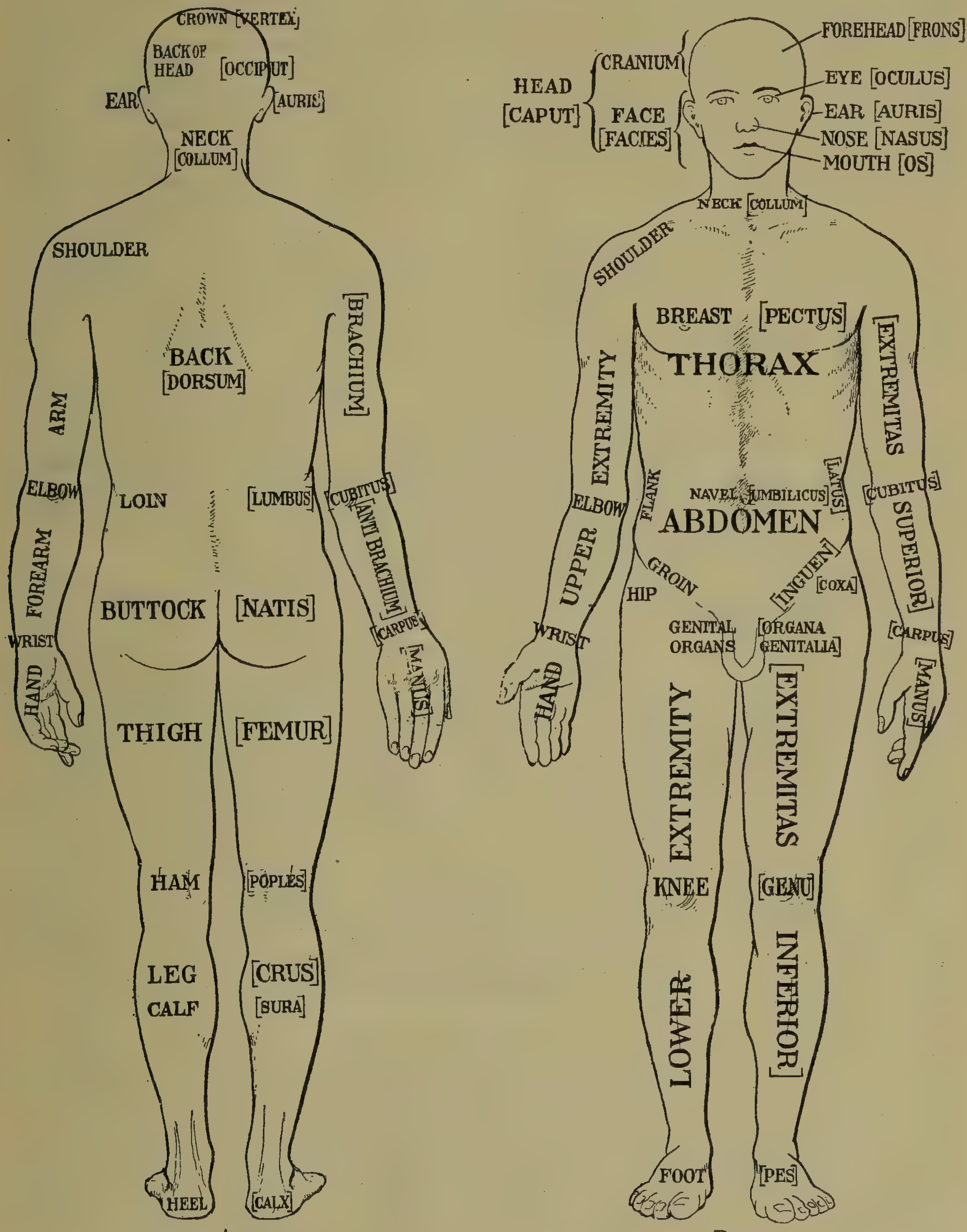


FIG. 1.—PARTS OF THE HUMAN BODY. A, Posterior view. B, Anterior view.

[sinciput], including *forehead* [frons]; *temples* [tempora]; *ears* [aures], including *auricles* [auriculæ].

The face includes the regions of the *eye* [oculus], *nose* [nasus], and *mouth* [os], the subdivisions of which will be given later under the appropriate sections.

The thorax includes: *breast* [pectus]; *mammary gland* [mamma]; and *thoracic cavity* [cavum thoracis]. The *back* [dorsum] includes the vertebral column [columna vertebralis]. The abdomen includes: *navel* [umbilicus]; *flank* [latus]; *groin* [inguen]; *loin* [lumbus]; and the *abdominal cavity* [cavum abdominis]. The

pelvis includes: *pelvic cavity* [cavum pelvis]; *genital organs* [organa genitalia], *buttocks* [nates], separated by a cleft [crena ani] at the *anus*. The *hip* [coxa] connects the pelvis with lower extremity.

In the lower extremity, the thigh is jointed to the leg by the *knee* [genu]. The foot includes: *heel* [calx]; *sole* [planta]; *instep* [tarsus]; *metatarsus;* and five *toes* [digiti I–V], including the *great toe* [hallux] and *little toe* [digitus minimus].

The upper extremity is joined to the thorax by the *shoulder*. The arm is joined to the forearm at the *elbow* [cubitus]. The hand includes: *wrist* [carpus]; *metacarpus,* with *palm* [vola or palma] and *back* [dorsum manus]. The five *fingers* [digiti I–V] include: *thumb* [pollex], *index* finger [index]; *middle* finger [digitus medius] *ring* finger [digitus annularis] and *little* finger [digitus minimus].

Organ-systems.—Each of the various parts of the body above outlined is composed of various *organs,* and the groups of related organs make up *organ-systems.*

The various organ-systems are treated as special branches of descriptive anatomy. The study of the *bones* is called *osteology;* of the *ligaments* and *joints, syndesmology* (or arthrology); of the *vessels, angiology;* of the *muscles, myology;* of the *nervous system, neurology;* and of the *viscera, splanchnology.* Further subdivisions are also made. The viscera, for example, include the *digestive* tract, *respiratory* tract, *urogenital* tract, etc.

Tissues and cells.—The body, as above stated, has various parts, each of which may be subdivided into its component systems and organs. A further analysis reveals a continued series of structural units of gradually decreasing complexity. Thus each organ is found to consist of a number of *tissues* (epithelial, connective, muscular or nervous). Finally, each tissue is composed of a group of similar units called *cells* which are the ultimate structural units of the body. The body may therefore be regarded as composed of myriads of cell units, organized into units of gradually increasing complexity, very much as a social community is composed of individuals organized into trades, municipalities, etc.

Most of the individual tissues can be recognized by their gross appearance. In fact, the principal tissues were first demonstrated by Bichat through skilful dissection, maceration, etc., and without the aid of the microscope. The cellular structure of the tissues was later discovered by Schwann in 1839.

Each cell is composed of a material called *protoplasm,* a viscid substance variable in appearance and exceedingly complex in chemical composition. Especially when oxidized, it readily breaks down into simpler chemical compounds, whereby energy (chiefly in the form of heat and mechanical energy) is liberated. It has also the power of absorbing nutritive material to build up and replace what was lost. Its decomposition results from stimuli of various kinds, and hence it is said to be irritable. The mechanical energy which it liberates is manifested by its contractility, especially in the muscle cells. It excretes the waste products produced by its decomposition. Each cell has the power, under favorable conditions, of reproducing itself by division. Protoplasm presents, in short, all the forms of activity manifested by the body as a whole; and indeed, the activities of the body are the sum of the activities of its constituent cells.

In the protoplasm of each cell is a specially differentiated portion, the *nucleus.* The nucleus plays an important part in regulating the activities of the *cytoplasm,* the general protoplasm of the cell body. The nucleus differs from the cytoplasm both structurally and chemically, and contains a very important substance, *chromatin,* which during cell division is aggregated into a definite number of masses called *chromosomes.* Further details concerning the cells and tissues may be found in the text-books of cytology and histology.

Constitutional anatomy.—By definition, constitutional anatomy concerns the physical make-up of the body. This structural make-up is determined primarily through heredity (the genotype), but also secondarily through environment. Therefore the actual organism (or phenotype) is always a complex resultant of the endogenous or genetic factors on the one hand, and of the exogenous or environmental influence on the other. Some authors restrict the term 'constitution' to the genotype, determined by genetic the factors alone; but the essential point is that in the interpretation of organic structure, at every stage of life, both the endogenous and the exogenous factors must be taken into account. No trait is either exclusively hereditary or entirely environmental in causation.

Biometry.—A scientific study of individuals and their structure, from the standpoint of constitutional anatomy, involves first the biometric determination of the corresponding norms. These include measures of central tendency, around which the individuals cluster. The *mean* is the average measurement for the group; the *median* designates the middle individual; the *mode* is the most frequent class. The frequency distribution for the various classes can be expressed either in tabular or in graphic form (usually as a curve). Moreover, by statistical methods the *probable errors* can be calculated, which indicate the reliability of the various determinations, with reference to chance variation.

In addition to the measures of central tendency, it is necessary also to determine the measures of dispersion or variation. Even among individuals of the same race, sex and age, varia-

tions occur in all their physical traits, including innumerable details of both gross and microscopic structure. The simplest measure of variation is the *range*, giving merely the highest and the lowest value of the series. By subtracting each individual from the mean value, the *deviations* are obtained. They may be expressed as the *mean deviation* or (by a more complicated formula) the *standard deviation.* The percentage of the mean formed by the standard deviation is termed the *coefficient of variation.* This coefficient is very useful in comparing the variability of different traits, or of the same trait in different groups or in the same group at different ages.

For example, stature or standing height is found to be more variable during infancy, but (according to Berkson) the variability decreases to a minimum at about 10 years. Thereafter variability increases around the age of puberty, probably because the accelerated puberal growth is reached by some individuals earlier than others. During the subsequent adolescent stage (16 to 20 years) the variability in stature again decreases to a minimum level characteristic of adults.

Weight is much more variable than stature, but it undergoes somewhat similar changes according to age, with a maximum variability around the age of puberty. For many details of physique and structure in the body and its various organs, exact measurements of the age changes are still lacking. However, it is of interest to note that at the age of puberty, sex differences become more distinct not only in structure but also in vital capacity, muscular strength and basal metabolism. These physiologic traits can be similarly measured and compared with each other and with the structural make-up of the body.

After the mean and the variation therefrom have been determined, another step is to measure the *correlations* between the variable component parts and organs of the body. (The degree of correspondence in variations for any two traits is expressed statistically as the coefficient of correlation.) One might expect to find the combinations occurring at haphazard, with no relation between the size or shape of any one part and that of the other parts with which it is associated. But, on the contrary, variations in one part usually involve more or less tendency to corresponding changes in other parts of the body. As a result, there are found certain patterns or types of organization. These types (like structure in general), though arising partly from environmental influences, probably depend largely upon the chromosomal structure (genes) of the germ plasm. They are therefore chiefly hereditary in character. Such types can, at least to a large extent, be described by statistical analysis of the individual data.

Constitutional types.—Through largely empirical observations by anthropometric and medical workers, numerous so-called types of physique have been recognized in both children and adults. These include the small and the large types, the thin (asthenic) and the stout (pycnic), the cerebral (large-brained), the athletic (muscular), and many others described with numerous synonyms. In most cases, however, these 'types' probably do not represent true biotypes (distinct groups, each with a genetic basis), but rather the more extreme variants in a normal frequency distribution.

In the case of stature, for example, we might recognize in any large group a short and a tall type of individual, but this would be merely an arbitrary classification. As is clearly indicated by the usual frequency distribution in such cases, the real type (i. e., the most characteristic representative of the group) is shown by those of medium height, while the tall and the short appear rather as atypical variants. If, however, our group contained an admixture of individuals belonging to a true dwarf racial type, or to a giant type, we should expect a corresponding modification of the frequency distribution curve, with secondary peaks indicating distinct modes for the subtypes.

Of the various types of physique, the most widely recognized and best studied pertain to the general body build. This can be measured quantitatively by the relative chest girth (ratio of chest girth to stature) or by the weight-height index (ratio of weight to height, height^2 or height^3). Frequency distribution curves for the weight-height index of build usually appear essentially unimodal, resembling those for height or weight. Davenport, however, has found polymodal curves indicating the existence of various types of body build throughout childhood and adult life. But as yet the data appear insufficient to establish these types satisfactorily on a statistical basis.

It may be noted that the body build normally varies according to age. The average index of build decreases markedly through childhood, from the relatively plump infant to the slender youth of twelve years. The index remains nearly constant through puberty, and thereafter increases slightly during the period of adolescence up to maturity and later.

Individual variations in body build appear at every age and are traceable partly to genetic (or hereditary) sources and partly to environmental factors. The mechanism by which the body build is determined is complex and in many respects still obscure. There is no doubt, however, that certain of the endocrine glands (notably the hypophysis and the thyroid gland) are active intermediary agents in the process of morphogenesis. Changes in these glands, involving increased or decreased activity in secretion, may profoundly affect the form and structure of the developing organism.

Among the environmental factors, nutrition is of prime importance in determining the body build. During malnutrition the body usually becomes slender through loss of weight, while stature remains nearly constant. In underfed children the emaciation may be intensified by a persistent dystrophic growth of the skeleton. Strangely enough, on the other hand, slenderness may also arise through the relatively rapid growth of the skeleton in well-nourished children. Thus the opposite extremes of nutrition may produce the same slender build. The stouter body build often found among children of the poorer classes probably involves a racial or genetic factor that overbalances the environmental influence. It is therefore unreasonable to conclude that all children 7 to 10 per cent or more below the so-called norms of weight are necessarily malnourished.

In connection with the question of constitutional types, the relations of structure and function are important. In general, the correlations between morphologic and physiologic

traits are lower than the intercorrelations between many of the physical characters. Body build, for example, shows only slight or insignificant correlations with pulse rate, blood pressure, or chest expansion. Vital capacity is more closely correlated, increasing with body build except in corpulent individuals, where the excess fat mechanically obstructs the respiratory mechanism.

Schlesinger finds among German children and adolescents a positive correlation between body build and muscular strength. This accords with general experience. In fact, the word 'stout' in popular speech means either stocky or strong. Schlesinger furthermore finds that the stockier children have greater vital capacity; while the slender group shows much more predisposition to certain constitutional defects, such as neuropathic disorders, enlarged lymph nodes and postural defects. He therefore concludes that, at least during youth, the broadly-built represents the superior and most desirable type of physique. It might be added that life insurance records in general indicate that among young adults the mortality is much lower among 'overweights' than in 'underweights,' although later in life the converse is true.

In general, it appears somewhat doubtful whether any single type of physique is to be regarded as superior in all respects even among adolescents. The organization best adapted to one environment may be unfitted for another. For example, great muscular strength is needed for heavy manual labor, but is quite unnecessary (perhaps even undesirable) for sedentary occupations. Similarly some types appear especially susceptible to disease. Physicians have long recognized a slender 'habitus phthisicus' and a stout 'habitus apoplecticus.' Many other disorders have been observed to vary according to age, sex and type of body build. The subject of the relationship between physique and specific predisposition or resistance to disease is therefore of great importance, but more careful and extensive investigation is required for definite conclusions in this field of constitutional medicine.

References.—*General:* For looking up the literature upon any anatomical topic, the best guide in general (up to 1914) is the Jahresbericht über die Fortschritte der Anatomie und Entwicklungsgeschichte, which contains classified titles and brief abstracts of the more important papers in gross anatomy, histology and embryology. The more recent period is covered by the Anatomische Berichte and the Biological Abstracts. Other useful aids are the Quarterly Cumulative Index Medicus and the catalogue of the Surgeon General's Library of the War Dep't. (Washington, D. C.). The latter two contain titles only, but cover the whole field of medicine. For *nomenclature:* His, Archiv f. Anat., 1895 (BNA system); Barker, Anatomical Nomenclature; Eycleshymer, Anatomical Names; Emmel, The BNA etc. *Cells and tissues:* Wilson, The Cell; Hertwig, Zelle und Gewebe (also English transl.); Schaefer, Microscopic Anatomy (in Quain's Anatomy, 11th ed.); Heidenhain, Plasma und Zelle; Kölliker, Gewebelehre; Prenant, Bouin et Maillard, Traité d'Histologie; Cowdry, Special Cytology; von Möllendorff, Handbuch der mikroskopischen Anatomie. *Constitution:* Brandt, Ergeb. d. Anat. u. Entw., 1929, Bd. 28; Measurement of Man, Univ. of Minnesota Press, 1930; Pearl, Medical biometry and statistics, 2nd ed.

SECTION I

DEVELOPMENTAL ANATOMY

By RICHARD E. SCAMMON, Ph.D.

DEAN OF MEDICAL SCIENCES, AND PROFESSOR OF ANATOMY, UNIVERSITY OF MINNESOTA

THE life history of man, in common with most higher organisms, is characterized by continuous change and presents a cycle in which may be recognized the succeeding phases of growth and differentiation, maturity, and old age or senescence. In man nearly one-third of the traditional span of life is required for the body to reach its full size and differentiation. This portion of the human life cycle may be called the developmental period, and the study of the structure of the body and its changes in this time may be termed developmental anatomy.

Divisions of the developmental period.—The developmental period is divided by the incident of birth into prenatal and postnatal epochs and in these a number of more or less arbitrarily defined subdivisions may be recognized. A scheme of the divisions of the developmental period is shown on the following table. In this scheme puberty is regarded only as a transition point between later childhood and adolescence. The length of the developmental period and of its several subdivisions varies greatly with sex, race, environment, and physical constitution. A distinction is often drawn between the anatomic or physiologic age of the individual, as indicated by the degree of physical development of the body, and the calendar or chronologic age. As females pass through most of the transitions of the developmental period a little earlier than do males the physiologic age of girls is usually somewhat in advance of that of boys of the same calendar age.

DIVISIONS OF THE DEVELOPMENTAL PERIOD IN MAN

Prenatal life
- *Period of the ovum.*
  From fertilization to the close of the second week of prenatal life.
- *Period of the embryo.*
  From the close of the second week to the close of the second (lunar) month.
- *Period of the fetus.*
  From the close of the second (lunar) month to birth at 10 lunar months.

Birth

Postnatal life
- *Period of the newborn* (Neonatal period).
  From birth to the close of the second (postnatal) week.
- *Infancy.*
  From 2 weeks to the close of the first year or until the habitual assumption of the erect posture (usually in the thirteenth or fourteenth month).
- *Childhood*
  - *Early childhood* (Milk-tooth period).
    From 1 to 6 years.
  - *Middle childhood.*
    From 6 to 9 or 10 years.
  - *Later childhood* (Prepuberal period).
    From 9 or 10 years to 12–15 years in females and 13–16 years in males.

  Puberty

  Fourteenth year in females. Sixteenth year in males. (Averages of typical American data.)
- *Adolescence.*
  From puberty to the last years of the second decade in females and to the first years of the third decade in males.

Growth and differentiation.—The changes which characterize the developmental period do not take place at the same time or at equal rates in all regions of the body, for each organ and part has its own peculiar life cycle. In a few

organs, such as the mesonephros of the embryo, this cycle is very short. Other organs persist during childhood and then decline, while the great majority continue, with varying degrees of change, throughout postnatal life.

The characteristic life cycle of the various organs depends upon the changes in the structural units which compose them and, in the last analysis, upon the growth and differentiation of their constituent cells. Each cell has a definite life cycle, an early period of rapid and vigorous changes, later periods of differentiation and maturity, followed by stages of degeneration and death. This cycle of cell changes is termed *cytomorphosis*. The length of life cycle of the various types of cells in the body differs greatly, some of the blood cells living probably a month or less while certain brain cells may survive throughout postnatal life. The growth of cells may take place either by the enlargement (hypertrophy) of individual cells or by the multiplication (hyperplasia) of cells by cell division. Cell division is necessary for continued cell growth for otherwise the cell would soon reach a size where its surface would be inadequate (for nutritive, respiratory and excretory purposes) to its mass. In general, however, cell division is most active in the early embryonic periods, during which the cells remain small. Later, cell division diminishes or ceases in most parts of the body, and growth is due chiefly to the enlargement of cells already present. The growth of the structural units of organs also follows this general rule, the production of new units being confined mainly to fetal and early postnatal life.

While the functional and structural differentiation of cells and structural units may take place during the period of their rapid multiplication these processes are usually partially disassociated and the phase of active differentiation comes some time after the period of most active growth.

THE EARLY DEVELOPMENT OF THE EMBRYO

The germ-cells and fertilization.—The period of development in man, as in the great majority of multicellular animals, is inaugurated by the process of fertilization through the union of the male germ-cell or spermatozoon with the female germ-cell or ovum.

The ovum and spermatozoon are differentiated, by the process of maturation, from certain more primitive germ-cells set aside from the general body or somatic cells at an early period in development. In maturation both the ovum and spermatozoon undergo profound nuclear changes and each becomes highly specialized in form and structure for its part in the fertilization process.

The ripe spermatozoon or sperm is a slender lance-like structure 0.05 or 0.06 mm. long (fig. 3).

The ripe human ovum or egg-cell is a spheroidal body whose greatest diameter is of the order of 0.1 mm. (fig. 2). It contains a nucleus about 0.02 mm. in diameter which is generally slightly eccentric in position. Suspended in the protoplasm of the cell-body are numerous droplets and granules which are presumably reserve food substances. The ovum is bounded by a delicate vitelline membrane.

Fertilization has not been observed in man but it has been studied in detail in several mammals and it is most probable that the process is essentially the same in all higher forms. After escaping from the ovary through the rupture of the Graafian follicle the ovum enters the ostium of the uterine tube and passes down the lumen. The union of the ovum with the spermatozoon probably takes place in most cases during this passage.

Segmentation of the ovum.—The fertilized ovum is converted into a solid ball of much smaller cells by a series of cell-divisions. This process is known as segmentation and the mass of cells resulting from it is called the *morula*. Like fertilization, segmentation has not been observed in man and our concepts of the process in the human species are based upon observations on the ova of lower animals. It is probable that the first segmentation divisions are equal but that the later ones are quite irregular. The morula which results from them is a solid body at first but an eccentrically placed cavity soon appears within it and the structure is differentiated into an outer shell, the *trophoblast*, and a cluster of cells termed the *inner cell-mass*. The inner cell-mass is broadly attached to the inner surface of the trophoblast. The cavity between the two is filled with fluid and bridged by delicate cellular strands, the *magma reticulare*.

It is probable that after fertilization at least ten days are required for the ovum to reach this stage of development. During this period the ovum has left the uterine tube and has come to rest on the inner surface of the uterus. The uterine epithelium in contact with the ovum is destroyed, presumably

through the activity of the cells of the trophoblast, and the ovum sinks into the uterine mucosa and is inclosed by it. Until implantation takes place the ovum is an independent organism dependent upon its own scanty reserve of food supply for nourishment. Consequently it grows little if any during this period. With implantation, however, the ovum becomes, in a fashion, a parasite upon the maternal organism from which it derives its nourishment throughout

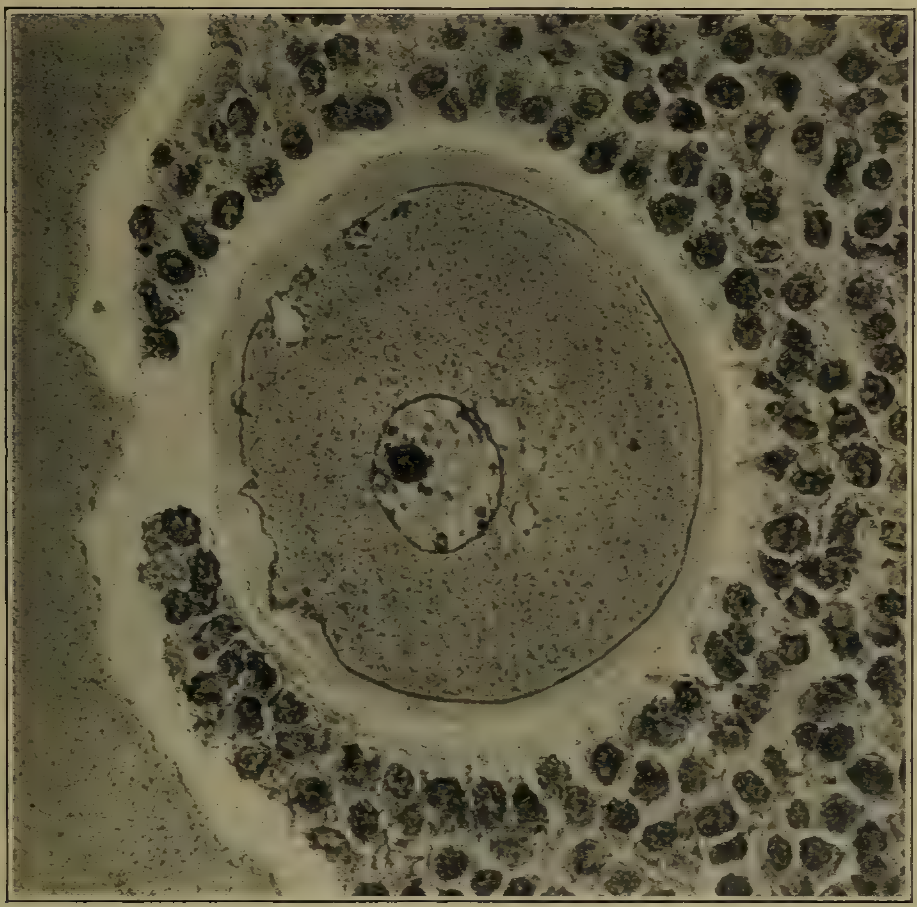


Fig. 2.—Mature Ovum, with Follicular Cells, of a Woman 36 Years Old. (After Thompson.) ×500.

the remainder of the fetal period. With the establishment of this relation the ovum enters on a period of extremely rapid growth.

Formation of the embryonic disk.—Two spaces now appear in the inner cell-mass, an upper one, the amniotic cavity and a lower one, the yolk-sac cavity. These are separated by a plate of cells, the *embryonic plate or disk*. At the same time a distinct layer of cells is differentiated on the outer surface of the cell-mass.

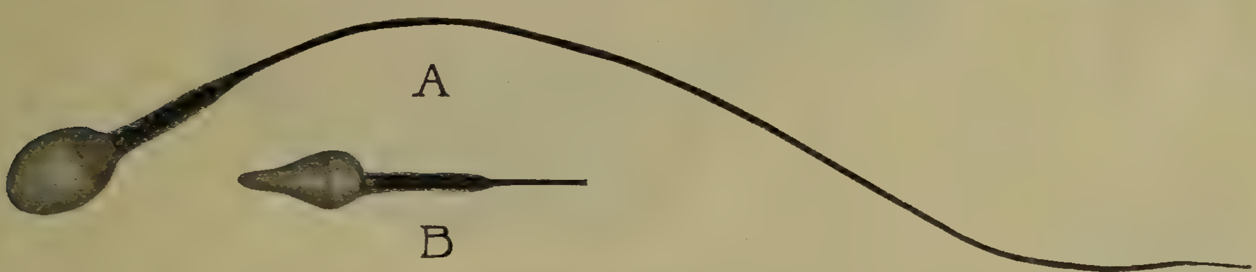


Fig. 3.—Mature Spermatozoa.
A, frontal view showing broad surface of the head: B, anterior portion in side view. (After Broman.) ×2500.

This layer is the extraembryonic mesoderm. It is probably formed in part from the cells of the inner cell-mass and the trophoblast and in part from the magma reticulare. The extraembryonic mesoderm forms a complete lining about the original cavity of the morula and this space is now termed the *extraembryonic celom*. As the extraembryonic celom is established the magma reticulare disappears and the connection between the inner cell-mass and the trophoblast is reduced to a short bridge of extraembryonic mesoderm, the connecting stalk (fig. 4).

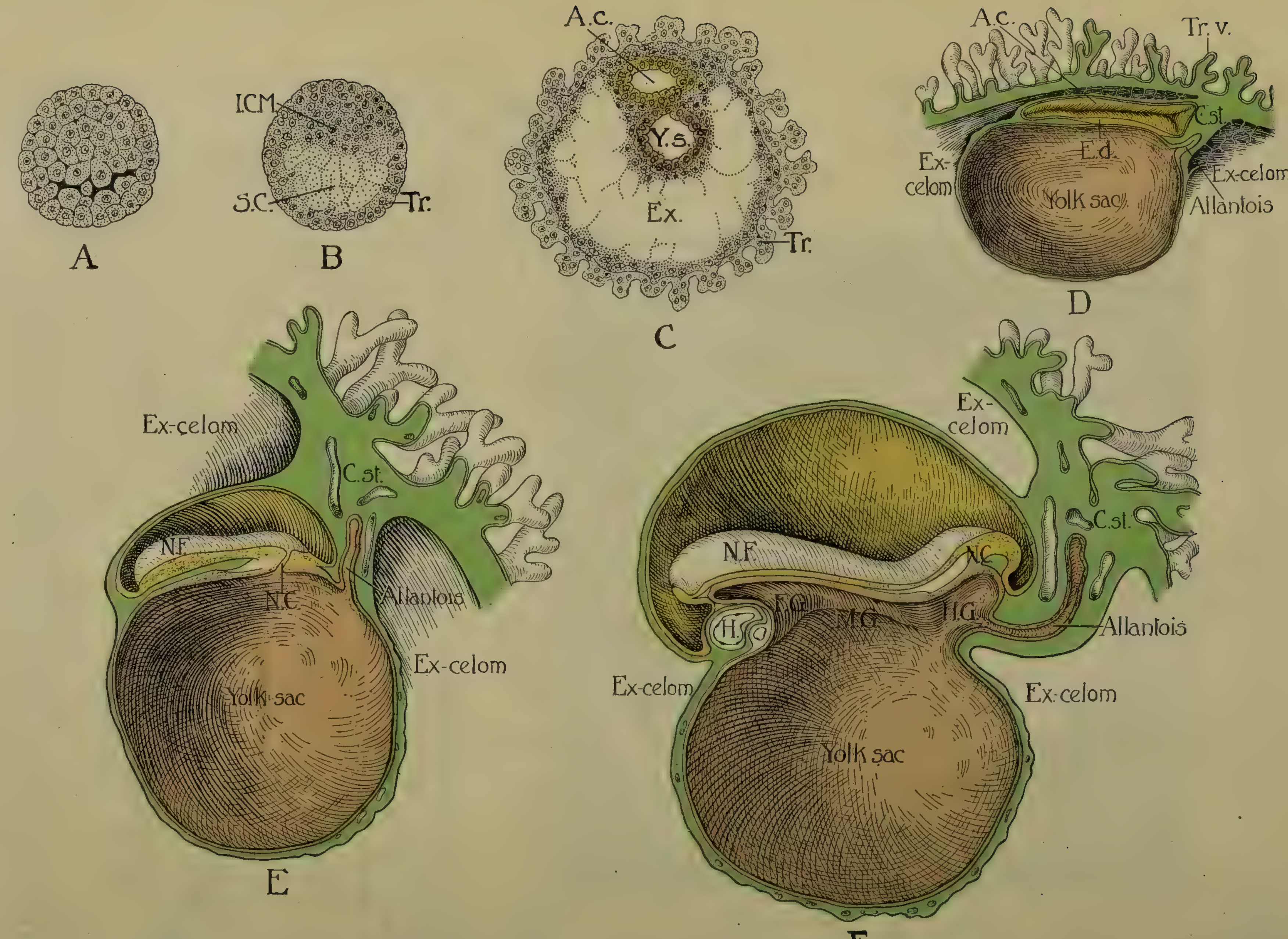


Fig. 4.—A Series of Diagrams Illustrating the Later Changes in the Ovum and the Formation of the Embryo. (Based on the figures of Broman, Brödel, Dandy, Eternod, Lewis, Miller and Streeter.)

A, morula (hypothetical). B, differentiation of the inner cell-mass and trophoblast (hypothetical). C, formation of the amniotic cavity, yolk-sac and extraembryonic celom. D, formation of the embryonic disk. E and F, formation of the archenteron and neural canal. A.c., amniotic cavity. C.st., connecting stalk. E.d., embryonic disk. Ex., extraembryonic celom. F.G., foregut. H., heart. H.G., hindgut. I.C.M., inner cell-mass. N.C., neurenteric canal. N.F., neural folds. S.C., segmentation-cavity. Tr., trophoblast. Tr.v., trophoblastic villi. Y.s., yolk-sac.

Our interest is centered in the embryonic disk, for the embryo is entirely a product of this structure: the remainder of the ovum gives rise to the supporting or nourishing structures for the developing embryo or else disappears comparatively early in prenatal life.

The embryonic disk in embryos of the third week is an oval plate having a maximum diameter of about 0.2 mm. It consists of three sheets of cells called the germ layers. The upper layer or ectoderm forms the floor of the amniotic cavity and becomes continuous with the walls of the amnion at the margins of the embryonic disk. The lower layer or entoderm forms the roof of the yolk-sac and is continued as the inner walls of this structure at the periphery of the embryonic disk. The middle layer or mesoderm forms an incomplete plate between the ectoderm and entoderm. At the margins of the embryonic disk it becomes continuous with the extraembryonic mesoderm which covers the outer surface of the inner cell-mass.

The subsequent history of the embryo is essentially that of the differentiation and the disposition of the germ-layers. Their contributions to the adult body are as follows:

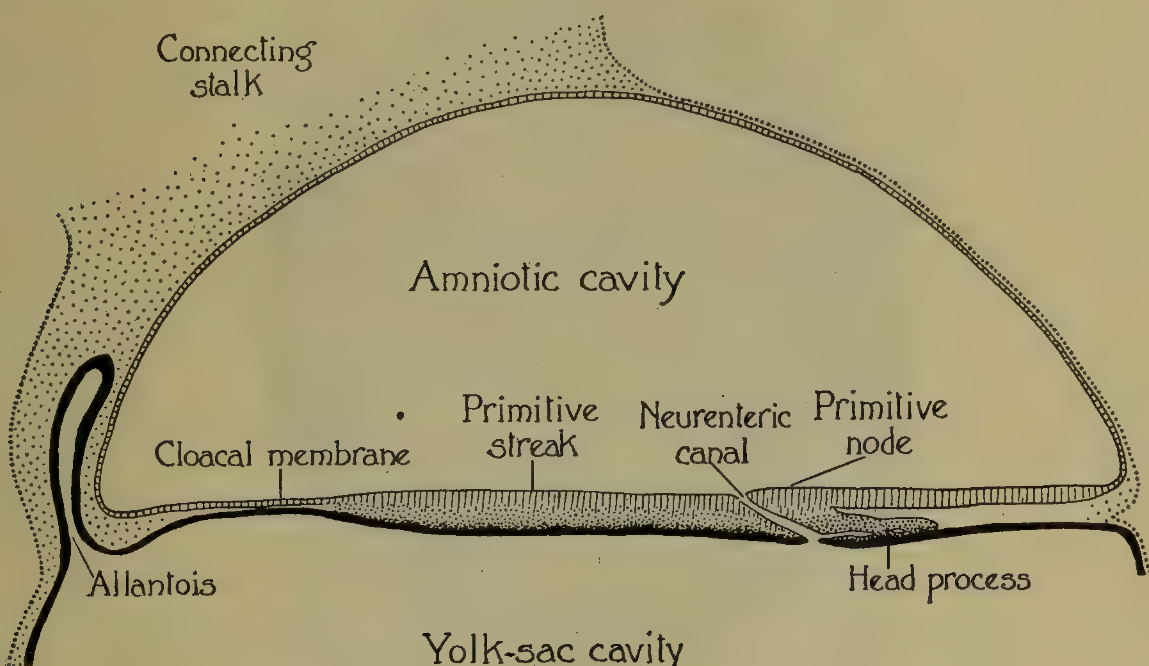


Fig. 5.—Diagram of a Longitudinal Section through the Long Axis of the Embryonic Disk at the Time of Formation of the Primitive Streak and Neurenteric Canal. (Based in part on the figures of Ingalls and Streeter.)

From the ectoderm are formed:

The central and peripheral nervous system, the epithelial internal ear, the lens, iris and retina of the eye. The epithelial portion of the skin and its appendages.

The lining of the buccal, nasal, and a part of the pharyngeal cavities and the paranasal sinuses; the enamel of the teeth; the salivary glands.

The lining of the anal canal; the lining of the vestibule in the female and a portion of the urethra in the male, with associated glands.

The anterior lobe of the hypophysis cerebri; the pharyngeal hypophysis. The paraganglia. Wandering cells from the ectoderm may contribute to the apparatus of mastication.

From the entoderm are formed:

The lining epithelium of the digestive tract, with the exception of the mouth, a part of the pharynx, and the anal canal; the parenchyma of the digestive glands, including the pancreas and liver. The lining of the larynx, trachea, bronchi and lungs.

The lining of a portion of the bladder; the lining of the female urethra and a part of the male urethra, with associated glands.

The parenchyma of the thyroid and parathyroid galnds; the reticulum and the thymic corpuscles of the thymus.

From the mesoderm are formed:

The skeletal and muscular structures and the connective tissues of the body. (Also some contribution is probably added from wandering ectodermal cells.)

The vascular system; the lymphoid and sanguifactive organs.

The serous membranes.

The genital glands and their ducts and accessory structures. The kidneys, ureters and the greater part of the bladder.

The dentine and cementum of the teeth.

The cortex of the suprarenal glands.

Early changes in the embryonic disk.—The first indications of the establishment of the embryo on the germinal disk appear early in the third week. At this time the ectoderm and entoderm in the posterior part of the longitudinal axis of the disk fuse, forming a band of cells known as the primitive streak. The primitive streak is indented by a dorsal primitive groove (fig. 6). It terminates anteriorly in an enlargement, the primitive node, and from the node a mass of cells, the head-process, extends forward in the midline, fusing below with the entoderm of the yolk-sac in this region. A narrow channel, the neurenteric canal, pierces the primitive node and connects the amniotic cavity with the yolk-sac cavity. The neurenteric canal is continuous with a cleft in the head-process termed the head-process canal (fig. 5). As these changes take place on the germinal disk a small tubular outgrowth, the allantois, arises from the posterior end of the roof of the yolk-sac and grows upward, behind the amnion, into the connecting-stalk.

The primitive groove, the primitive streak, the primitive node, neurenteric canal, and head-process are ephemeral structures which may be regarded as representing a highly modified

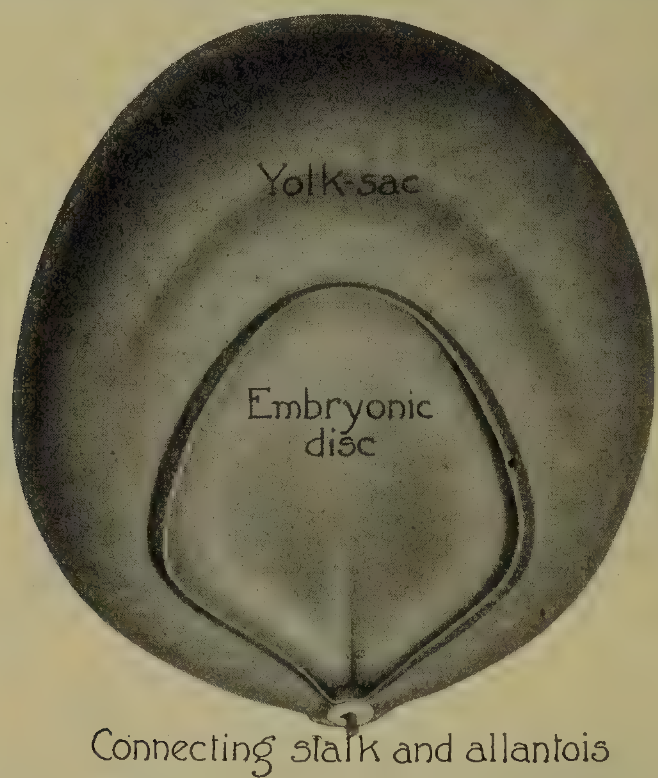


Fig. 6.—Dorsal View of the Embryonic Disk and Yolk-sac of an Embryo of the Early Part of the Third Week. (After Streeter.)

process of gastrulation in the human embryo. The primitive streak and node and the head-process join the mesoderm laterally and presumably contribute cells to this germ-layer. The head-process also gives rise to a longitudinal rod of cells, the notochord, which forms the median longitudinal axis of the embryo and is subsequently associated with the skeleton; possibly its ventral part is incorporated in the entoderm of the yolk-sac. With this distribution of its material the head-process disappears as a separate structure. The primitive streak becomes relatively shorter with the growth of the embryo anterior to it and the consequent migration backward of the primitive node. After the third week it is no longer recognizable. The neurenteric canal is normally obliterated in the third week.

The topography of the embryonic disk.—Although only slight signs of differentiation are visible on the surface of the embryonic disk in the third week it is possible to map out upon it more or less definite areas corresponding to all of the various regions of the future body, as shown in fig. 7. This diagram illustrates the areas representing the major, definitive body regions. There is considerable evidence, however, that the material occupying these areas, takes origin from the neighborhood of the primitive node. Beginning anteriorly, the head region is relatively enormous in size, occupying the entire area in front of the primitive node and forming about half of the entire disk. The cervical, thoracic, lumbar, and sacrococcygeal regions appear successively smaller, approaching the posterior end of the disk. It is also a striking fact that the future dorsal region of the body wall, corresponding to the central portion of the disk, along each side of the midline, is now larger than the ventrolateral regions, which occupy a relatively narrow zone around the periphery of the disk.

Early changes in the germ layers.—The definitive embryo is formed by the rapid growth of the dorsal region of the embryonic disk and by a series of folds and cleavages of the germ-layers of this area. The **ectoderm** plays a most active part in these early transformations. Shortly after the primitive streak is established, the ectoderm along the midline of the embryonic disk is thickened into a neural plate which extends from the primitive node to the anterior end of the disk. The lateral margins of the plate grow rapidly and rise from the surface of the disk as a pair of longitudinal neural folds or ridges which bound a shallow neural groove (figs. 8 and 12*A*). The neural plate is converted into the *neural tube* by

FIG. 7.—TOPOGRAPHY OF THE EMBRYONIC DISK. Diagram of probable relations at the length of about 1 mm. ng, neural groove. pn, primitive node. pp, primitive pit. U, upper limb. L, lower limb.

the further growth of the neural ridges which fold over the neural groove and fuse in the midline. This process begins in the future cervical region and extends forward and backward from this level (fig. 12*A*). The extreme anterior and posterior ends of the tube remain open for a time as the anterior and posterior neuropores. With their subsequent closure the walls of the tube are completed and its cavity is entirely separated from the amniotic cavity. The neural tube gives rise to the brain, spinal cord, and retinæ and optic nerves. Its further history is considered in connection with the nervous system.

The ectoderm which covers the periphery of the embryonic disk is carried over the dorsal surface of the neural tube with the infolding of the neural ridges. It forms the external covering of the embryo.

The entoderm.—As the neural plate is formed from the ectoderm on the upper surface of the embryonic disk, the entoderm lying below this region is

folded into the primitive digestive tube or *archenteron*. In embryos of the latter part of the third week three divisions, the *foregut*, the *hindgut*, and the *midgut* may be recognized in this structure (figs. 4*E*, 4*F*). The midgut is a shallow groove still broadly connected with the yolk-sac, the foregut is a pocket-like projection from the midgut extending forward under the anterior part of the neural plate, and the hindgut is a similar but shorter projection which extends into the caudal region of the developing embryo.

With the further growth of the archenteron the foregut and hindgut become considerably elongated and the connection of the midgut with the yolk-sac is reduced to a short, wide yolk-stalk. In this process the upper part of the posterior wall of the yolk-sac is incorporated in the floor of the hindgut, and the allantois now takes origin from this part of the archenteron instead of the yolk-sac. The later history of the entoderm will be considered in connection with the development of the digestive and respiratory tracts.

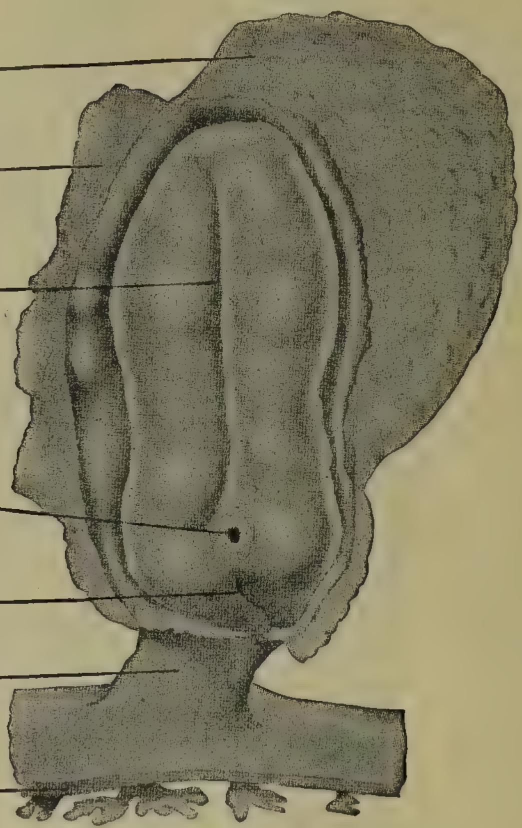


FIG. 8.—HUMAN EMBRYO 1.54 MM. LONG. Viewed from above, the roof of the amniotic cavity having been removed. (Minot, after Graf Spee.)

The mesoderm.—The mesoderm of the human embryo appears to have a dual origin, being formed primarily from the extraembryonic mesoderm of the inner cell-mass and secondarily from the primitive streak, primitive node, and head-process and from wandering cells derived from the ectoderm. After the formation of the notochord the mesoderm takes the form of a pair of plates which lie on either side of the longitudinal embryonic axis and which are continuous laterally with the extraembryonic mesoderm covering the amnion and yolk-sac. Behind the primitive node these plates fuse with the primitive streak across the midline of the embryonic disk but anterior to the node they are separated by a medial space which contains the notochord (figs. 9, 10).

Some of the later changes in the mesoderm are shown in fig. 10. Each plate of mesoderm is divided by a longitudinal groove into three parts. These are (1) a narrow medial strip, the medial or paraxial mesoderm, (2) the intermediate mesoderm which forms a slender cord lying beneath the longitudinal groove, and (3) a broad band of lateral mesoderm. The *medial mesoderm* is subdivided by a series of transverse clefts into a row of blocks or segments known as the *mesodermic somites*. At the same time the lateral mesoderm splits into an upper (outer) or somatic layer and a lower (inner) or splanchnic layer. The space between these two layers is the embryonic body cavity or *celom*. It becomes continuous with the extraembryonic celom at the lateral margins of the embryonic disk.

The appearance of the mesodermic somites marks the beginning of metamerism, the arrangement of the body in successive segments or metameres. The somites form first in the occipital region and rapidly differentiate in the craniocaudal direction. In embryos 7 or 8 mm. in length about 40 pairs of somites can be distinguished.

The anterior end of the *medial mesoderm* does not undergo segmentation in the human embryo. It is continued into the head region. From it are formed the cranial bones, certain of the muscles of the head and connective tissue.

Fig. 9.—Cross-sections of a Series of Young Human Embryos. All drawn at the same magnification. (Slightly modified from Graf Spee.)

A, embryo of the middle of the third week. B, embryo of the end of the third week. C, embryo of the early part of the fourth week. D, embryo of the latter part of the fourth week. E, embryo of the fifth week. A.c., amniotic cavity. C.st., connecting stalk. Y.s., yolk-sac. The mesoderm is indicated in stipple.

A small cavity, the *myocele*, appears in the center of each typical somite and the wall differentiates into an upper lateral part, the *dermomyotome*, and a lower medial part, the *sclerotome*. From the dermomyotomes are formed the voluntary muscles of the trunk, neck, and a part of the head; while the sclerotomes take part in the development of the axial skeleton. Probably both parts of the somite contribute cells to the mesenchyma which forms the connective tissue of the body wall, and the supporting structures and voluntary muscles of the limbs.

The greater part of the *intermediate mesoderm* is also divided into segments or *nephrotomes* (corresponding to the somites), portions of which form the transitory uropoietic organs, the pronephros and mesonephros. The posterior part of the intermediate mesoderm remains unsegmented as the nephrogenic cord which later contributes to the development of the permanent kidney.

The *lateral mesoderm* shows no evidences of segmentation. The lateral cavities which are formed between its upper and lower layers soon lose their

connection with the extraembryonic body cavity and fuse ventrally in the midline, forming the general celom to be described later (p. 57).

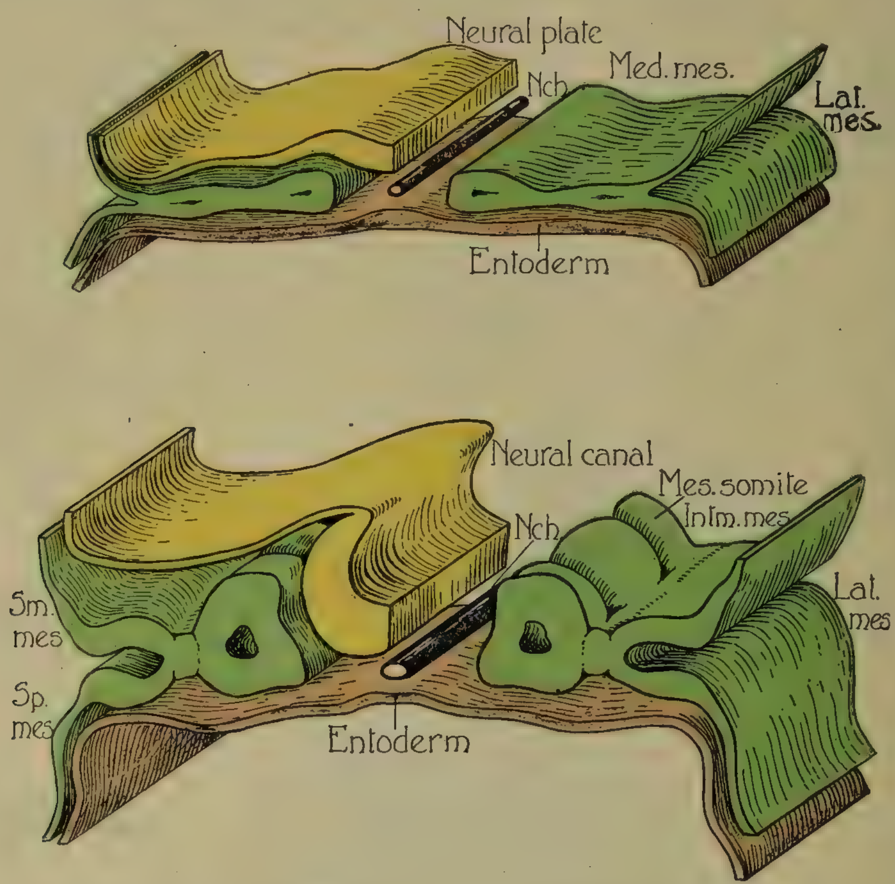


FIG. 10.—STEREOGRAMS ILLUSTRATING THE EARLY CHANGES IN THE MESODERM.
Intm.mes., intermediate mesoderm. Lat.mes., lateral mesoderm. Nch., notochord. Sm.mes., somatic layer of lateral mesoderm. Sp.mes., splanchnic layer of lateral mesoderm. Ectoderm, yellow; mesoderm, green; entoderm, red.

THE DEVELOPMENT OF THE EXTERNAL BODY-FROM

The early transformations of the germ-layers convert the embryonic disk into a cylindrical structure which is only partially connected with yolk-sac and connecting stalk (fig. 11). The cylindrical body wall now encloses two tubes (neural and enteric) with a longitudinal axis (notochord) between them, and is

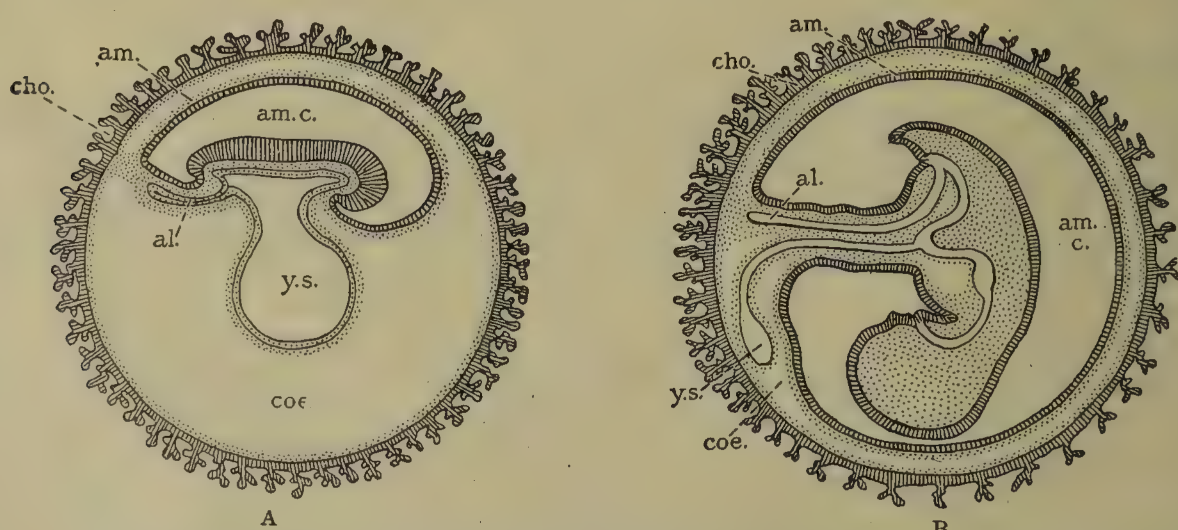


FIG. 11.—DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE EMBRYONIC MEMBRANES AND THE FORMATION OF THE UMBILICAL CORD. (After Lewis.)
al., allantois. am., amnion. am.c., amniotic cavity. cho., chorion. coe., celom. Y.s. yolk-sac.

covered by an outer layer of skin-ectoderm which is continuous along the sides of the embryo with the ectoderm of the amnion. The head is relatively large and is separated from the disk below it by a deep head fold. The caudal end

of the embryo is prolonged into a short tail-bud which is also marked off from the disk by a shallow tail-fold. The middle portion or trunk is still widely connected with the disk, but its boundaries are indicated by distinct lateral folds.

The embryo becomes further separated from the other structures derived from the inner cell-mass by the deepening of the head, tail, and lateral folds; and its connection with these structures is reduced to a slender *umbilical cord*. This cord contains the allantois and yolk-stalk (with their surrounding mesoderm) and is covered by the ectoderm which is reflected from the amnion upon the external surface of the embryo.

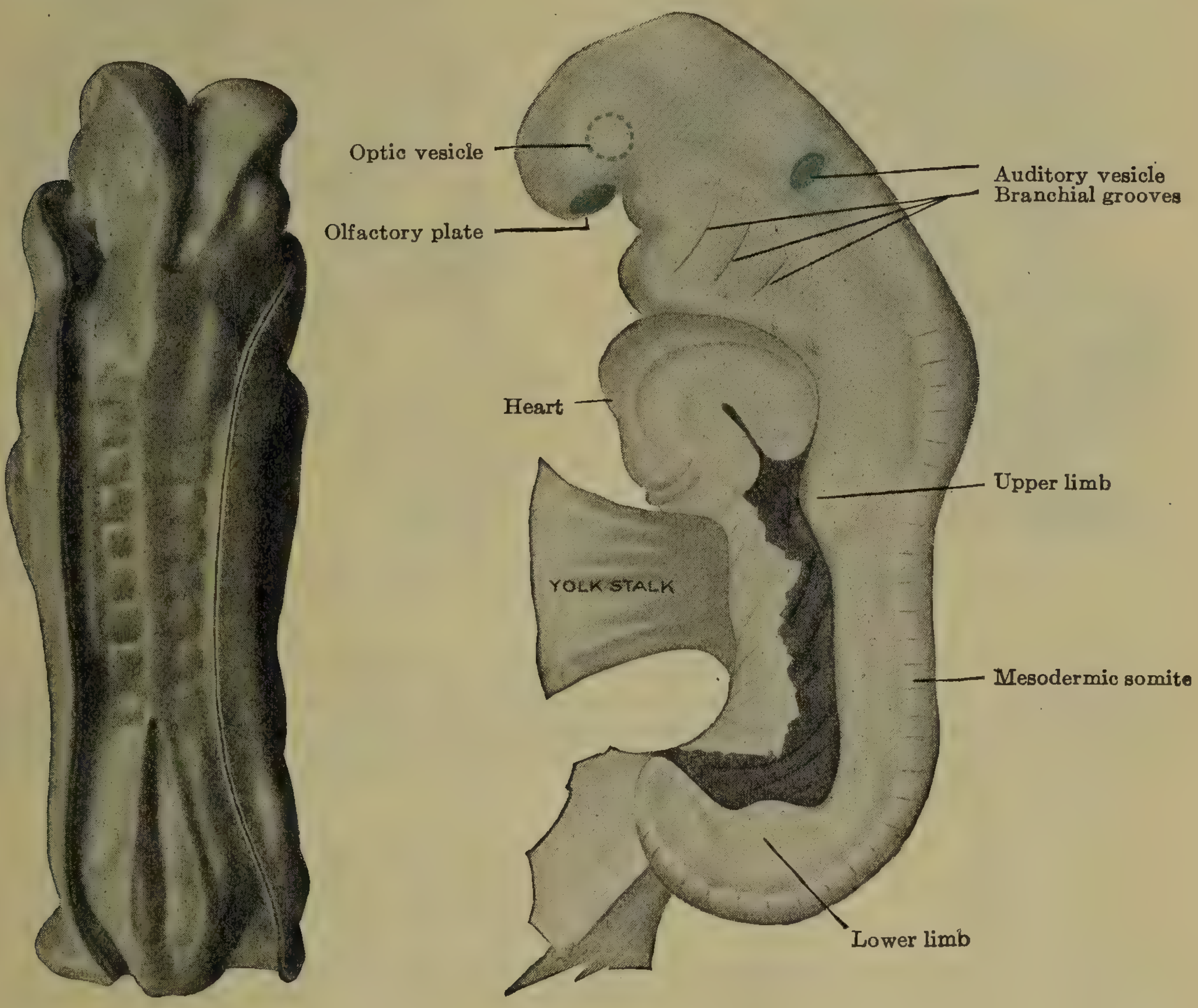


FIG. 12.—A, HUMAN EMBRYO 2.11 MM. LONG. (FROM A MODEL BY ETERNOD.) B, HUMAN EMBRYO 4.2 MM. LONG, SHOWING THREE BRANCHIAL GROOVES. (After His.)

Coincident with these changes, the longitudinal axis of the embryo is modified by the formation of a series of flexures or bends. The head is flexed on the trunk first by an anterior cephalic flexure, and soon after by a more posterior cervical flexure, and the caudal part of the trunk and the tail are bent downward in a semicircular curve (fig. 12B). Later the rapid growth of the dorsal region throws the entire body into a partial spiral (coiled either to the right or left) so that its outline, when seen in lateral view, may be almost circular (fig. 13).

The ventral part of the body increases in size very rapidly in the second fetal month through the great growth of the contained viscera. With this growth the axis of the trunk is straightened and the cervical flexure partially eliminated. The cephalic and caudal flexures are never completely obliterated, although the latter is obscured by the growth of the lower limbs; and the external evidences of the former are masked by the subsequent changes in the proportions of the head and face.

A well marked tail appears which in embryos 7 to 8 mm. long may be nearly one-sixth as long as the body. Regression of the tail structure begins in the sixth week and by the ninth week it has usually entirely disappeared.

Deveploment of the head and neck.—The head is divisible from an early stage, into a neural portion including the brain, eyes and internal ears with their

supporting structures, and a facial or visceral part which contains the anterior termination of the digestive-respiratory tract. The growth and differentiation of these two portions are quite dissimilar. The neural portion is by far the larger in the young embryo and this predominance is never completely lost although it is greatly reduced during both fetal and postnatal life by the growth of the accessory structures of the mouth, nose and pharynx.

FIG. 13.—HUMAN EMBRYO 4.02 MM. LONG. (After Hochstetter.)

FIG. 14.—HUMAN EMBRYO 11.5 MM. LONG. (After Minot.)

In the fourth and fifth weeks the visceral portion of the head undergoes marked external changes. A median *oral sinus* or embryonic mouth is formed on the ventral surface, and anterior to the sinus a pair of small *nasal pits*. The nasal pits are bounded laterally by lateral nasal processes; and a broad medial

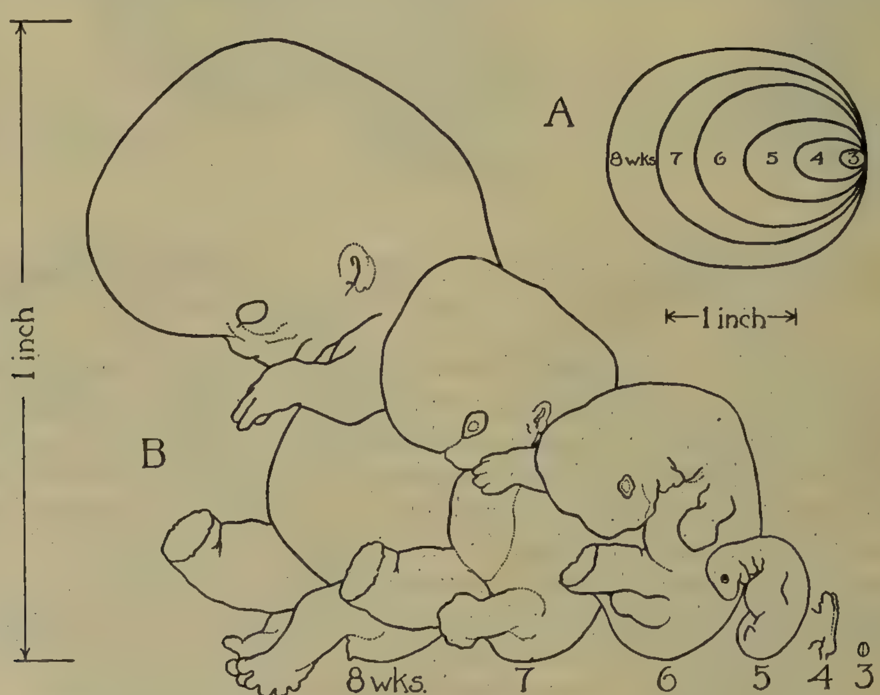


FIG. 15.—A, OUTLINES OF AVERAGE HUMAN OVA FROM 3 TO 8 WEEKS OLD, ONE-HALF NATURAL SIZE. B, OUTLINES OF HUMAN EMBRYOS FROM THE THIRD TO THE EIGHTH WEEK, ENLARGED 2.5 TIMES. (After Evans.)

process separates them and extends downward forming the middle part of the upper boundary of the oral sinus. The remainder of the margin of the oral sinus is formed from the mandibular and maxillary processes of the first branchial arch, the maxillary processes forming the lateral thirds of the upper boundary and the mandibular processes the entire lower margin. The maxillary and medial

nasal processes are separated for the time by shallow lacrimal grooves (figs. 13, 14 and 17).

The margins of the sinus are completed by the coalescence of the mandibular processes below and the fusion of the maxillary and medial nasal processes above. The lower part of the definitive *nose* is formed by the fusion of the lateral and medial nasal processes at the lower margins of the nasal pits and the subsequent growth of the medial process, particularly in the midline above the nares. The later development of the external features of the face is illustrated by the series of outlines in fig. 18.

As these changes take place in the facial region the lateral surfaces of the neck are indented by a series of four (paired) *branchial* (visceral) *grooves* which are separated by the *branchial arches.* The upper part of the first of these grooves is deepened to form the *external auditory meatus,* the margins being elevated to form the *auricle.* The region corresponding to the second, third, and fourth grooves becomes depressed, forming the *cervical sinus* which soon closes over and normally disappears.

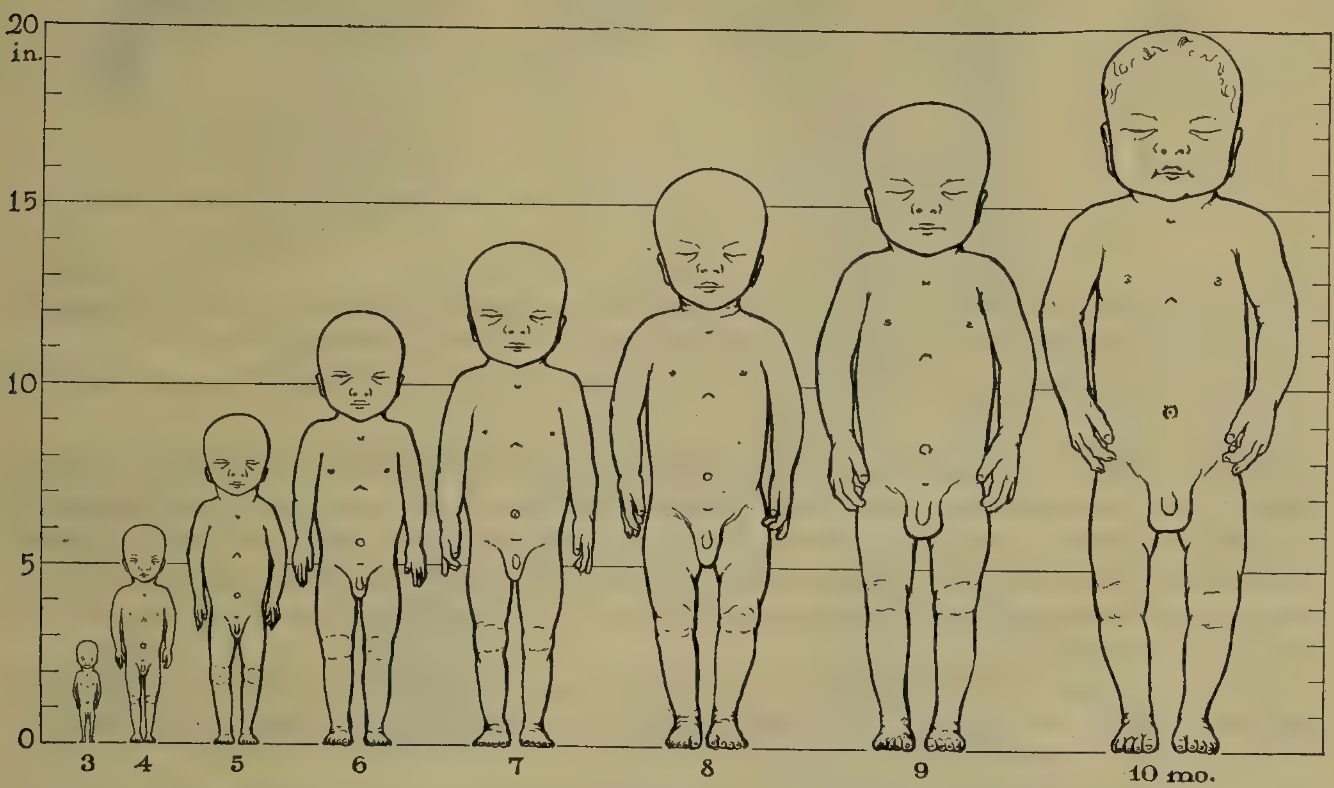


Fig. 16.—A Series of Drawings Illustrating the Changes in Size and Form of the Human Fetus from the Third to the Tenth Month. (After Scammon and Calkins.)

Development of the trunk.—In the young embryo the trunk appears as a cylindrical body flattened from side to side and exhibiting externally the modeling of the viscera contained within it. In fetal life, with the development of the skeleton and trunk musculature and the rounding of the visceral mass, the trunk takes on an ovoid form, largest at the level of the umbilicus and almost circular in cross section. In spite of the changes in the form and relative proportions of the contained viscera, the relative proportions of the trunk remain almost unchanged from the close of the third fetal month to birth. In the early part of infancy, also, there is little change in the form of the trunk, but after the assumption of the erect posture there is a reduction of the relative anteroposterior diameter of both the thoracic and abdominal regions accompanied by a decrease in the relative size of the umbilical region and a relative increase in the lumbar region. These changes continue throughout childhood and early adolescence.

Development of the extremities.—The limbs appear about the third week of fetal life as short ridges which project from the lateral surfaces of the cranial and caudal ends of the trunk. Each ridge is differentiated into a limb-bud in which may be recognized a flattened distal segment representing the hand or foot, and a rounded proximal segment representing the remainder of the limb. The latter is again divided by a slight constriction into a distal part, corresponding to the forearm or leg, and a proximal part corresponding to the arm or thigh. The digits are formed as radiating ridges on the lateral surfaces of the hand and

foot segments. As these ridges grow more rapidly than the bodies of these segments they soon project beyond their margins as definitive fingers or toes.

The axes of the limbs undergo three main changes in position in their early development. At first the limb-buds project outward at right angles to the lateral surface of the body. Later they are bent caudally and ventrally so that their former ventral surfaces face medially. And finally each limb is rotated

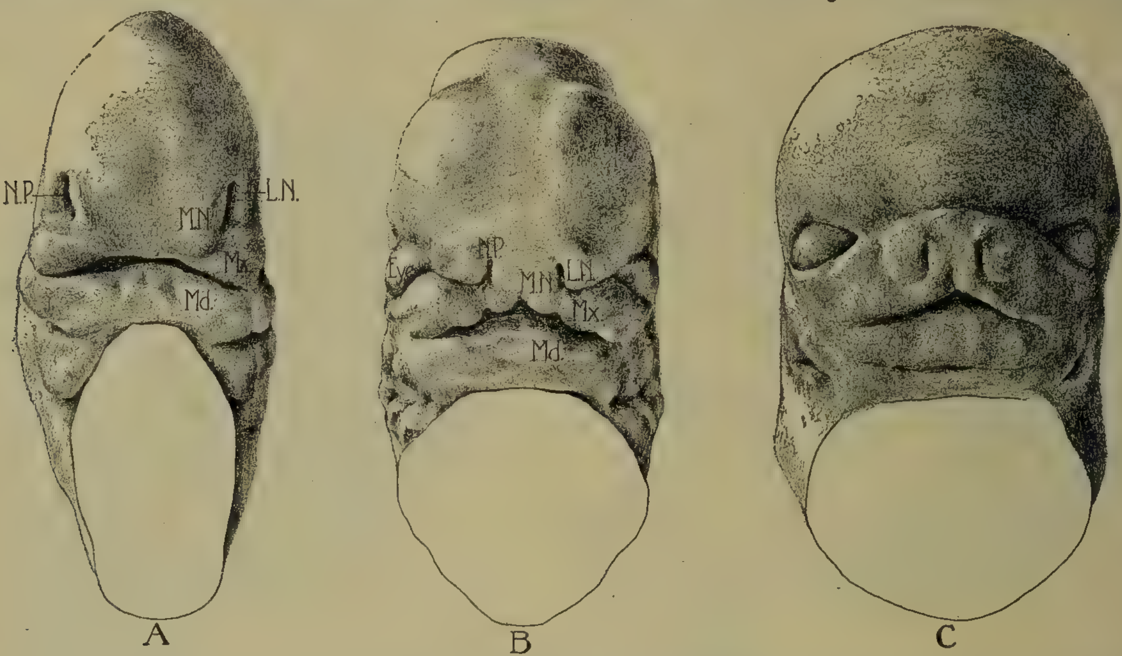


FIG. 17.—DEVELOPMENT OF THE FACE IN THE SECOND FETAL MONTH. (From a series of models made in the Department of Embryology of the Carnegie Institution.)

L.N., lateral nasal process. Md., mandibular process. M.N., medial nasal process. N.P. nasal pit. Mx., maxillary process.

about its long axis through an angle of approximately 90 degrees. This rotation takes place in opposite directions in the arm and leg. The arm is turned outward so that the thumb comes to lie on the lateral (outer) margin of the limb and the palm faces ventrally (in supination), while the leg rotates inward and the great toe comes to lie on the medial margin of the limb, and the plantar surface of the foot faces dorsally.

In embryonic life the development of the arm precedes that of the leg and it is not until after birth that the lower extremity exceeds the upper one in length.

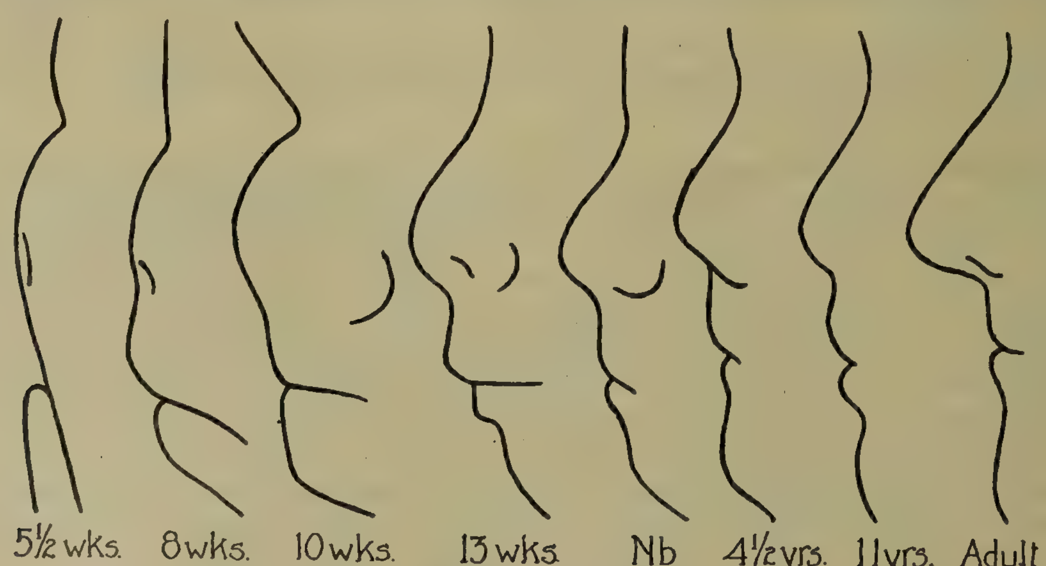


FIG. 18.—A SERIES OF PROFILES ILLUSTRATING THE CHANGES IN THE FORM AND PROPORTIONS OF THE FACE IN THE DEVELOPMENTAL PERIOD. (After Peter.)

In postnatal life the lower limb increases in length more rapidly than the upper; at about two years their length is equal and in the adult the lower limb is about one-sixth longer than the upper. The adult relations of the different segments of the limbs (arm, forearm and hand, and thigh, leg and foot) are practically established early in prenatal life although there is some reduction in the relative length of the hand and the height of the foot in the postnatal period.

FIG. 19.—DEVELOPMENT OF THE UPPER EXTREMITY. (After Retzius.)

A, anterior limb-bud of an embryo 12 mm. long. B, anterior limb-bud of an embryo 15 mm. long. C, anterior limb-bud of an embryo 16 mm. long. D, forearm and hand of an embryo 25 mm. long. E, hand of a fetus 52 mm. long. All ×6.

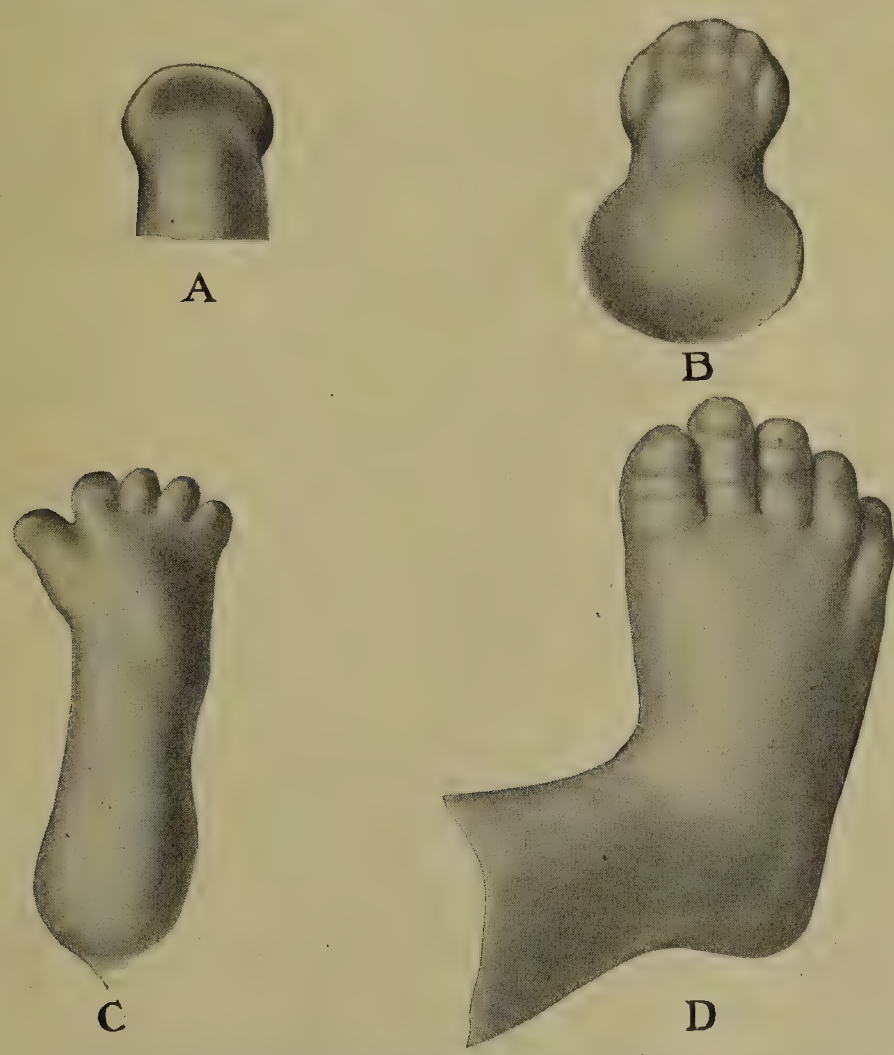


FIG. 20.—DEVELOPMENT OF THE LOWER EXTREMITY. (After Retzius.)

A, Posterior limb-bud of an embryo 17 mm. long. B, posterior limb-bud of an embryo 19 mm. long. C, leg and foot of an embryo 25 mm. long. D, foot of a fetus 52 mm. long. All ×6.

THE GROWTH OF THE BODY AND ITS PARTS

Growth of the body in weight.—The diameter of the ripe human ovum is approximately 0.1 mm. Consequently, if the egg-cell is considered as a perfect sphere, its volume is about 0.0000005 cc. and its weight, assuming the specific gravity to be 1.0, is about 0.0000005 gm. If the average weight of the body in the third decade be considered as 65 kilos (about 143 pounds) we may estimate the total increment in the body-weight during the developmental period at about 130 billion-fold. Considered from this point of view, almost all of the weight increment takes place in prenatal life, for in this period the body increases in mass about 6.5 billion times while from birth to maturity the gain is but 20-fold. From the standpoint of absolute growth, on the other hand, the body acquires about 5 per cent. of its adult weight before birth and about 95 per cent. thereafter. The growth of the body in weight is indicated in the following tables.

PRENATAL GROWTH IN LENGTH AND WEIGHT (After Jackson)

Age in lunar months	Crown-rump or sitting height (Mall), cm.	Crown-heel or standing height (Mall), cm.	Weight at end of month, grams	Ratio of monthly increase to weight at beginning of month
0	(diameter of ovum = 0.1 mm.)	....	(Ovum = 0.0000005 g.)	....
I	0.25	0.25	0.004	7999.99
II	2.5	3.0	2.0	499.0
III	6.8	9.8	24.0	11.0
IV	12.1	18.0	120.0	4.0
V	16.7	25.0	330.0	1.75
VI	21.0	31.5	600.0	0.82
VII	24.5	37.1	1000.0	0.67
VIII	28.4	42.5	1600.0	0.60
IX	31.6	47.0	2400.0	0.50
*X	33.6	50.0	3200.0	0.33

* 270 days (Mall).

AVERAGE PHYSICAL MEASUREMENTS OF AMERICAN CHILDREN IN THE FIRST FOUR YEARS OF POSTNATAL LIFE. (Based in part on the figures of Crum and Taylor.)

Age	Sex	Weight, pounds	Height, inches	Chest girth, inches	Head girth, inches
Birth	Boys................	7.3	20.5	13.0	14.0
	Girls................	7.1	20.0	12.9	13.8
6 months	Boys................	18.0	26.5	17.4	17.4
	Girls................	16.7	25.9	17.1	17.1
12 months	Boys................	21.9	29.4	18.6	18.5
	Girls................	20.7	28.9	18.1	18.0
18 months	Boys................	24.6	31.7	19.1	19.1
	Girls................	23.4	31.1	18.6	18.5
2 years	Boys................	27.1	33.7	19.5	19.4
	Girls................	26.4	33.4	19.4	19.0
3 years	Boys................	32.2	37.1	20.6	19.9
	Girls................	30.5	36.7	20.4	19.4
4 years	Boys................	35.9	39.5	21.1	20.1
	Girls................	33.7	39.0	20.4	19.7

Growth in length.—Growth in length has certain characters in common with growth in weight although the relative lineal increase of the body in the developmental period is obviously much smaller than the relative growth in mass. At the end of the first fetal month the length of the embryo is approximately 0.25 cm. This is increased 10-fold in the second fetal month but thereafter the relative rate of growth becomes progressively slower. The period of most rapid absolute growth in length is in the fourth fetal month, during which there is a gain of about 8 cm. (from 10 cm. in the twelfth week to 18 cm. in the sixteenth). After this there is a gradual decline in the absolute as well as the relative rate of lineal increase.

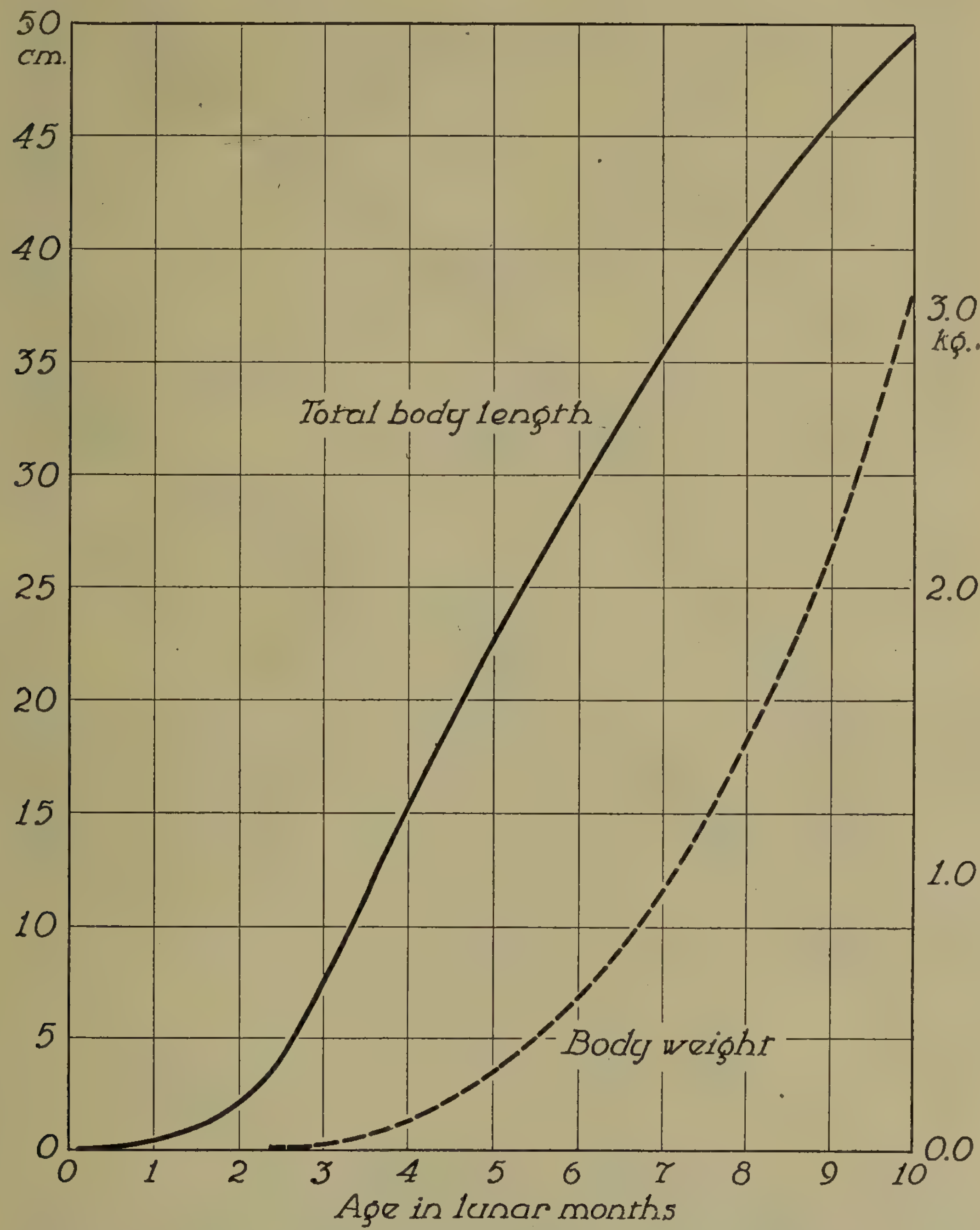


FIG. 21.—CHART OF THE AVERAGE GROWTH IN LENGTH AND WEIGHT IN FETAL LIFE. (Based on formulae developed by Calkins and Scammon from the data of Mall, A. W. Meyer, Jackson and others.)

The growth in length in fetal life is indicated in a preceding table (p. 22) and by the upper curve in fig. 21. The age of the fetus may be roughly estimated from its standing height by 'Hasse's rule'; namely: that before the fifth month the age in fetal months is equal to the square root of the total (standing or crown-heel) height, while after the fifth month the age equals one-fifth of the standing height in cm. This gives approximate results except for the first 2 months.

The length of the body at birth usually falls between 48 and 52 cm. (approximately 19 to 21 inches). The birth-length, like the birth-weight, is influenced by sex, race, and a number of other factors. In the neonatal period there is often a slight decrease in length due to changes in bodily dimensions in the recovery from the molding effects of birth.

The curve of postnatal growth in length is a sinuous one similar to the curve of postnatal weight increase and the same phases may be recognized in it. Length increases about 30 per cent. (15 cm. or 6 inches) in the first six months and about 50 per cent. (25 cm. or 10 inches) in the first year (fig. 22). During early and middle childhood the lineal increase is very slow, averaging only about 6 or 7 cm. per year. The prepuberal length increase, like the weight increase, begins earlier in girls than in boys and is completed sooner. The body increases approximately 3.3 times in length during the postnatal developmental period. Growth in length usually ceases at about 18 years in females and soon after 20 in males.

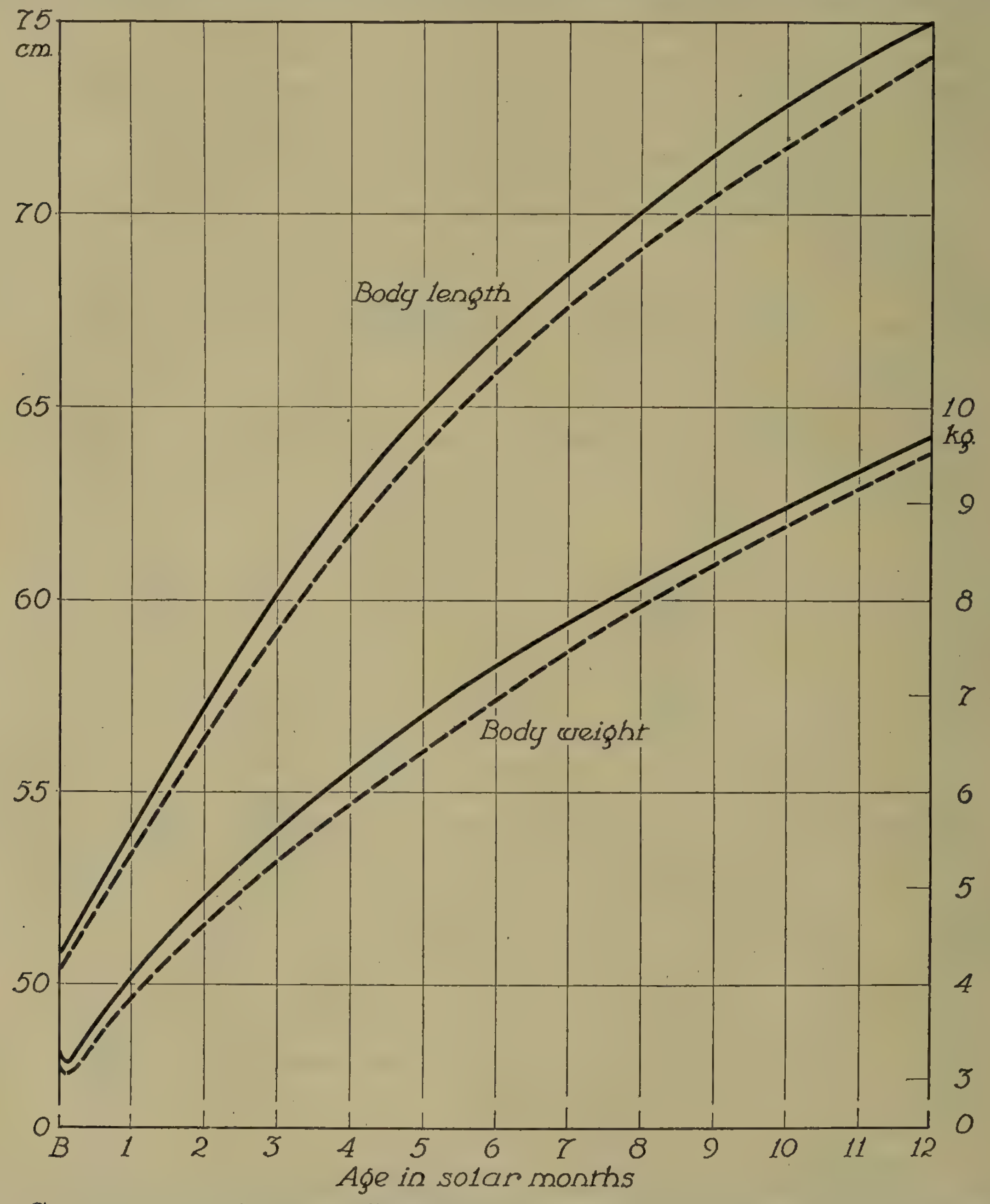


FIG. 22.—CHART OF THE AVERAGE GROWTH IN HEIGHT AND WEIGHT IN THE FIRST YEAR. (Based on the data of Richdorf, Minneapolis children.) Solid lines, males; broken lines, females.

The relation between the length and the weight of the body changes greatly in the developmental period. In later fetal life and early infancy the mass of the body is much greater in proportion to its length than at any subsequent time. The decline in relative weight begins about the middle of the first year and continues until after puberty. Thereafter there is a period of relative mass increase which may continue throughout maturity. During infancy and childhood females are relatively lighter than males but after puberty there is little difference in this relationship.

The surface area of the body in the developmental period.—The metabolism of the body is greatly influenced by the relation of its surface or cutaneous area to its mass or volume, and this relation is greatly altered in the course of postnatal development. The surface area of the average newborn child is about 2500 square cm. (400 square inches). This is doubled in the first year and is tripled in the middle of childhood. There is a period of rapid increase in surface area

before puberty and the total gain between birth and maturity is about 7-fold. But the weight of the body increases approximately 20-fold in this time and there is consequently a great reduction in the ratio of surface area to mass or volume (from over 800 square cm. of surface area per kilogram of body weight in the newborn to less than 300 square cm. per kilogram in the adult.).

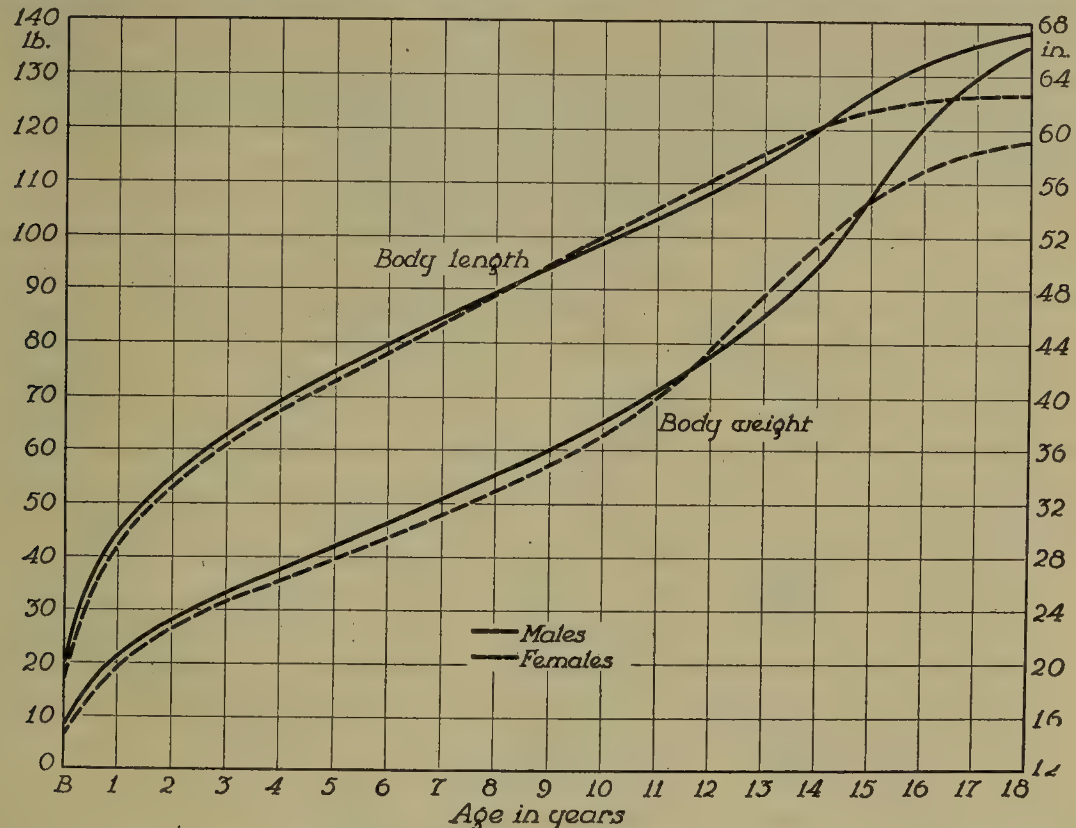


FIG. 23.—CHART SHOWING AVERAGE POSTNATAL GROWTH IN HEIGHT AND WEIGHT. (Based upon the collected data of Emerson and Manny.)

The relative growth of the parts of the body.—Growth and differentiation do not take place at the same time or rate in the various parts of the body and the changes in proportions which occur in the developmental period are dependent on this lack of uniformity. While each part passes through its own cycle of changes, these changes as a whole tend to follow what is known as the *law of developmental direction;* for it is generally found that development (including

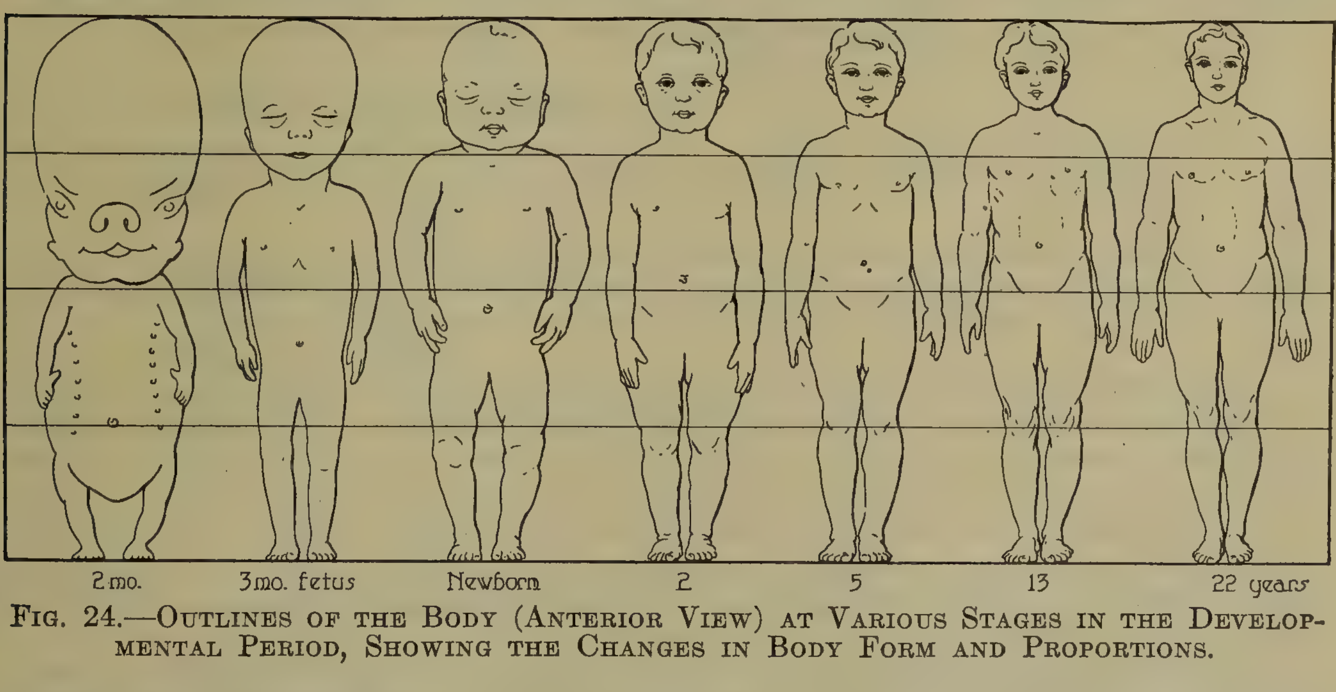


FIG. 24.—OUTLINES OF THE BODY (ANTERIOR VIEW) AT VARIOUS STAGES IN THE DEVELOPMENTAL PERIOD, SHOWING THE CHANGES IN BODY FORM AND PROPORTIONS.

growth and differentiation), in the long axis of the body, appears first in the head region of the body and progresses toward the tail region and similarly development in the transverse plane begins in the mid-dorsal region and progresses lateroventrally (in the limbs proximodistally).

Some of the changes in the proportions of the body and the relative size of its several parts are indicated in figs. 24, 25 and 26. The *head* is the largest

part of the body in earlier stages, forming about one-half of the body in the second fetal month, about one-quarter at birth, and from 6 to 8 per cent. in maturity. The *trunk* as a whole remains of about the same relative size throughout the developmental period (45 to 50 per cent.) although the thoracic portion reaches its maximum in the earlier stages and the pelvic portion not until adolescence. The *lower limbs*, like the pelvis, develop slowly, forming about 3 per cent. of the body at the end of the period of embryo, about 15 per cent. at birth and reaching about 30 per cent. in the adult. The *upper limbs* also form about 3 per cent. of the body weight at the close of the embryonic period. They increase to 8 or 9 per cent. at birth and maintain thereafter about the same relative size.

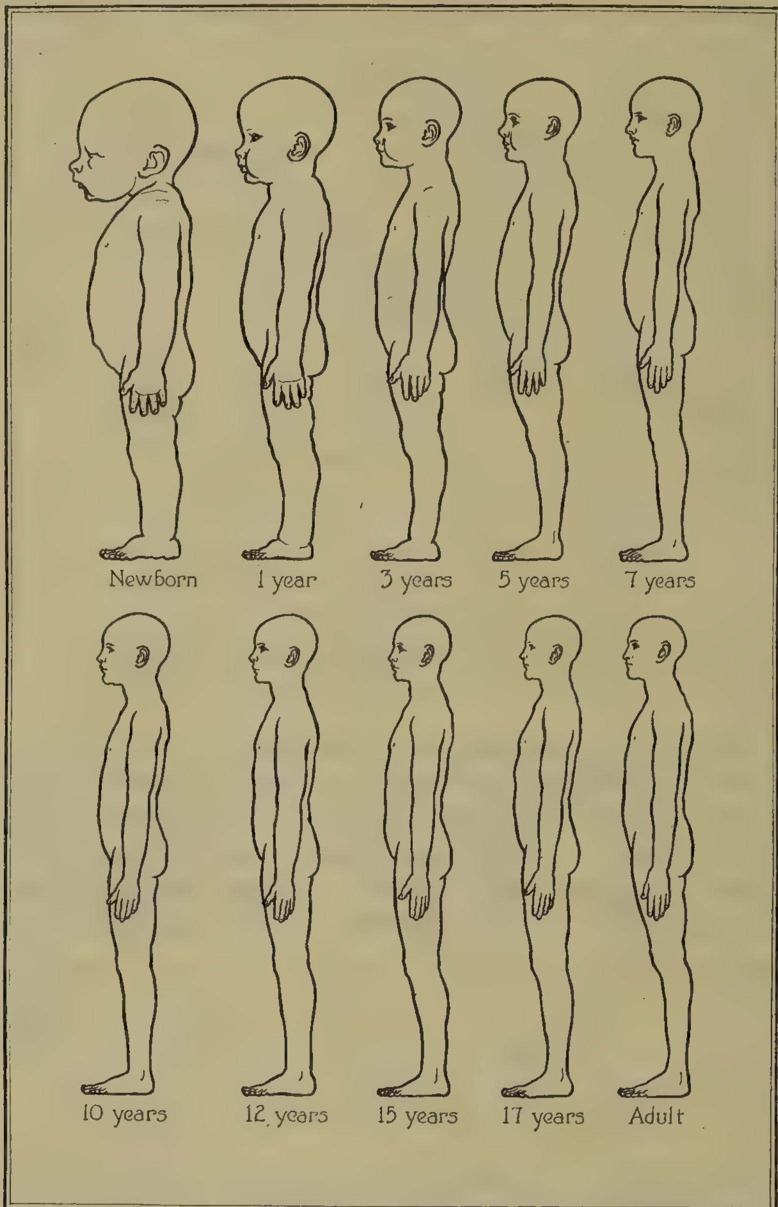


Fig. 25.—Outlines of the Body (Lateral View), Showing the Changes in Body Form and Proportions at Various Periods of Postnatal Life.

These changes cause a great increase in the relative weight and volume of the caudal or lower part of the body; and with them the *midpoint* of the body (between crown and sole) is gradually shifted from the upper margin of the thorax at the end of the embryonic period to the level of the umbilicus at birth, and to the level of the crest of the pubis in the adult. The center of gravity is also shifted caudally from the cervical region in the embryo to the point where the inferior vena cava pierces the diaphragm at birth, and to a point just in front of the sacral promontory in the adult.

The relative growth of systems.—There is a marked difference in the growth of the various systems of the body. The *skeleton* grows comparatively slowly during the greater part of prenatal life but increases much more rapidly in the last two fetal months. At birth it forms from 15 to 20 per cent. of the body. Its postnatal growth apparently proceeds with that of the body as a whole, the total increase in weight between birth and maturity being about 20-fold. The *musculature* also grows rather slowly in the young embryo but increases to

about 25 per cent. of the body at birth and to 40 or 45 per cent. in the adult. The blood-vessels apparently also increase in relative weight after birth. The *central nervous system*, on the other hand, is relatively enormous in the young embryo, decreasing from about 25 per cent. of the body in the second fetal month to about 15 per cent. at birth and to between 2 and 2.5 per cent. in the adult. Data

FIG. 26.—DIAGRAM ILLUSTRATING THE CHANGES IN RELATIVE VOLUMES OF VARIOUS PARTS OF THE BODY IN THE DEVELOPMENTAL PERIOD.

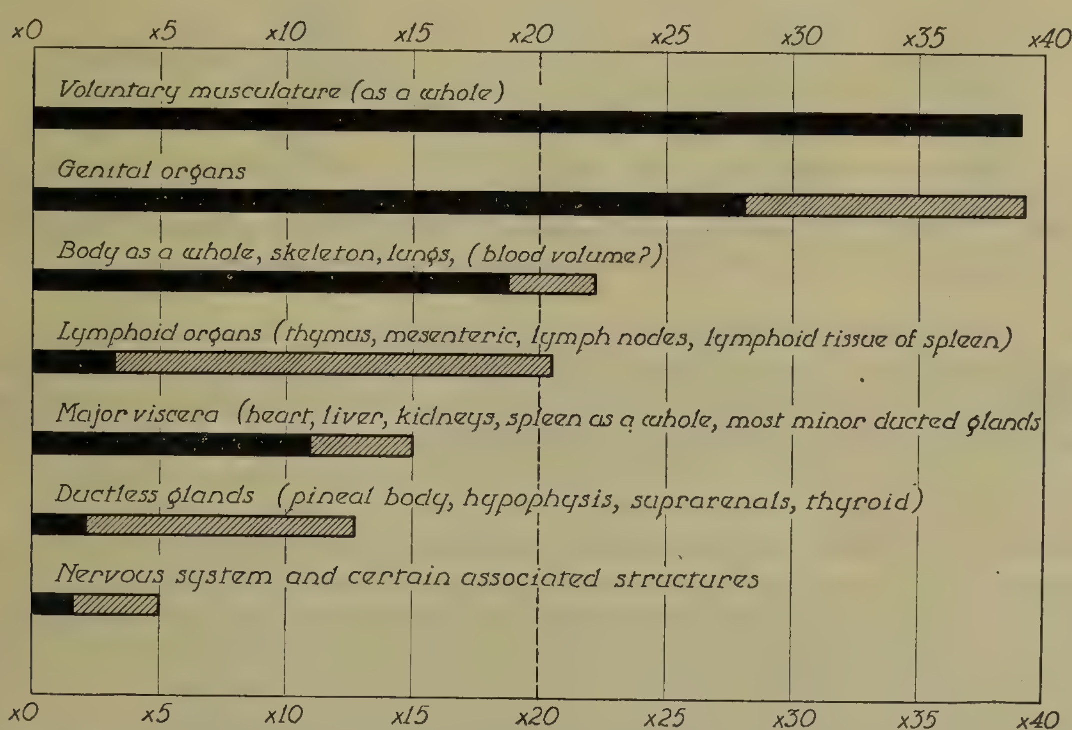


FIG. 27.—DIAGRAM ILLUSTRATING THE RELATIVE POSTNATAL INCREASE IN THE SIZE OF THE BODY AS A WHOLE AND SOME OF ITS PARTS. The shaded segments represent the differences between the maximal and minimal relative increases of the several structures in each group.

for the peripheral nervous system and the skin are somewhat scanty and rather unsatisfactory, but it is evident that both undergo a considerable reduction in relative weight in the postnatal developmental period. The *visceral group* (as a whole) shows a slow but steady decrease in relative weight after the embryonic period, forming about 15 per cent. of the body weight in the second month, about 9 per cent. in the newborn, and from 5 to 7 per cent. in the adult.

Growth of organs.—While in general the individual organs follow the course of growth of the visceral group, each organ has its own characteristic scheme of relative growth. As a rule, after appearing in the embryo, each organ increases more or less rapidly to a maximum relative size, after which, although increasing in absolute size, it decreases in relative size through subsequent prenatal and postnatal life to maturity.

Curves of the absolute growth of the various organs in the period of the fetus all appear much alike, showing an initial period of slow increase followed after the fifth month by a terminal phase of rapid growth. This uniformity is lost following birth and most of the major organs, on the basis of the course of their postnatal growth, can be classified in 4 main groups—general, nervous, genital and lymphoid (fig. 28).

The *general group* includes the digestive, respiratory, urinary organs, the heart, and the spleen as a whole. These organs increase rapidly in

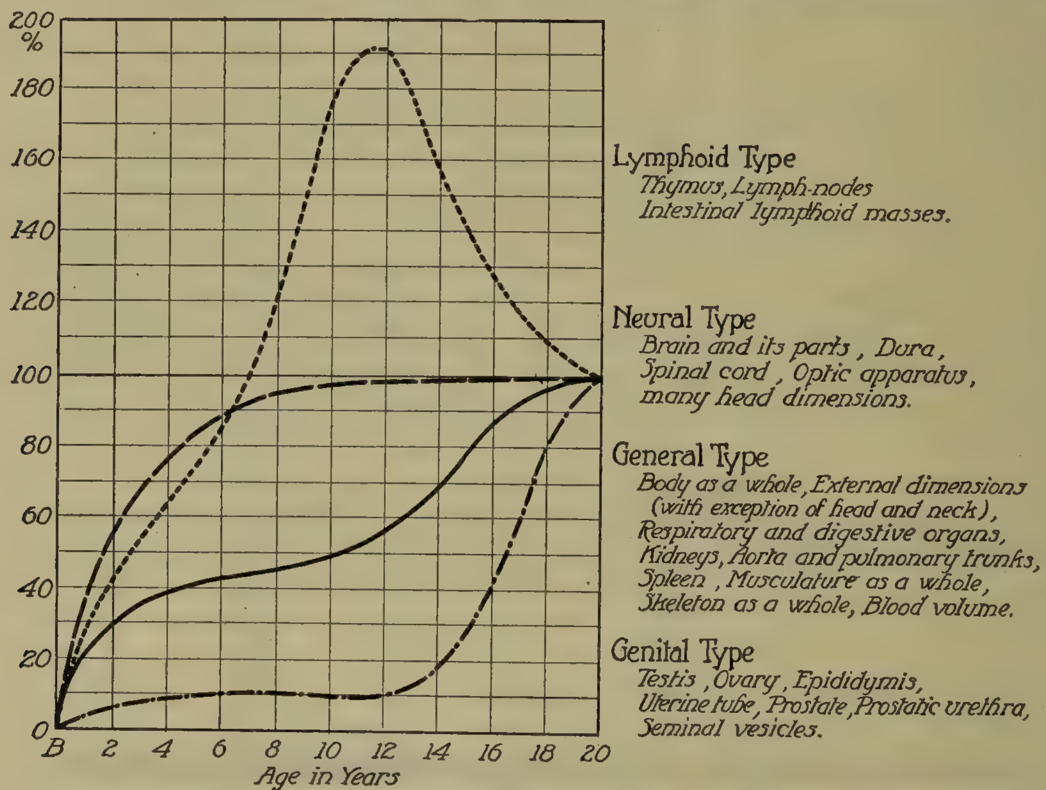


FIG. 28.—CHART ILLUSTRATING THE COURSE OF GROWTH OF THE VARIOUS TYPES OF ORGANS. The growth of the various organs is calculated in per cent. of their adult weight. (From Harris, Jackson, Paterson, and Scammon, 'The Measurement of Man,' by Permission of the Publisher, The University of Minnesota Press, Minneapolis.)

weight in infancy and the first part of early childhood. In the latter part of early childhood and in middle childhood they grow quite slowly. They enter on a second phase of rapid growth in the prepuberal period, and this is followed by a terminal phase of slow increase in adolescence. In general the growth of the organs of this group is similar to the growth of the body as a whole.

The *nervous group* includes the brain, spinal cord, and eyeballs. These structures grow very rapidly in infancy and have completed over 90 per cent. of their postnatal increase by the close of early childhood.

The organs of the *genital group* (all genital organs with the exception of the uterus) grow very slowly until the prepuberal period, when they enter on a phase of the rapid increase which extends into or through adolescence.

The structures of the *lymphoid group* (excluding the red pulp of the spleen but including the thymus) are large at birth, grow rapidly until puberty, and then decline in absolute weight.

The organs which do not fall under any of the preceding categories are the suprarenal glands, the uterus, the hypophysis and possibly the thyroid gland. Their growth is considered in connection with their development in the following sections.

THE SKELETON

The skeleton, including the bones, cartilages, ligaments, and joints, is derived from the mesoderm. The process is inaugurated by the formation, in the future skeletal regions, of masses of thickened mesenchyma known as scleroblastema. The hard parts of the skeleton,

the bones and cartilages, arise in the more condensed parts of the scleroblastema while the joints are formed from the intervening portions. The majority of the thickened scleroblastemal masses are differentiated into cartilage. Certain of these cartilages persist throughout life while a few may be converted at a later time into fibrous tissue. But by far the greater number are replaced by bone during the later development of the skeleton.

Most of the bones of the body arise through the replacement of previously formed bodies of cartilage by bony material, while a smaller number are formed directly in the membranous scleroblastema. The former are known as cartilaginous or replacement bones and the latter are termed membranous or investment bones. All the bones of the extremities, the bones of the spinal column and thorax, the auditory ossicles, the hyoid bone, and the greater part of the bones of the base of the skull are cartilaginous bones. The bones of the face and the greater part of the vault of the skull are membranous bones. Certain of the skull bones are formed partly in membrane and partly in cartilage.

The **process of ossification** begins in discrete foci which are known as centers of ossification. These centers are formed from time to time throughout the developmental period, the first

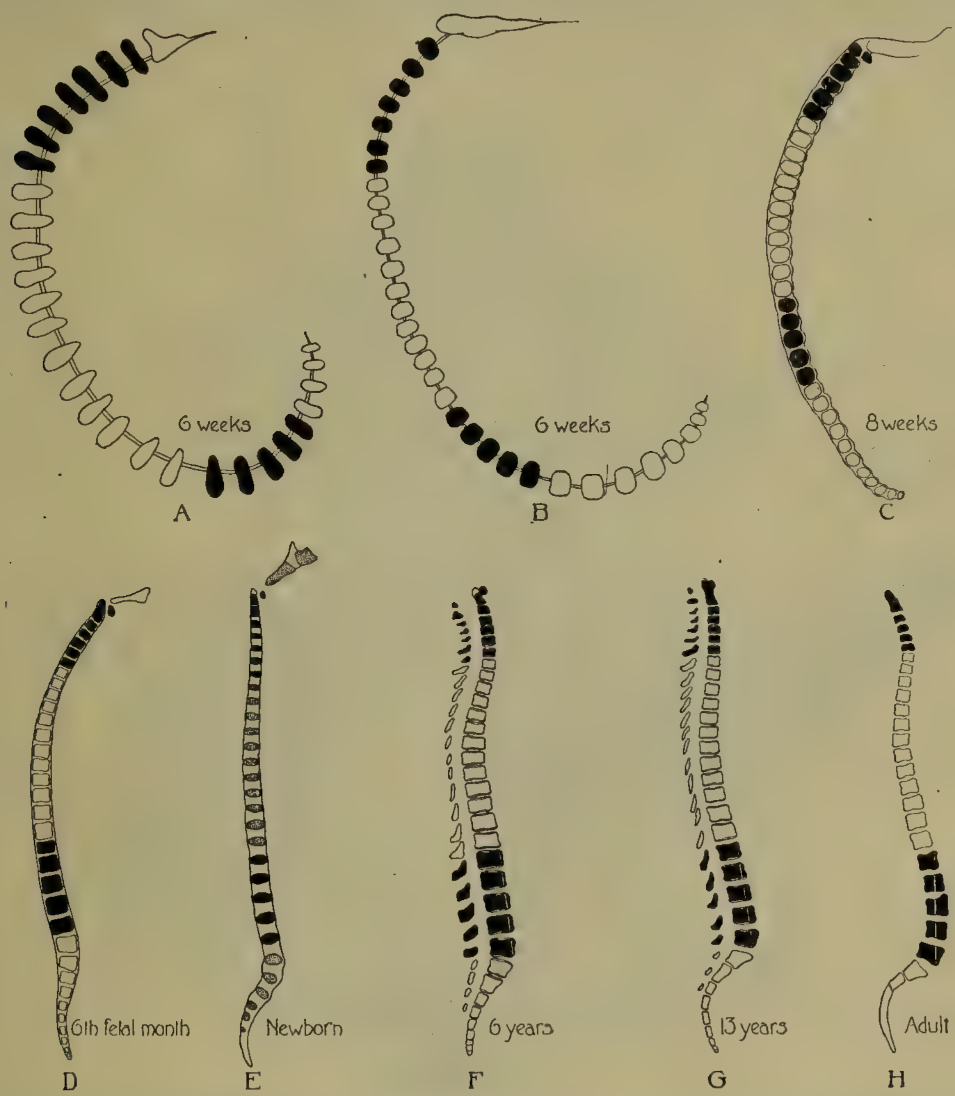


FIG. 29.—MEDIAN SAGITTAL SECTIONS OF THE VERTEBRAL COLUMN AT VARIOUS AGES ILLUSTRATING THE DEVELOPMENT OF THE NORMAL SPINAL CURVATURES. Cervical and lumbar vertebræ indicated in black. (Based in part on the figures of Bardeen, Williams and Cunningham.)

appearing in the clavicle in embryos of the sixth week and the last, in the epiphyses of the vertebral column, in the third decade of postnatal life. Over eight hundred centers are formed in the body and of these slightly more than half appear after birth.

Almost all bones of the adult are formed from one or more centers of ossification; the relation of the total number of bones in the mature skeleton to the total number of centers being approximately as 1 to 3. The ossification centers of all bones of the body with the exception of those of the carpus, tarsus, skull, and sternum, may be divided into two general classes, the primary and secondary. The primary centers which form the greater part of the bone almost always appear before birth. Such centers, when located in long bones, are known as diaphyses. The secondary centers or epiphyses are, with one or two exceptions, formed during postnatal life. A further consideration of the nature of diaphyses and epiphyses will be found in the section on Osteology (pp. 88, 89).

As the formation of new centers and the fusion of older ones proceeds at unequal rates during the first two decades, the number of separate bone masses in the body varies from year to year during this period. The **number of bones** in the average newborn child is 270. This number is reduced in the first 2 or 3 years of life through the fusion of primary centers which are present before birth. From this time until puberty, however, the number increases steadily through the formation of epiphyses and the ossification of the carpus and tarsus. In the four-

teenth year there are about 350 separate bony masses in the body. After puberty the number again increases rapidly until nearly the middle of the third decade. Often it is not until middle life that the number of bones is reduced to the usual quota of 206, excluding the smaller sesamoids.

The spinal column.—In the latter part of the first month the notochord is surrounded by a sheath of mesenchyme in which may be recognized segmentally arranged masses which represent the vertebræ and are formed from the sclerotomes of the mesodermic somites. Dorsal prolongations from these masses grow up on either side of the neural tube forming the arches of the vertebræ, and at the same time lateral outgrowths appear which represent the various lateral projections of the vertebræ, including the costal processes.

In the second and third fetal months the cervical and sacral regions form the greater part of the vertebral column (fig. 29). At birth the cervical part forms approximately one-fourth, the thoracic part one-half, and the lumbar part one-fourth of the entire movable spine. In the adult the thoracic portion continues to form approximately one-half of the free vertebral column, but the lumbar portion is increased to about one-third, and the cervical portion is reduced to one-fifth or one-sixth of the whole. It is probable that in most cases these proportional postnatal changes take place in the first 3 years.

Fig. 30.—Diagram Showing the Categories to which the Bones of the Skull Belong. (After McMurrich.) The unshaded bones are membrane bones, the heavily shaded represent the chondrocranium, while the black represents the branchial arch elements.

AS, alisphenoid. ExO, exoccipital. F, frontal. Hy., hyoid. IP, interparietal. Z, zygomatic. Mn, mandible. Mx, maxilla. NA, nasal. P, parietal. Pe, periotic. SO, supraoccipital; Sq, squamosal; St, styloid process; Th, thyroid cartilage; Ty, tympanic.

During the first fetal month the vertebral column shows a pronounced ventral *flexion*. From this time until birth the free portion gradually becomes straighter while the sacral portion first becomes straighter and later acquires a second ventral curve. In the newborn child the free column forms a single gentle curve with an anterior (ventral) concavity extending from the first cervical to the last lumbar vertebra, while the sacrum is directed somewhat posteriorly. The cervical curve appears when the infant begins to lift its head but neither at this time nor later does it become a fixed flexure. The lumbar curve appears as the child assumes the upright posture. It forms very slowly and throughout childhood and adolescence it may be effaced by stretching the spine. Later the lumbar curve is fixed, in a measure, by the anterior thickening of the lower lumbar vertebræ and the intervertebral disks between them. This process begins in later childhood and continues slowly until maturity. For further details on the curvatures, see p. 103.

The cartilaginous vertebræ are formed by the appearance of centers of chondrification of the blastemal vertebræ. There are four of these centers for each vertebra, two lateral ones which soon fuse in the body, and one for each side of the vertebral arch. The ossification of the vertebræ is considered in the section on Osteology.

The material between the vertebral masses is later converted into the outer portions of the intervertebral disks; and the segments of the notochord which occupy these regions form the nuclei pulposi. The vertebral portions of the notochord degenerate.

The *length* of the movable or free vertebral column (cervical, thoracic, and lumbar vertebræ) at the end of the second fetal month is about 2 cm. This is more than doubled in the third month, nearly quadrupled in the fourth, and increased almost 10-fold by birth when the average length is almost 20 cm. (8 in.). Between birth and maturity the movable vertebral column increases in length between 2 and 2.5 times, about two-thirds of this growth being accomplished before puberty. After the second fetal month the vertebral column forms from 40 to 45 per cent. of the total length of the skeleton.

Development of the skull.—The bones of the skeleton of the head may be divided into three main categories (fig. 30): (1) the group of cartilage bones developed mainly in the base of the skull around and anterior to the cephalic portion of the notochord and about certain of the organs of sense; (2) the membrane bones which form the vault of the skull and the framework of the upper part of the face; and (3) the cartilage bones which have their origin from the cores of the branchial arches. The distinction between these three parts of the head skeleton is often imperfect, for their parts overlap and fuse during development and the relations between them are constantly shifted and modified.

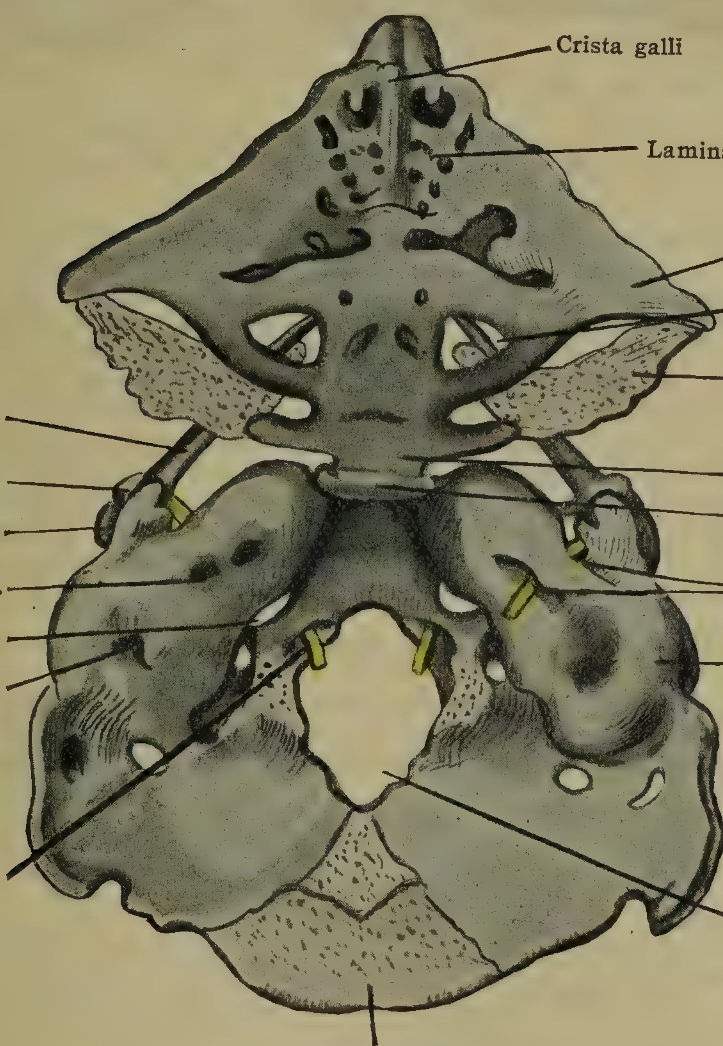


FIG. 31.—MODEL OF THE CHONDROCRANIUM OF A HUMAN FETUS 8 CM. IN LENGTH. Cartilage in blue. Viewed from above. (After O. Hertwig.)

In the skull, as in the other parts of the skeleton, three stages, the blastemal or membranous, the chondrogenous, and the osseogenous, may be recognized although they overlap considerably and do not proceed at the same rate in all parts of the head skeleton.

Toward the end of the first month the brain is enclosed in a membranous sac formed by the condensation of the surrounding mesenchyma. The basal portion of this sheath forms a thickened plate which surrounds the cephalic portion of the notochord and projects forward beyond its anterior termination. The occipital portion of this plate is greatly expanded and is connected with the fibrous capsules around the developing internal ears. The anterior part of the plate extends forward into the nasal region.

The formation of the *chondrocranium* in the basal portion of the cranial blastema begins early in the second month and is practically complete by the close of the third (fig. 31). The caudal or occipital portion of the chondrocranium forms almost a complete ring around the foramen magnum and extends laterally about the base of the posterior part of the brain. Lying anterior to the occipital portion of the skull on either side are the cartilaginous auditory capsules. The contiguous borders of the occipital portion of the skull and the auditory capsules are partly fused, but lacunæ in this region indicate the position of the future hypoglossal and jugular foramina and transmit the structures which pass through these openings in the adult skull. A median bar of cartilage, which represents the basilar portion of the occipita

bone and the body of the sphenoid, passes forward from the anterior margin of the foramen magnum and terminates in an expanded frontonasal plate. Two pairs of processes arise from this median mass. The posterior (alisphenoid) represents a part of the greater wing of the sphenoid and the anterior clinoid processes. The latter fuse with the frontonasal plate enclosing the optic foramina. The medial portion of the frontonasal plate extends forward into the nasal region forming the fundament of the ethmoid bone and a part of the nasal capsule. The lateral portions (orbitosphenoid) spread over the eyes and represent the lesser wings of the sphenoid.

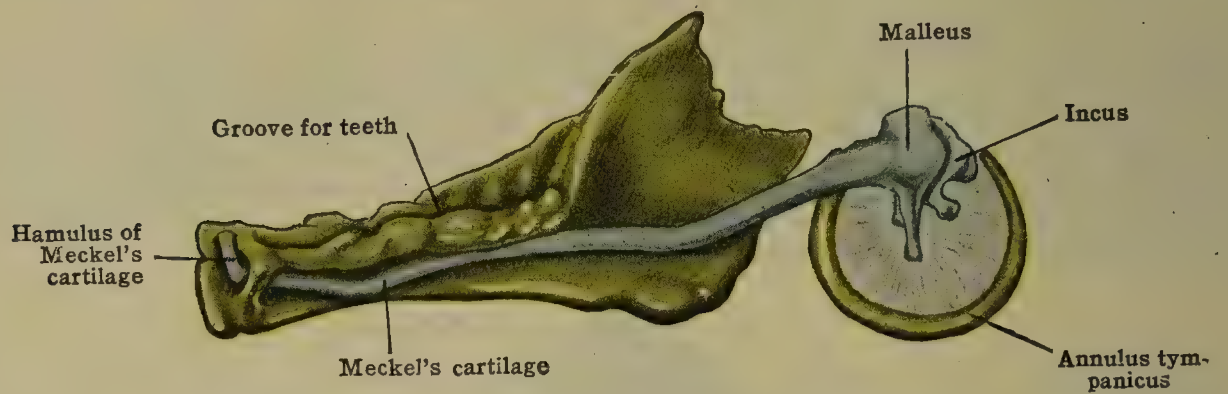


FIG. 32.—MANDIBLE SHOWING RELATIONS OF MECKEL'S CARTILAGE IN A HUMAN FETUS OF 8 CM. CROWN-RUMP LENGTH. (After Kollmann.)

The *visceral elements of the skull* are derived from cartilages formed in the branchial arches with the addition of certain membrane bones. The cartilage of the first arch is known as Meckel's cartilage. It extends from the outer surface of the auditory capsule through the mandibular process to the ventral median line. The upper portion of Meckel's cartilage is differentiated into two parts which form two of the auditory ossicles, the malleus and the incus. The lower part is enclosed in a sheath of membrane bone which forms the mandible (fig. 32). All of this part of the cartilage disappears with the exception of its medial tip which is probably involved in the formation of the mental protuberance. The upper portion of the cartilage of the second or hyoid arch forms a portion of the stapes and a part of the styloid process of the temporal bone while its lower segment gives rise to the lesser cornu and a part of the body of the hyoid bone. The upper portions of the third, fourth and fifth arches form no permanent structures. The lower part of the third arch gives rise to the greater cornu and a part of the body of the hyoid bone, and the lower parts of the fourth and fifth arches are involved in the formation of the thyroid cartilage.

The further history of the ossification of the bones of the head will be found in the section on Osteology.

Growth of the skull.—The most striking characteristic of the fetal skull is the great predominance of the neural over the visceral portion. During the period of the chondrocranium the base of the cranium is large as compared with the roof or vault but with the growth of the

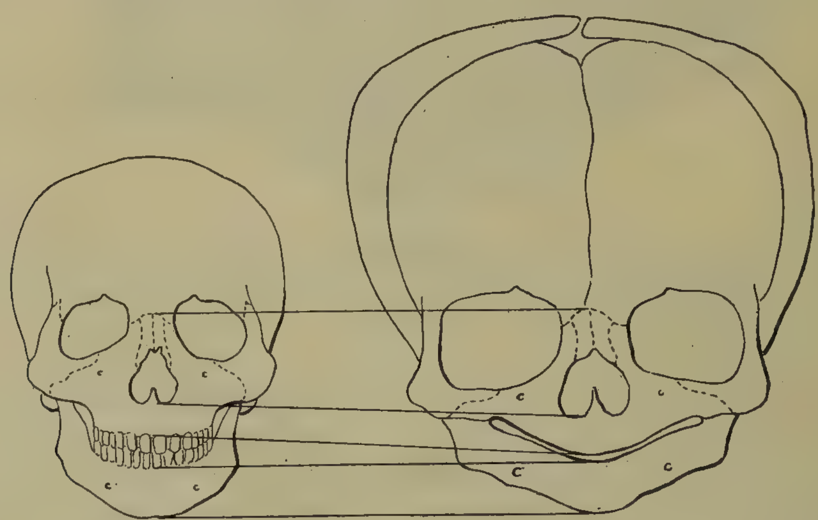


FIG. 33.—SKULLS OF THE NEWBORN AND ADULT. Drawn to the same face height to illustrate the relative proportions of the facial and neural skeleton at birth and in maturity. (After Holl.)

cerebral hemispheres the vault becomes increasingly prominent. In early stages of development the occipital region forms by far the largest part of the cranium. Later the parietal portion enters on a period of rapid growth and becomes the predominant region, and finally in the last fetal months the frontal region becomes the center of most vigorous expansion.

At birth the skull is large as compared with the rest of the skeleton. The neural portion is still much larger than the visceral or facial, the relation between the two being as 8 to 1, as compared with the ratio of 2.5 to 1 in the adult (fig. 33). The vault in comparison with the base of the cranium is also much larger than in later life.

The bones of the cranial vault are quite thin and are separated by narrow strips of membrane which are expanded at the angles of the parietal bones into areas of some size which are known as *fontanelles.* Theoretically fontanelles may be formed at any point on the calvarium which is equidistant from three or more contiguous centers of ossification. There are some 26 such points on the vault of the skull and constant or occasional fontanelles have been found in most of these locations. Two median and single fontanelles (the frontal and occipital), and two lateral and paired fontanelles (the sphenoidal and mastoid), are commonly present at birth. Their positions are shown in figs. 34 and 194–196. Besides these constant fontanelles, numerous accessory ones may be present. The more important ones, the parietal, cerebellar and metopic fontanelles, are all located along the sagittal suture.

The involution of the frontal fontanelle usually begins about three months after birth and is generally completed early in the second year. The occipital fontanelle is generally closed by the end of the first trimester. The sphenoidal fontanelle commonly closes in the first 6 months and the mastoid fontanelle between 12 and 18 months after birth. The obliteration of the fontanelles takes place by the progressive ingrowth of the edges of the bone which bounds them, but occasionally separate ossification centers may arise within them and form independent bones which occupy all or part of the original space.

The skull as a whole grows less in postnatal life than the other divisions of the skeleton, the neural portion increasing in volume about 5 times and the facial portion about 12-fold. Between birth and maturity the *cranial capacity* rises from 400 to 1500 cc. and the horizontal circumference of the skull from about 32 cm. to 48 or 50 cm. Most of this growth takes place

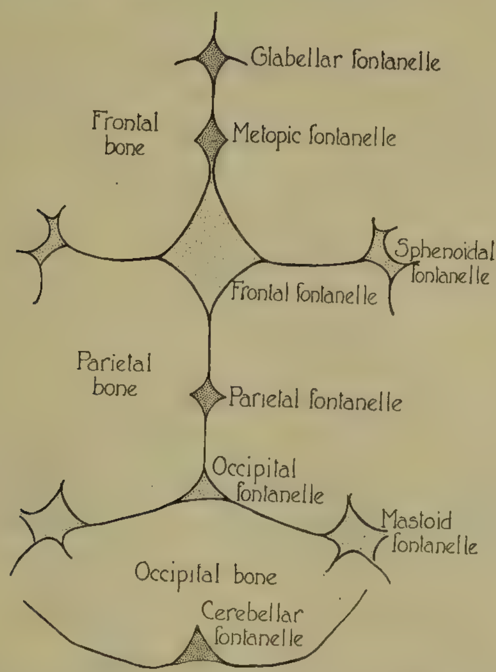


Fig. 34.—Diagram of the Calvarium at Birth, Showing the Positions of the Constant and the more Important Accessory Fontanelles. Constant fontanelles shaded in light stipple, accessory fontanelles in heavy stipple.

in the first two or three years after birth (fig. 35). The postnatal growth of the skull is closely associated with the growth of other structures of the head and particularly with those of the brain and eyeballs, the teeth and paranasal sinuses, and certain of the larger muscles. These structures influence the growth of the skull at different periods: the brain and eyeballs mainly in infancy and early childhood, the teeth and paranasal sinuses mainly in middle and later childhood, and the muscles mainly in adolescence.

During infancy all parts of the skull grow rapidly, the cranial capacity increasing from 400 cc. at birth to 700 cc. at 6 months and over 1000 cc. at 18 months. The face grows even more rapidly than the cranium in this period, the ratio between the two being reduced from 1 to 8 at birth to 1 to 6 in the second year. Most of the early growth of the face is due to the expansion of the orbits, which accomplish over half of their postnatal growth in the first 2 years, but there is also a marked growth of the maxillæ and mandible in connection with the development of the deciduous dentition.

From 2 to 7 years the growth of the skull is continued, although less rapidly than in infancy. The cranium expands slowly, the vault growing more than the base. The facial skeleton grows more rapidly than the neural portion and by 5 years the ratio between them is 1 to 5. Most of the growth is in the lower part of the face and is associated with the expansion of the dental arches and the development of the maxillary sinuses.

In middle and later childhood the skull grows little, aside from the lengthening of the face which accompanies the establishment of the permanent dentition. In adolescence the growth of the skull again increases. The cranium enlarges slightly in all diameters, mainly through the increase in the thickness of the bones of the vault, and the face completes its growth with the full development of the paranasal sinuses and the upper and lower dental arches. As a rule these later changes are more extensive in the male than in the female skull.

The thorax.—The formation of the thorax is first indicated in the blastemal period by the development of the costal processes of the thoracic vertebræ. These structures represent the future ribs. They assume a rod-like form and rapidly grow ventralward in the thoracic body wall. Their distal ends unite craniocaudally, forming longitudinally directed sternal bands

on either side of the ventral midline. The fundament of the unpaired sternum is formed by the side-to-side union of these bands, together with a small mass (the episternum) which is derived from a band of thickened mesenchyma connecting the sternal ends of the developing clavicles.

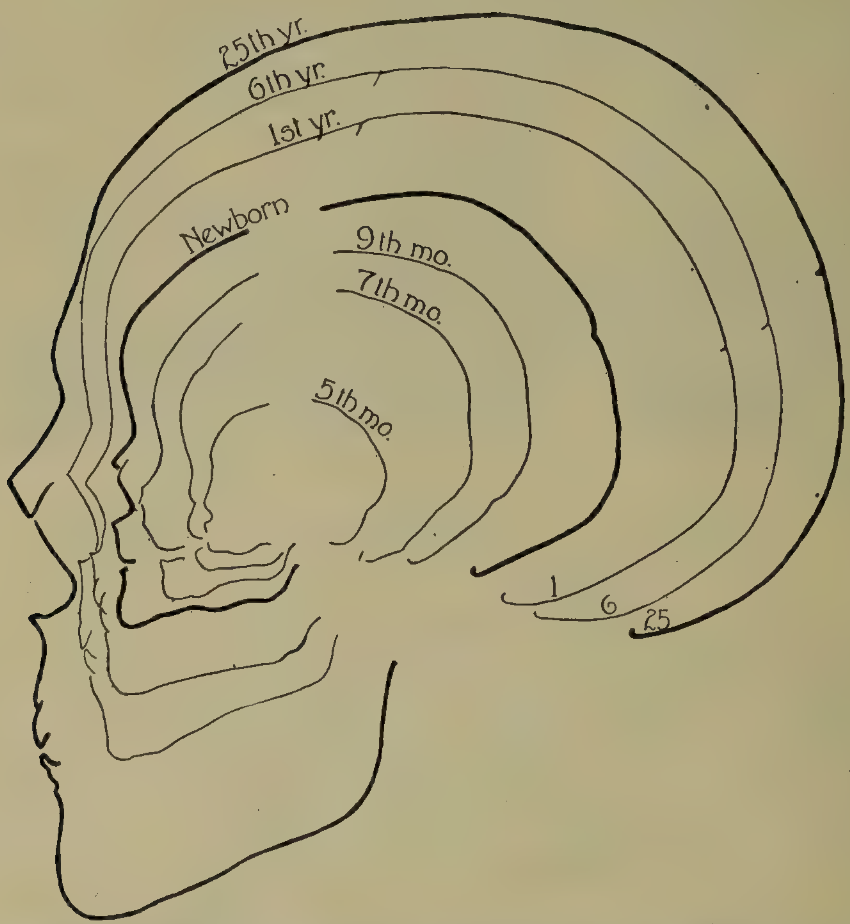


FIG. 35.—TRACINGS OF MEDIAN SAGITTAL SECTIONS OF THE SKULL AT DIFFERENT AGES, ILLUSTRATING THE RATE OF GROWTH OF THE CRANIUM. (Based on the figures of Corrado and Welcker.)

FIG. 36.—SEMI-DIAGRAMMATIC TRACINGS OF THE AXIAL SKELETON OF THE NEWBORN AND ADULT, AS SEEN IN MEDIAN SECTION. The two figures are drawn to the same stem (crown-rump) length. (Slightly modified from Stratz.)

Some of the later changes in the *form of the thorax* are shown in fig. 37. In early stages the thorax is conical and is nearly circular in cross-section. At the time of their origin the ribs lie parallel with one another and are almost horizontal, but they soon incline

downward (figs. 50–53). After birth and particularly after the erect posture is assumed there is a progressive reduction of the relative anteroposterior diameter of the thorax and its base is relatively contracted. These changes are possibly due in part to the effect of gravity on the viscera and to the reduction in relative size of the organs of the upper abdominal region.

The postnatal growth of the thorax, as determined by external measurements, particularly of the horizontal chest circumference, seems to follow the course of the growth of the body in height and weight. There is a period of rapid increase in infancy and a part of early childhood, a period of slow growth in middle childhood, followed by a phase of rapid growth in prepuberty and perhaps early adolescence, and finally a terminal period of slow increase to maturity.

The pelvis.—The pelvis is formed in part from the fixed vertebræ of the sacrum and coccyx, which are developed around the lower portion of the notochord, and in part from the blastemal ossa coxæ which are developed from the proximal portions of the mesenchymal cores of the lower limb-buds. These elements are not closely associated at the time of their differentiation and the complete pelvic girdle with definite fundaments of the pubic symphysis and the sacroiliac articulations is not established until about the end of the second month. In early fetal life the pelvis is relatively small. After the third month all of the pelvic diameters grow at approximately the same rate and there are only minor changes in the shape of the pelvis from this time to birth.

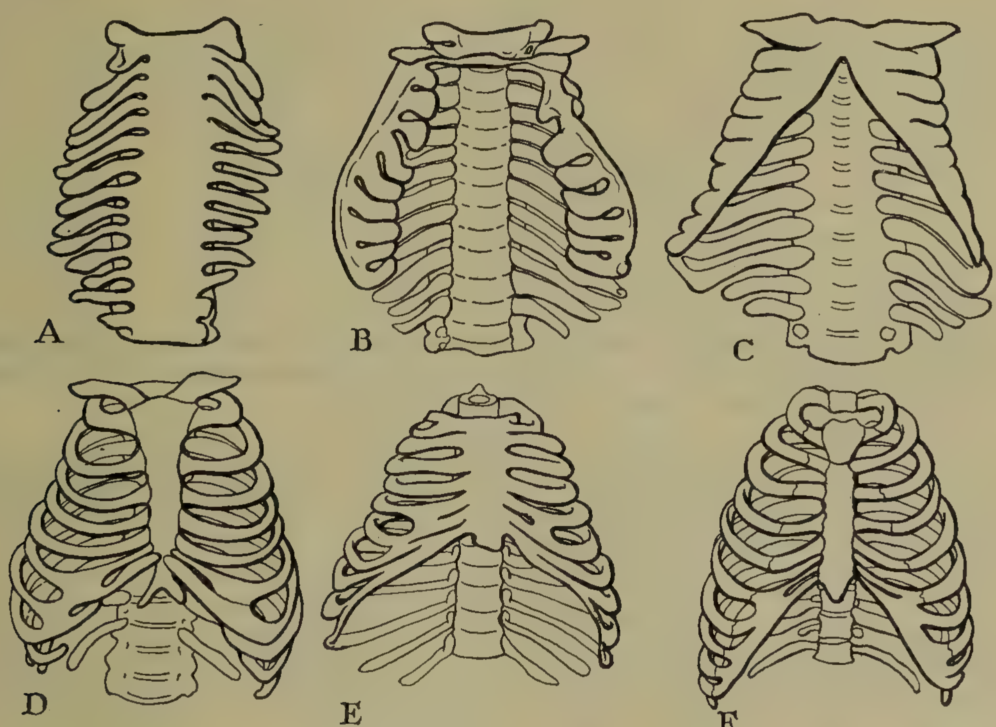


FIG. 37.—ANTERIOR VIEWS OF THE SKELETAL THORAX AT VARIOUS STAGES OF DEVELOPMENT. (In part after Müller.)

A, of an embryo 13 mm. long. B, of an embryo 14 mm. long. C, of an embryo 15 mm. long. D, of a fetus of 6 months. E, of a full-term newborn child. F, of an adult.

The *pelvis of the newborn* differs from that of the adult in a number of particulars (fig. 38). It has a distinctly conical form and its length is greater in proportion to the transverse and conjugate diameters. The pelvic cavity is relatively as well as absolutely much smaller than in the adult. The superior aperture approaches a circle more closely than in later life, although even at birth the transverse diameter is greater than the conjugate. The dimensions of both the lesser pelvic cavity and the inferior aperture are smaller in proportion to the superior aperture than at maturity. The sacrum forms a greater portion of the pelvic circumference and is less depressed between the ilia. The sacral promontory is less marked, but a second prominence may be indicated at the level of the linea terminalis. There is little indication of the sacral concavity. The acetabula are very large and shallow at birth while the obturator foramina are relatively small. The pelvis is more vertical in position than later, the plane of the superior aperture forming an angle of 80° in the horizontal as compared with 50° to 60° with the adult, while the long axis of the symphysis pubis is more nearly perpendicular.

During the first 2 years of life the pelvis grows rapidly in all dimensions. This growth is continued at a slower rate from 2 to 5 years, but there is comparatively little increase between 5 and 10 years. There is a second period of more rapid growth in later childhood and adolescence, and by the end of the second decade the pelvis has almost obtained its adult dimensions, although many of the pelvic epiphyses do not unite with the main bones until the twenty-fifth year.

Until the infant assumes an erect position, the pelvis changes but little in form. As this position becomes habitual, the sacrum descends between the ilia and the promontory is definitely established. With this there is a relative expansion of the ala of the ilia, an increase in the pubic angle and a bending of the sacrum backward. The increase in the transverse diameter of the pelvis is brought about mainly by the growth of the sacrum and the posterior parts of the ilium. Growth also takes place along the line of apposition of the three divisions of the os coxæ in the acetabulum, but there is probably comparatively little growth, at least in males, at the symphysis pubis. The pelvic growth which occurs after puberty is practically all epiphyseal.

Sexual differences in the pelvis appear about the sixth fetal month, mainly in the form of differences in the pubic angle and the shape of the ilia. The pelvis of the newborn male is larger than that of the female, the sacrum is relatively wider, the ilia less vertical, the pubic angle more acute and the acetabula shallower and more horizontal. The sexual differences of the newborn pelvis, aside from those of size, are usually masked in the early period of rapid

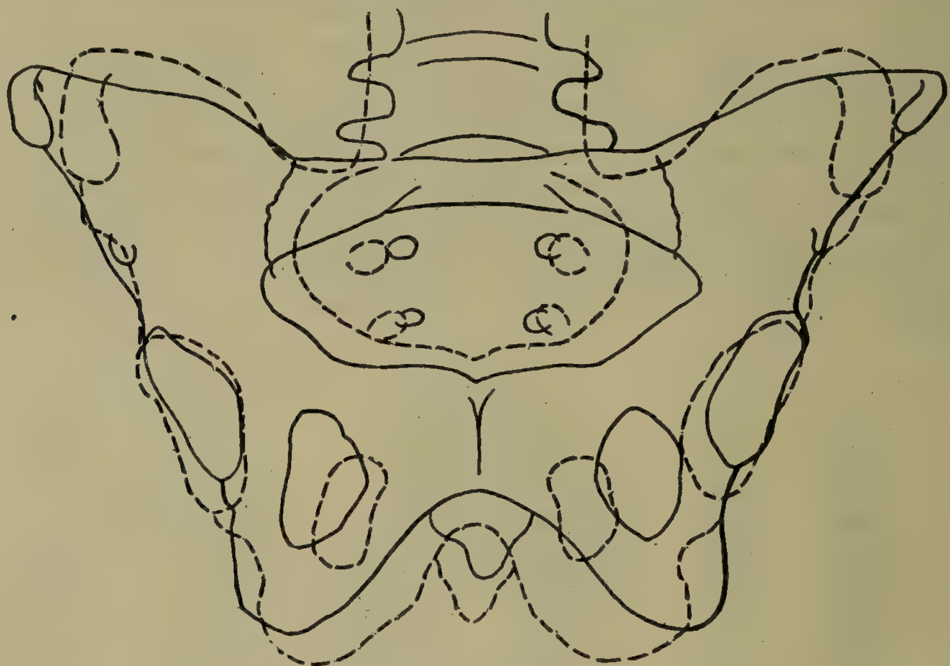


Fig. 38.—Drawing of Anterior Views of the Pelves of an Adult Male and a Male Newborn Drawn to the Same Absolute Size and Superimposed. Adult pelvis in solid line, newborn pelvis in broken line. (After Merkel.)

growth and do not reappear until the prepuberal period. During the first decade the pelvic measurements of boys are usually larger than those of girls, but after this time the dimensions of the female pelvis are generally the greater.

THE VASCULAR SYSTEM

In this section the consideration of the vascular system will be limited to a description of the establishment and course of the early embryonic circulation, an account of the fully estab-

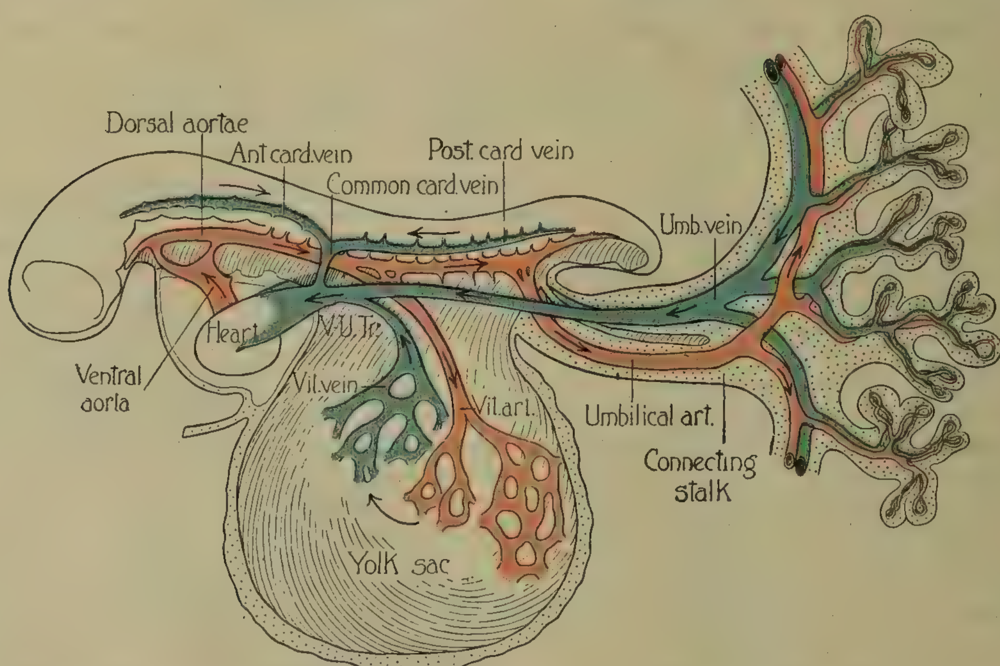


Fig. 39.—Diagram of the Circulation of a Young Human Embryo. (Based in part on the figures of Watt and Brödel.)

lished circulation of the late fetus, and the changes in the circulatory system at birth; including an outline of the general growth of the vascular structures. The morphologic changes by which the various segments of the embryonic circulatory system are transformed to the adult structures are described in connection with the Vascular System (pp. 704 and 761).

In man and the higher mammals the development of the vascular system is extremely precocious, associated with the small amount of food substances stored in the ova of these forms

and the consequent necessity of a system of vessels which can draw nourishment and oxygen from the maternal circulation and distribute them to the tissues of the embryo.

Fundaments of the first vessels in man appear in the form of cords, cellular strands, and cysts in the extraembryonic mesoderm at a stage preceding the establishment of the embryo on the germinal disk. These structures are organized into two sets of anastomosing cords; one, the umbilical or allantoic, which is associated with the connecting stalk, allantois, and the trophoblast; and the other, the vitelline, which spreads out in the mesoderm of the yolk-sac. Trunks formed from these networks pass, in the mesoderm, to the margin of the germinal disk. As the tubular embryo is formed from this structure, they enter the developing body either as definite trunks or as capillary plexuses, and form the framework of the embryonic vascular system.

The course of the embryonic circulation.—The form of the circulatory system in the young embryo is illustrated by fig. 39. The blood from the capillaries of the chorion (the modified trophoblast) passes to the embryo through the paired umbilical or allantoic veins. Before entering the embryo these vessels are joined by the vitelline veins which collect the blood from the yolk-sac. These vessels form the vitelline-umbilical trunks (V.U.Tr.) which enter the body, on either side, in the splanchnic mesoderm below the foregut and join in the tubular heart, which is formed from them. From the heart the ventral aortæ pass below and then around the anterior part of the foregut and gaining its dorsal surface run backward as the paired dorsal aortæ. The dorsal aortæ give off the vitelline arteries (Vit. art.) which return blood to the capillaries of the yolk-sac and finally terminate in the umbilical or allantoic arteries which run to the chorion through the connecting stalk and end in the chorionic capillaries. The dorsal aortæ also give rise to a number of segmentally placed arterial sprigs which supply the tissues of the embryo. The blood from these vessels is collected by venules which empty into longitudinal venous trunks, the anterior and posterior cardinal veins. The cardinal veins on either side drain into a short common cardinal vein (duct of Cuvier) which opens into the posterior part of the heart-tube in common with the vitelline-umbilical trunks.

The umbilical veins are the nourishing vessels of the embryo, for they carry blood from the chorionic capillaries where it has received oxygen and food-stuffs (by osmosis) from the maternal circulation. These substances are absent from the vitelline veins, for the yolk-sac of the human embryo contains no reserve food material. Theoretically, at least, there is a mixture of arterial blood from the umbilical vessels and venous blood from the common cardinal veins in the posterior end of the heart; but the actual difference between the arterial and venous blood in the young embryo is probably very slight since the volume of the blood-stream is relatively large and the rate of circulation presumably very rapid.

The fetal circulation.—The course of the blood in the late fetus is shown in diagrammatic fashion in figs. 39 and 40. The pure or arterial blood from the placental capillaries enters the body by the single umbilical vein, and passes through this vessel to the liver where it is joined by a branch of the portal vein carrying venous blood. The blood from the sinus formed by the union of these two vessels passes through the *ductus venosus* which joins with the inferior vena cava (either directly or through the left hepatic vein). As the vena cava is carrying blood from the capillaries of the lower part of the body there is a further mixture of venous and arterial blood at this point. The stream of mixed blood now passes through the terminal portion of the vena cava and enters the caudal portion of the right atrium. The superior vena cava also enters the right atrium, bringing back venous blood from the head and superior extremities. The opening of the superior vena cava with its valves is so placed that the stream from this vessel is directed toward the *foramen ovale* between the right and left atria.

Despite this anatomical arrangement, however, experimental evidence indicates that the blood of the inferior and superior venæ cavæ is completely mixed in the right atrium. The blood from the right atrium flows in part into the left atrium, where it is joined by a considerable stream of venous blood, returning from the lungs through the pulmonary vein. It then passes into the left ventricle and thence to the systemic circulation through the arch of the aorta. A portion of the blood from the right atrium passes into the right ventricle and through it to the pulmonary artery. A small part of this stream is diverted to the right and left pulmonary arteries to supply the lungs, but the main current passes through the *ductus arteriosus* (Botalli) to pass into the descending arch of the aorta, joining the stream from the left ventricle which has come through the aortic arch. The blood passing through the aorta continues downward through this vessel, and such as remains after supplying the aortic branches flows into the umbilical arteries and thence back to the capillaries of the placenta.

Several *peculiarities of the fetal circulation* which are particularly striking may be enumerated. But one vessel in the body of the fetus, the umbilical vein, carries strictly arterial blood, and this vessel supplies no part of the body directly, except a small portion of the liver. The blood entering the right atrium from the inferior vena cava has already received venous mixtures from three sources (the portal vein, the inferior vena cava, and the vena azygos major). There is a complete mixture of blood from the superior and the inferior vena cava in the right atrium and a further addition of venous blood from the pulmonary vein in the left atrium. Thus the circulating blood of the fetal body is mixed throughout, venous and arterial. Its efficiency under these conditions probably depends: (1) on its very large quantity compared with the volume of the fetus; (2) on the rapidity of its circulation; and (3), on the relatively slow rate of catabolism (and hence slight amount of waste products) in the fetal organism.

The establishment of the adult circulation.—The change from the fetal to adult type of circulation is brought about by the closure of the fetal blood-passages, the umbilical vessels, the ductus venosus, the ductus arteriosus, and the foramen ovale. This change is not as abrupt as was formerly thought. With the establishment of respiration the ductus arteriosus collapses, and all the blood from the pulmonary artery passes through the branches of these vessels into the capillary bed of the lungs. This leads to an increased flow from the pulmonary veins into the left atrium and pressure in this chamber gradually rises. At the same time, with the tying of the umbilical cord, or in most cases even with the simple interruption of this

structure, the fetal ends of the umbilical arteries and veins are contracted and their lumina obliterated. With this change, blood no longer flows through the umbilical vein and the current of blood through the ductus venosus ceases.

The actual obliteration of the fetal blood-passages rarely begins in the first fortnight of postnatal life. The obliteration of the ductus venosus is brought about through the interruption of its epithelial lining and invasion of its lumen by the connective tissue of the tunica media and tunica interna. The vessel is generally completely closed by the end of the first month. Obliteration of the ductus arteriosus takes place in much the same way, generally in the first half year of postnatal life, but sometimes not before the close of the first year. The occlusion of the foramen ovale is apparently brought about by the proliferation of connective tissues in

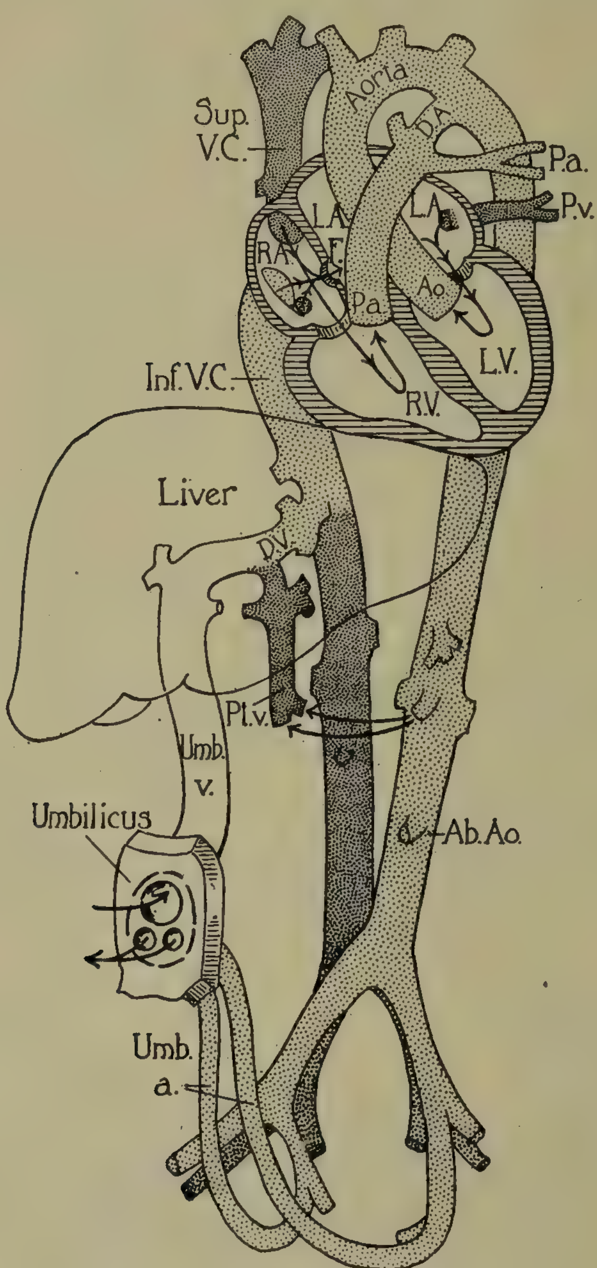


FIG. 40.—DIAGRAM OF THE FETAL CIRCULATION.

Ab.Ao., abdominal aorta. Ao., ascending aorta. D.A., ductus arteriosus. D.V., ductus venosus. F., foramen ovale. Inf. V.C., inferior vena cava. L.A., left atrium. L.V., left ventricle. P.a., pulmonary arteries. Pt.v., portal vein. P.v., pulmonary veins. R.A., right atrium. Sup.V.C., superior vena cava: Umb.a., umbilical arteries. Umb.v., umbilical vein.

the valve and at the margin of the foramen. At the close of one year the foramen is obliterated in about one-half of all cases, but the opening remains patent to the probe in nearly one-fourth of adult hearts. The obliteration of the umbilical arteries and vein begin shortly after birth with the organization of the thrombus at the cut end of the vessel; but the process is not complete throughout the intra-abdominal portion of these vessels until several weeks after birth. For changes in the umbilicus, see p. 1278.

The growth of blood-vessels.—In the young embryo the blood-vessels have very thin walls and their caliber is relatively enormous; that of the dorsal aorta, for example, is nearly one-fifth the transverse diameter of the body in the third week. In fetal and postnatal life the blood-vessels continue to increase in absolute diameter even to very old age, but their relative diameter is steadily reduced, at least until maturity. In the developmental period, the different vascular trunks constantly adjust to the changing volumes of the areas which they supply and to modifications in the caliber of vessels which drain from them. Thus the arterial trunks to the head increase in size during the period of rapid growth of this part while those of the lower limbs grow slowly in early life but increase rapidly when these members enter a period of active

growth. And the abdominal aorta undergoes an actual decrease in diameter for a period after birth when the umbilical arteries which drain it are obliterated.

The walls of arteries in the fetal period are relatively thicker, compared with the diameters of their lumina, than in postnatal life; but their absolute thickness increases slowly to an advanced age. In fetal life the growth of the walls of arteries takes place almost entirely in the tunica media and tunica externa, the tunica interna remaining almost unchanged from the fourth fetal month until birth. After birth, however, the relative growth of the interna is much more rapid than that of the other coats. Apparently there is little growth of the tunica media after puberty although the interna increases throughout postnatal life.

In early life the veins are relatively smaller than the arteries with which they are associated. The veins increase in relative size until maturity and then undergo a relative decrease.

There are but few observations on the growth of vessels in length, but these seem to indicate that the lineal growth of blood-vessels is closely correlated with the lineal growth of adjacent structures.

Growth of the heart.—In the second fetal month the heart forms about 3.6 per cent. of the body. The relative weight decreases to about 0.7 per cent. at the close of fetal life. With the great increase in the weight of the body in the first year the relative heart-weight drops to about 0.5 per cent., and from this time there is a very slow decrease until the middle years of adult life when the average relative weight of the heart is 0.4 to 0.45 per cent. It should be remembered that during fetal life the heart not only sends the blood through the capillaries of the body but also through those of the fetal portion of the placenta. The relation of the weight of the heart to the combined weight of the body and placenta in the latter fetal months is not far from the adult ratio of heart-weight to body-weight (0.47 to 0.45 per cent.).

The growth in absolute weight of the heart in postnatal life follows the course of the visceral group of organs. The birth-weight of the organ (20 to 25 grams) is doubled in the first year, tripled in 4 years and increased 6 to 8-fold by puberty. The total postnatal gain in absolute heart-weight is usually about 12-fold.

The mass of the walls of the various chambers of the heart is distinctly modified in the developmental period. The atria form a considerably larger proportion of the heart-weight in the fetus than in the adult, the reduction in their relative weight taking place mainly in early infancy. In the fetal period the weight of the right ventricle is equal to or greater than that of the left. But the additional work which falls to the left ventricle after the separation of the systemic and pulmonary circulations at birth causes this portion of the heart to grow so rapidly that by the close of the first year it is nearly twice the weight of the right ventricle.

The lymphoid and sanguifactive organs.—The first *blood-cells* of the human embryo are differentiated in connection with the developing blood-vessels of the yolk-sac; but the liver soon becomes a seat of blood-formation and remains a sanguifactive organ until birth. The *bone-marrow* appears as the primary marrow cavities are formed in the course of the ossification of the different bones, and since the first ossification centers do not appear until the sixth week there is little differentiation of bone-marrow until after the period of the embryo. The *spleen* appears in the fifth week as a thickening of the layers of splanchnic mesothelium of the dorsal mesogastrium, the splenic pulp being differentiated from a mass of dense mesenchyma formed by the proliferation of cells from the splanchnic layer of the region. The fundaments of lymph-glands appear in the third month as collections of lymphoid cells about plexuses of lymphatic capillaries. The formation of lymph-glands continues through fetal life and probably for an indefinite time after birth. For development of the lymphatics in general, see Lymphatic System, p. 775.

The growth of lymphoid tissue has been considered in connection with the growth of organs. It is characterized by a relatively great amount of lymphoid tissue at birth, an increase in absolute amount until about puberty and a subsequent decline in amount both absolute and relative (fig. 28). The spleen, however, does not follow this course. It is relatively small in early fetal life but increases in the latter part of the period, forming about 0.3 per cent. of the body at birth. During postnatal life it declines in relative weight, forming less than 0.2 per cent. of the body in the adult. The increase in the absolute weight of the spleen in postnatal life follows the course of the splanchnic group of organs.

THE NERVOUS SYSTEM

The early development of the brain.—Even before the neural plate is folded into the neural tube it is differentiated into an anterior expanded portion which represents the brain and a narrower posterior part which represents the spinal cord. As the anterior part of the plate becomes tubular it is further divided by grooves into three swellings or vesicles, the forebrain, midbrain, and hindbrain (figs. 41A and B). As these chambers differentiate, the axis of the cephalic portion of the tube is bent first at the level of the midbrain (the cephalic flexure) and soon after at the juncture of the hindbrain at the cord (the cervical flexure). The floor of the middle portion of the hindbrain is curved ventrally at a much later time, forming the third or pontine flexure. For further details and figures of the early development of the brain, see pp. 13, 827.

Before the forebrain is completely closed it is expanded transversely forming lateral outpouchings, the optic vesicles. Each optic vesicle forms a distal optic cup which produces the retina of the eye, while its proximal optic stalk remains attached to the forebrain as the optic nerve. The point of attachment of the optic stalks marks the line of division of the forebrain into two secondary vesicles, an anterior telencephalon and a posterior diencephalon. Somewhat later a second pair of lateral outpouchings are formed from the walls of the telencephalon dorsal to the optic evaginations. These are the cerebral vesicles. They form the cerebral hemispheres and (secondarily) the olfactory lobes and tracts. The diencephalon forms a smaller part of the forebrain. Its floor is depressed posterior to the optic stalks, forming the embryonic infundibulum from which are differentiated the posterior lobe of the hypophysis,

the mammillary bodies, the tuber cinereum, and the infundibulum of the adult. The lateral walls of the diencephalon are thickened, forming the thalamus and geniculate bodies. The roof becomes membranous anteriorly to form the epithelial layer of the tela chorioidea; posteriorly it forms the pineal body.

The walls of the mesencephalon become greatly thickened, their dorsal portion forming the corpora quadrigemina and their ventral portions the greater part of the cerebral peduncles (crura cerebri).

Three secondary divisions can be recognized in the hindbrain or rhombencephalon: (1) a narrow isthmus, which is continuous with the mesencephalon anteriorly; (2) a short middle segment, the metacephalon; and (3) a large posterior portion, the myelencephalon. The isthmus changes little in form in later development. It is represented in the adult by a portion of the brain-stem which includes the anterior medullary velum, and parts of the brachium conjunctivum (superior cerebellar peduncles) and of the cerebral peduncles. The metencephalon forms an expanded and thickened ring of the brain-tube immediately behind the isthmus. Its dorsal part forms the cerebellum and its ventral portion the pons. In early stages the myelencephalon forms a widely expanded chamber with a membranous roof and a thick floor which is continuous with the cord without any sharp line of demarcation. The myelencephalon becomes the medulla oblongata, a part of the roof forming the posterior medullary velum.

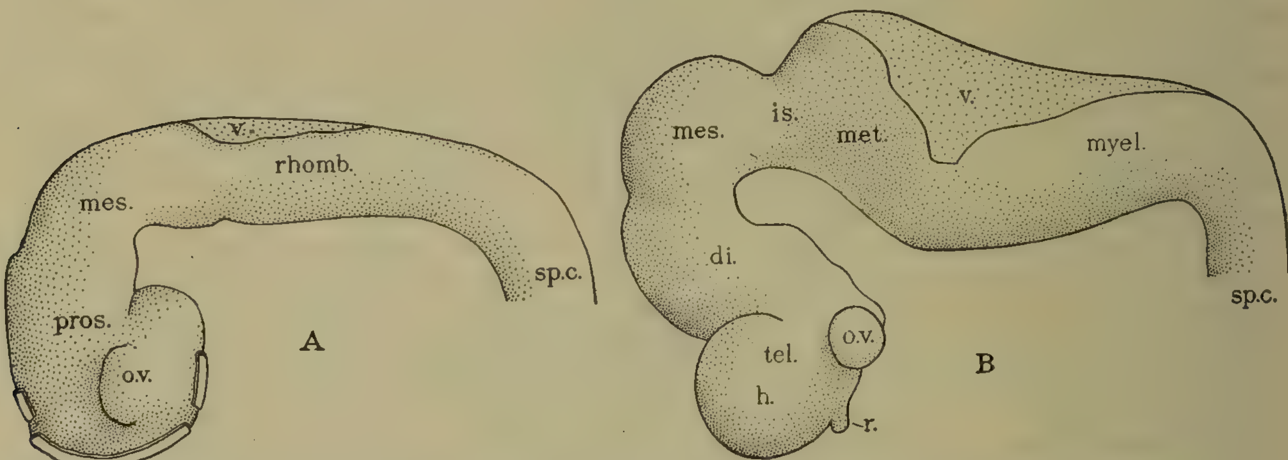


FIG. 41.—A, THE BRAIN OF A 4.0 MM. HUMAN EMBRYO. (From Lewis, after Bremer.) B, THE BRAIN OF A 10.2 MM. EMBRYO. (From Lewis, after His.)

Except the isthmus, is., the principal subdivisions of the brain are indicated by prefixes of the term encephalon. sp.c., spinal cord. h., hemisphere. o.v., optic vesicle. r., rhinencephalon. v., roof of the fourth ventricle.

The spinal cord.—In the young embryo the spinal cord extends to the extreme caudal end of the body; but with the regression of the tail in the latter part of the second fetal month there may be recognized an anterior or trunk portion which will form the definitive spinal cord, and a posterior or caudal segment which undergoes partial involution, forming the filum terminale. The distinction between these two portions is definitely established before the middle of the third month. The cervical and lumbar enlargements of the cord can be recognized by the end of the third month. For relations at various stages, see figs. 48–53.

The cerebrospinal cavities.—The central lumen of the neural canal is never lost but exists throughout life in a modified form as the central canal of the spinal cord and the ventricles of the brain. The lumen in the lower end of the trunk portion of the spinal cord remains as a chamber of some size, the *ventriculus terminalis*, but in the remainder of the cord it is reduced in relative size through the fusion of the dorsal part of the lateral walls to the minute central canal. In the myelencephalon and the metencephalon the lumen is expanded, forming the fourth ventricle; while in the isthmus and mesencephalon it is reduced to a narrow channel, the Sylvian aqueduct. The third ventricle represents the expanded anterior end of the canal in the forebrain and the lateral ventricles its lateral extensions which are produced with the evagination of the cerebral vesicles, the points of origin of these extensions being represented by the interventricular foramina. The epithelial layers of the choroid plexuses which project into the third and fourth ventricles are formed by the invaginations of the membranous wall of the brain in these regions and the morphologic continuity of the walls of the canal is not interrupted, at least during the embryonic and the early fetal periods. The so-called fifth ventricle (cavum septi pellucidi) has no developmental relation to the cerebrospinal cavities, being formed much later between the apposed medial walls of the hemispheres.

Growth of the central nervous system.—The relative weight of the central nervous system in the developmental period has been considered in connection with the general growth of systems. The absolute weight of the *brain* at the end of the third fetal month is about 3.5 gm. This is increased about 10-fold by the middle of the fetal period and about 100-fold by birth. The weight of the *brain* is more than doubled in infancy and is increased about 3-fold by the close of the first period of childhood. Thereafter the rate of absolute growth is very slow, the adult weight, which is about 3.6 times that of the newborn, being commonly attained by the close of the fifteenth year.

The *spinal cord* weighs about 0.15 gm. at the close of the third fetal month, increasing about 5-fold by the middle of the fetal period and 20-fold by birth. The cord increases about 8-fold in postnatal life, most of this growth taking place in infancy and early childhood. The spinal cord forms about 15 per cent. of the central nervous system in the second fetal month but there-

after it forms a decreasing proportion until birth when it is less than 1 per cent. In postnatal life, on the other hand, this ratio gradually rises to about 2 per cent.

The parts of the brain also show changing relations in relative size during the developmental period. The *brain-stem* follows the course of the cord, forming a larger proportion of the brain in fetal life, a gradually decreasing proportion in the later part of prenatal life, and a small relative increase after birth. The *cerebellum*, on the other hand, grows very slowly in early fetal life but in the later fetal months enters a period of rapid relative growth which continues through infancy and early childhood. It forms about 3 per cent. of the brain in the third fetal month, about 6 per cent at birth, and about 10 per cent. in maturity. For topography of the developing brain, see figs. 48–53, also fig. 785.

The development of the peripheral nerves.—When the neural tube separates from the surface ectoderm there is left between these two structures a narrow plate of ectodermal cells known as the neural crest. These cells give rise to all of the sensory nerves of the cerebrospinal system, with the exception of the optic and olfactory nerves whose development is considered in connection with the sense organs. The motor nerves and the motor portions of the mixed nerves, on the other hand, are formed by processes from cells located in the ventral or ventrolateral portion of the neural tube. The course of development of the spinal and cranial nerves is described in the section on the NERVOUS SYSTEM.

The eye.—Four elements enter into the formation of the main structures of the eye. These are: (1) the optic vesicle, derived from the lateral wall of the forebrain; (2) the lentic or optic placode, formed by a thickening of the surface ectoderm over the optic vesicle; (3) a zone of surface ectoderm immediately surrounding the lentic placode but which does not share in its thickening; and (4) the head mesenchyma which surrounds the optic vesicle and placode.

The optic vesicle gives rise to the retina (both nervous and pigmented layers), the epithelium covering the posterior surface of the iris and ciliary body and the optic nerve. The lentic placode is converted into a lentic vesicle which later forms the lens. The surface ectoderm immediately surrounding the lentic placode produces the anterior epithelial layer of the cornea, the epithelium of the conjunctiva and the parenchyma of the lacrimal gland. The surrounding mesenchyma forms the sclerotic and choroid coats of the eye and their derivatives. The vitreous body is probably derived in part from the ectodermal and in part from the mesenchymal elements of the eye. The further history of the eye is described in connection with the section on the SPECIAL SENSE ORGANS (p. 1166).

The ear.—As has been previously described (pp. 19, 32), the outer ear is formed from the first branchial groove or cleft, the middle ear is a derivative of the first branchial pouch, and the auditory ossicles are formed from the upper ends of the cartilages of the first and second branchial arches. The inner ear is formed from the otocyst, a closed sac formed from the otic or auditory placode which appears as a thickening of surface ectoderm above the first branchial arch. The development of the ear is considered in more detail in the section on the SPECIAL SENSE ORGANS (p. 1190).

The ear in childhood.—The ear of the newborn and infant differs from that of the adult in several important details. The external auditory meatus is relatively short and straight and there is no true bony meatus. The tympanic membrane is slightly smaller than in the adult, but it acquires its full size in infancy. It is slightly more horizontal in early life. The tympanic cavity and ossicles have reached their full size at birth and the epitympanic recess and antrum are quite as large as in maturity if not larger. The antrum lies entirely above the tympanic cavity and its lateral wall is only about 1 mm. thick. The mastoid process does not develop until after the first year and the mastoid cells usually appear in later childhood. The auditory (Eustachian) tube has about one-half of its adult length at birth but its diameter is quite as great as in maturity. The tube is almost horizontal in the infant, the oblique course of the adult tube being acquired with the growth of the nasopharynx in middle and later childhood. The internal ear has practically its adult dimensions at birth.

The olfactory organ.—The organ of smell is developed from the epithelium of the upper part of the nasal fossæ, whose history is described later in connection with the development of the digestive tract. The olfactory nerve is formed by the processes of specialized cells which remain in the olfactory mucosa. A rudimentary olfactory organ, the *vomeronasal organ of Jacobson*, is represented in the embryo by a pair of small pouches in the nasal septum. These may disappear in the later part of fetal life, but frequently persist as vestiges in the adult (see p. 1131).

THE DEVELOPMENT OF THE DIGESTIVE TRACT

Early development.—In the early embryo four main structures may be recognized which play a part in the later development of the digestive and respiratory tracts. These are: (1) the nasal pits and (2) the oral sinus, which are lined with ectoderm derived from the covering of the inferior surface of the head; (3) the archenteron, formed from the entoderm of the roof of the yolk-sac; and (4) the cloacal membrane. These elements form the epithelial lining of the digestive and respiratory tracts and the parenchyma of the glands connected with them. At a later time there is associated with them a considerable amount of mesenchyma which gives rise to the muscular wall and the connective tissue investments of the tubes and to the supporting framework of the associated glands.

Some of the general changes in the development of the digestive tract are shown in figs. 42, 48–51. The oral sinus is deepened and its roof gives rise to a median pocket (Rathke's pouch), which later separates and forms the anterior lobe of the hypophysis. At the same time the *buccopharyngeal membrane* separating the sinus from the cephalic end of the pharynx disappears and the ectoderm and entoderm becomes continuous in this region. The foregut is differentiated into an upper expanded pharynx and a lower tubular segment which later forms the esophagus, stomach, and a portion of the duodenum. The *midgut* elongates and its connection with the yolk-sac is reduced to a slender yolk-stalk. The *hindgut* is differentiated into an

upper tubular portion and a lower expanded chamber, the *cloaca*. The latter is continuous with the allantois and its floor is formed in part by the cloacal membrane. The cloaca is later divided, in the frontal plane, into a dorsal rectum, continuous with the midgut, and a ventral urogenital sinus which receives the allantois.

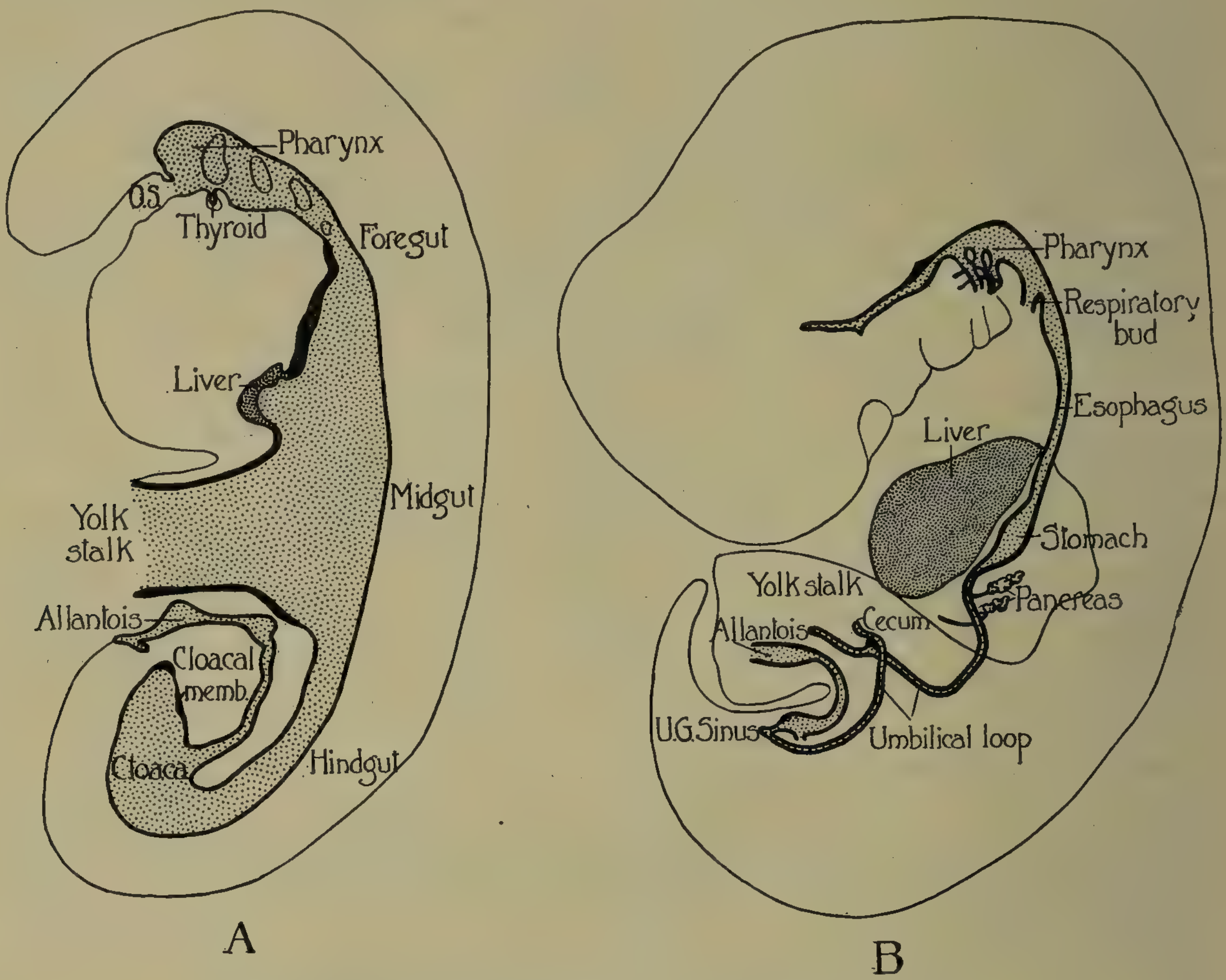


FIG. 42.—RECONSTRUCTIONS OF THE DIGESTIVE TRACT.

A, of an embryo 2.5 mm. long. (After Thompson and Lewis.) B, of an embryo 10 mm. long. (After Phisalix.)

The mouth.—The floor of the embryonic mouth or oral sinus is formed by the inner surfaces of the mandibular processes. The margins of its roof are formed laterally by the maxillary processes and anteriorly by the medial nasal process; and its central portion includes two membranous plates which separate the oral cavity from the *nasal pits* above. These plates

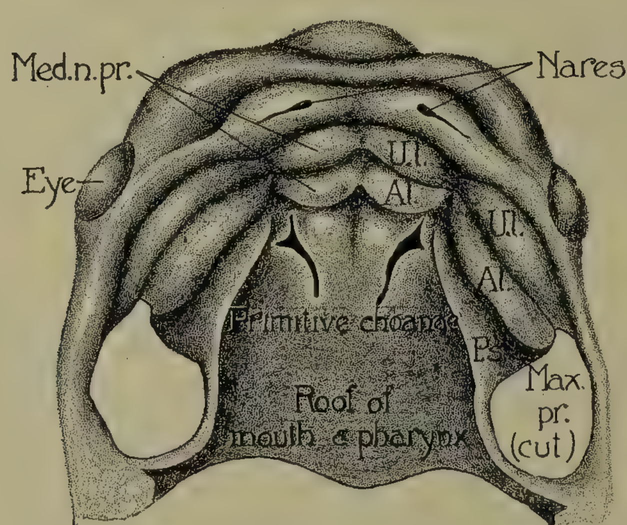


FIG. 43.—RECONSTRUCTION OF THE ORAL REGION OF AN EMBRYO OF THE SECOND MONTH. (From Schaeffer after Kollman and Keith.)

Al., alveolar processes. Max.pr., maxillary process. Med.n.pr., medial nasal process P.s., palatine shelves. U.l., upper lip.

soon disappear and the oral sinus communicates with the nasal chambers by paired *primitive choanæ* (fig. 43). The definitive palate is formed by the growth of the paired *palatine shelves* which arise from the medial borders of the maxillary processes and grow toward each other, fusing in the midline. In this manner the upper part of the original oral cavity is left above

the palatine shelves, forming the inferior portions of the permanent nasal fossæ. The formation of the boundaries of the mouth has been considered in connection with the development of the face (p. 18). After their establishment they are invaded by ridges of oral epithelium which form the oral vestibule separating the lips and cheeks from the alveolar processes.

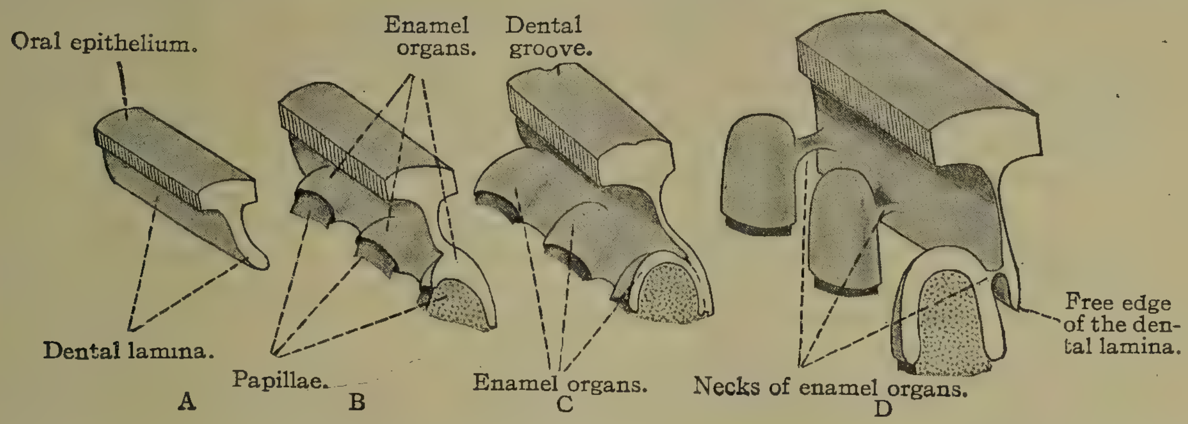


FIG. 44.—DIAGRAMS SHOWING THE EARLY DEVELOPMENT OF THREE TEETH. One is shown in vertical section. (After Lewis and Stöhr.)

The teeth.—The teeth are formed in part from the oral ectoderm and in part from the mesoderm of the cores of the maxillary and mandibular arches. The ectodermal portion arises as vertical outgrowths from oral epithelium known as dental shelves, which extend into the alveolar processes and lie parallel with and medial to the labial grooves. A series of twenty cup-shaped expansions, the *enamel organs*, form on the free edges of the dental shelves. Each of these caps a small mass of condensed mesenchyma, the *dental papilla* (figs. 44 and 45).

The enamel organs enlarge rapidly and their connections with the dental shelves are reduced to slender necks. Each organ is differentiated into three parts: (1) a thin outer membrane

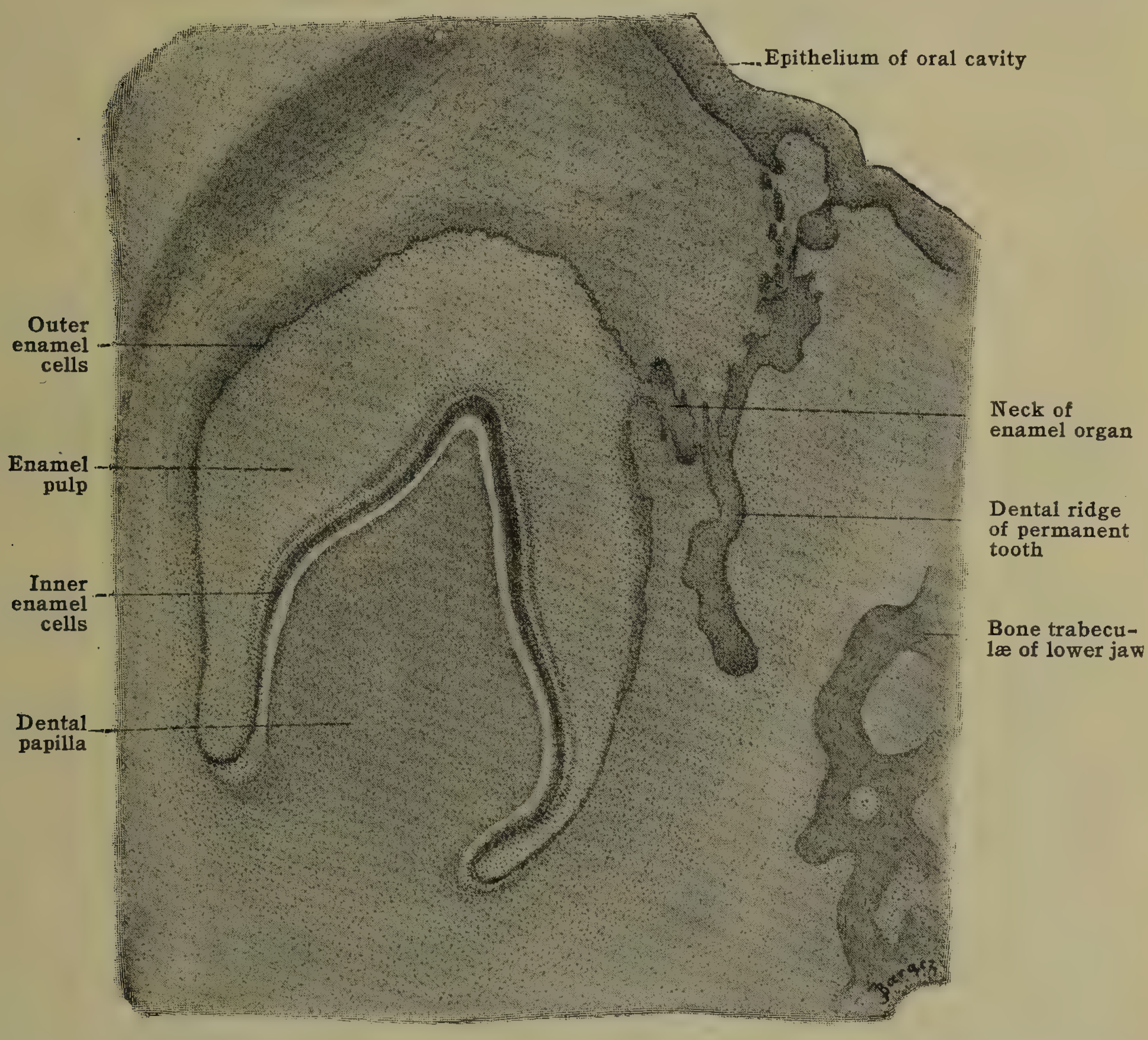


FIG. 45.—SECTION SHOWING LATER STAGES OF TOOTH DEVELOPMENT. (After Szymonowicz.)

attached by the neck to the dental shelf; (2) an inner membrane composed of a single layer of high columnar cells or ameloblasts; and (3) an intervening spongy mass, the enamel-pulp. Coincident with these changes the dental papilla is differentiated into a peripheral layer of columnar cells or odontoblasts, which immediately underlies the inner layer of enamel organ, and a dense central core which is highly vascularized.

The portion of the dental shelves which is not involved in the formation of the deciduous teeth gives rise to a second set of enamel-organs for the permanent dentition.

The *calcification* of the teeth begins in the eighteenth fetal week after the crowns are well outlined (fig. 45). The process starts at the crown of the tooth and extends toward the root Simple teeth, such as the incisors, have single centers of calcification while teeth with two or more cusps have separate centers for each cusp, which soon fuse in a single mass. Calcification takes place in both the ectodermal and the mesodermal parts of the tooth germ. The cells of the inner layer of the enamel organ (ameloblasts) become greatly elongated and a deposit of enamel, in the form of fine globules, appears at their outer margins and gradually fills the cells, converting them into the *enamel-prisms.* The peripheral cells of the dental papilla (odontoblasts) likewise assume a columnar form and a deposit of dentine is laid down between them and the ameloblasts. As this material increases the odontoblasts retreat toward the center of the dental papilla, but processes which extend from them remain imbedded in the dentine as the dentinal fibers. The *cementum* which covers the dentine of the root is produced in connection with the surrounding mesenchyma in a manner similar to the formation of membrane-bone. The center of the dental papilla with its blood-vessels, lymphatics and nerves remains as the *pulp* of the tooth.

At the time of birth the germs of all the deciduous teeth and of all the permanent teeth, except the second and third molars, are present, and those of the deciduous teeth and the first

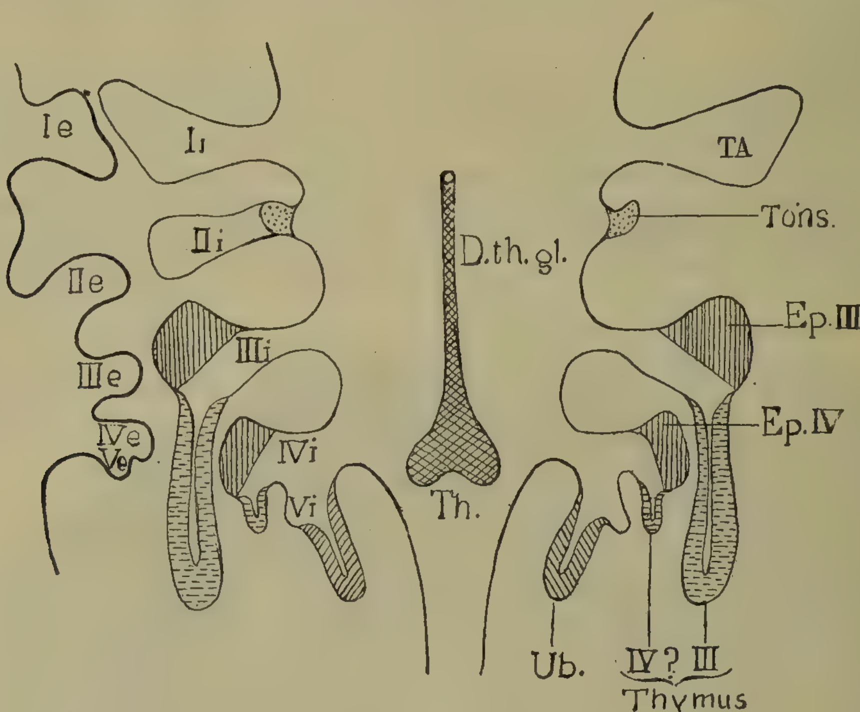


Fig. 46.—Diagram to Show the Derivatives of the Branchial Pouches.

Ie, IIe, IIIe, IVe, Ve, external branchial grooves. Ii, IIi, IIIi, IVi, internal branchial pouches. TA, auditory tube and tympanic cavity. Tons., palatine tonsil. EpIII, EpIV, parathyroid glands. Ub, ultimobranchial body. Th., thyroid gland. D.th.gl., ductus thyroglossus. (Modified from Keibel and Mall.)

permanent molars are partially calcified. The germs of the second permanent molars are formed in the second postnatal month but those of the third molars do not appear until about the fifth year. The later history of the teeth, including the chronology of their eruption, is considered in connection with the digestive tract (p. 1214).

The tongue.—The anterior part of the tongue is formed from a pair of lateral lingual swellings which appear in the floor of the mouth, at the level of the first branchial arch, early in the second month. These fuse together medially, replacing an earlier median swelling in this region, the *tuberculum impar.* The posterior part of the tongue is formed from the medial portion of the second, and possibly the third, branchial arch. The *musculature* of the tongue arises in situ from the thickened mesenchyma of the lingual region but its innervation (by the hypoglossal nerve) as well as its comparative development indicate that it was originally derived from certain of the occipital somites. The epithelium of the tongue is probably partly of ectodermal and partly of entodermal origin, the terminal sulcus indicating the boundary between the two layers.

The salivary glands.—The parotid gland is formed from a shelf-like outgrowth of the epithelium at the angle of the mouth between the maxillary and mandibular processes; and the submaxillary and sublingual glands are formed from similar outgrowths from the medial and lateral angles of the grooves between the tongue and lower alveolar processes. The general scheme of the later development of submaxillary and parotid glands and the major portion of the sublingual gland is much the same. Each grows backward as a keel-like flange which becomes detached from the oral epithelium except for a small anterior connection which represents the future ostium of the duct of the gland. The proximal portion of the outgrowth forms the main duct of the gland, the distal expanded portion giving rise, by repeated divisions, to the smaller ducts and alveoli. The minor sublingual mass is developed from a series of separate outgrowths.

The pharynx.—The pharynx forms a considerable portion of the digestive tube in the young embryo. Its relative size undergoes a marked decrease in fetal life, followed by a slower reduction after birth. During infancy and childhood the length of the pharynx increases rapidly while the anteroposterior diameter grows slowly and the width remains almost unchanged. All diameters increase in middle and later childhood but the growth in length is still the most rapid. In adolescence there is a limited growth of all diameters.

During the fourth week four pairs of *branchial* (*pharyngeal*) *pouches* are formed from the lateral walls of the pharynx and a single median outgrowth (the thyroid diverticulum) appears in its floor. The pharyngeal pouches correspond in position to the branchial grooves, which are formed on the external surface of the neck, and are separated by the branchial arches. They give rise to a number of structures which are quite dissociated in later life (figs. 46 and 61).

The *first pouch* is directed dorsally and laterally. Its outer extremity is expanded forming the tympanic cavity of the middle ear, while its proximal part is converted into the auditory (Eustachian) tube. A dorsal recess from the *second pouch* forms the tonsillar sinus and the epithelial portion of the palatine tonsil. The histories of the *third* and *fourth pouches* are somewhat similar. Both form dorsal and ventral diverticula; the former give rise to the parenchyma of the parathyroid glands and the latter to the reticulum and thymic (Hassall's) corpuscles of the thymus in the case of the third pouch and, occasionally, in the case of the fourth. The stalks of these pouches merge in the piriform recess. A pair of small *ultimobranchial bodies*, which possibly represent a fifth pair of pouches, arise from the lateral walls of the pharynx behind the fourth pouches. They form epithelial masses which migrate into the cervical region and are intimately associated with the thyroid. It is improbable that they form any part of this structure but they may give rise to small epithelial masses known as the *glandula insularis cervicalis*.

Schema of Branchial Derivatives

First branchial element	*Arch*	
	Muscle mass	Muscles of mastication, anterior belly M. digastricus, M. tensor tympani
	Nerve	N. trigeminus
	Bar (skeletal element)	Sphenomandibular ligament, malleus, incus, tip of mandible, portion of coronoid process (?)
	Cleft (including bounding ectoderm)	External auditory meatus, external layer of tympanic membrane
	Pouch (including bounding entoderm)	Eustachian tube, cavity of middle ear, mastoid cells and their lining epithelium, interna layer of tympanic membrane
Second branchial element	*Arch*	
	Muscle mass	Posterior belly M. digastricus, M. stylohyoideus, M. stapedius, muscles of expression, M. occipitalis, M. frontalis.
	Nerve	N. facial-intermedius
	Bar (skeletal element)	Arch of stapes, stylohyoid process, stylohyoid ligament, lesser cornua and body of hyoid bone
	Cleft	(No derivative in the adult)
	Pouch (including bounding entoderm)	Part of tonsillar fossa, epithelium covering the palatone tonsil and lining its crypts
Third branchial element	*Arch*	
	Muscle mass	M. stylopharyngeus, upper constrictors of pharynx
	Nerve	N. glossopharyngeus
	Bar	Greater cornua of the hyoid bone
	Cleft	(No adult derivative)
	Pouch (including lining entoderm)	
	Stalk	(In recessus piriformis?)
	Upper diverticulum	Parenchyma of parathyroid glands
	Lower diverticulum	Thymic corpuscles and reticulum of thymus
Fourth (and possibly succeeding) branchial elements	*Arch*	
	Muscle mass	Part of constrictors of pharynx, M. pharyngopalatinus, M. glossopalatinus, M. levator veli palatini, M. uvulae, muscles of the larynx, M. chondroglossus.
	Nerve	N. vagus-accessory (in part)
	Bar (skeletal element)	Upper part of thyroid cartilage, thyro-hyoid ligament, triticeous cartilage (?)
	Cleft	(No adult derivative)
	Pouch (including bounding entoderm)	
	Stalk	(In recessus piriformis?)
	Upper diverticulum	Parenchyma of parathyroid glands
	Lower diverticulum	Occasionally thymic corpuscles and reticulum of the thymus (?)

The palatine tonsils.—About the fourth fetal month solid epithelial buds from the floor of the second pouch invade the surrounding connective tissue. These are later converted

into the fossulæ and glands of the palatine tonsil. Lymphoid cells are found in the mesenchymal tissue under the tonsillar epithelium in the sixth fetal month, but definite lymphoid nodules are not present until nearly the time of birth. The postnatal growth of the palatine tonsil is extremely variable. In many cases they reach their highest development in the fifth or sixth year and involution takes place in later childhood. Apparently, in other instances, their growth may continue to puberty or early adolescence. Early in the third fetal month the *plica triangularis* arises from the floor of the pharynx opposite the second pouch and grows upward over a portion of the tonsillar sinus. At the time of birth the plica triangularis forms a fold which surrounds the tonsil, except for a small portion of its posterior border, and covers a part of its free surface. The fusion of the plica triangularis with the walls of the tonsillar sinus is already under way at this time and many specimens show the characteristic subdivisions of the cavity which are found in the adult. In later fetal life and at birth the tonsil lies somewhat higher in the sinus than in later life and its axis is horizontal. The tonsil descends during infancy and its longer axis becomes vertical.

The pharyngeal tonsil and bursa.—Early in the second fetal month there appears in the roof of the pharynx a small pouch, the *pharyngeal bursa,* from which there develop a series of radiating folds which extend anteriorly nearly to the nasal openings. In the later fetal months these are invaded by lymphoid tissue and are converted into the *pharyngeal tonsil.* The structure reaches its maximum development in early childhood. Its involution generally begins in the prepuberal period and is completed in early adolescence. The bursa pharyngea is commonly converted into a small closed cyst which remains throughout adult life.

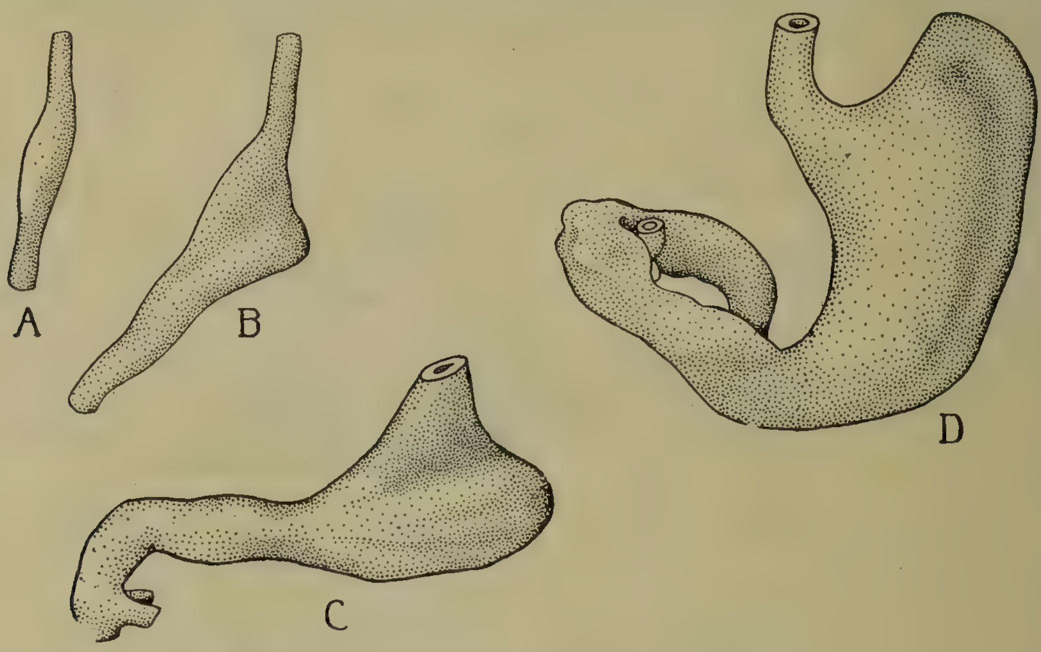


Fig. 47.—Development of the Stomach.

A, embryo 5 mm. long. B, embryo 8 mm. long (after Broman). C, embryo 10 mm. long. D, embryo 19 mm. long (after Lewis).

The esophagus.—The esophagus in young embryos is a short tube of relatively large caliber, flattened from side to side. During the early part of the second month it becomes considerably elongated but is reduced in relative diameter and assumes a cylindrical form. At birth the tube is 8 to 10 cm. (3 to 4 in.) in length from the cricoid cartilage to the cardia. Its length is doubled in the first three years and tripled by puberty, but there seems to be little longitudinal growth thereafter.

The stomach.—The stomach appears in the fourth week as a spindle-shaped enlargement of the lower part of the foregut. This is soon subdivided by the *incisura angularis* (or gastric angle) into an upper expanded cardiac and a lower tubular pyloric portion (fig. 47). The fundus develops as an outpouching of the cardiac portion in the latter part of the second month and the gastric canal ('Magenstrasse') is established about the same time. A little later the pyloric portion is subdivided into pyloric canal and antrum. As these changes take place the stomach is bent to the right at the level of the incisura angularis, and the entire organ is rotated from left to right through about 90 degrees. After this time the stomach changes little in form until distended by its contents, either before or immediately after birth, when there is a considerable expansion of the fundus, body and greater curvature.

In early stages, the long axis of the stomach is vertical. With the establishment of the incisura angularis it often becomes transverse or oblique but it commonly returns to the vertical position in late fetal life. With the distension which occurs at birth the long axis again becomes obliquely transverse and this position is usual until the erect posture is habitually assumed, when the vertical position again becomes the more common. At the time of its differentiation the stomach lies in the upper part of the thorax but in early fetal life it descends to the upper abdominal region. There is little later change in the positions of the orifices of the stomach but with its subsequent growth in size and changes in form the lower margin gradually descends in the abdomen during the greater part of childhood.

The stomach grows with great rapidity in the latter part of fetal life and this rate is continued in the first trimester of postnatal life. The stomach increases in weight about 24 times between birth and maturity, its postnatal growth following the course of the splanchnic group

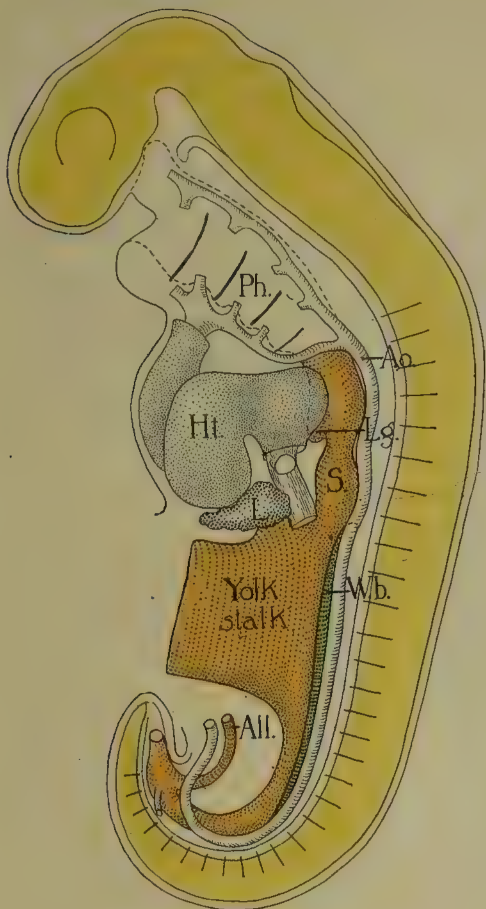


FIG. 48.

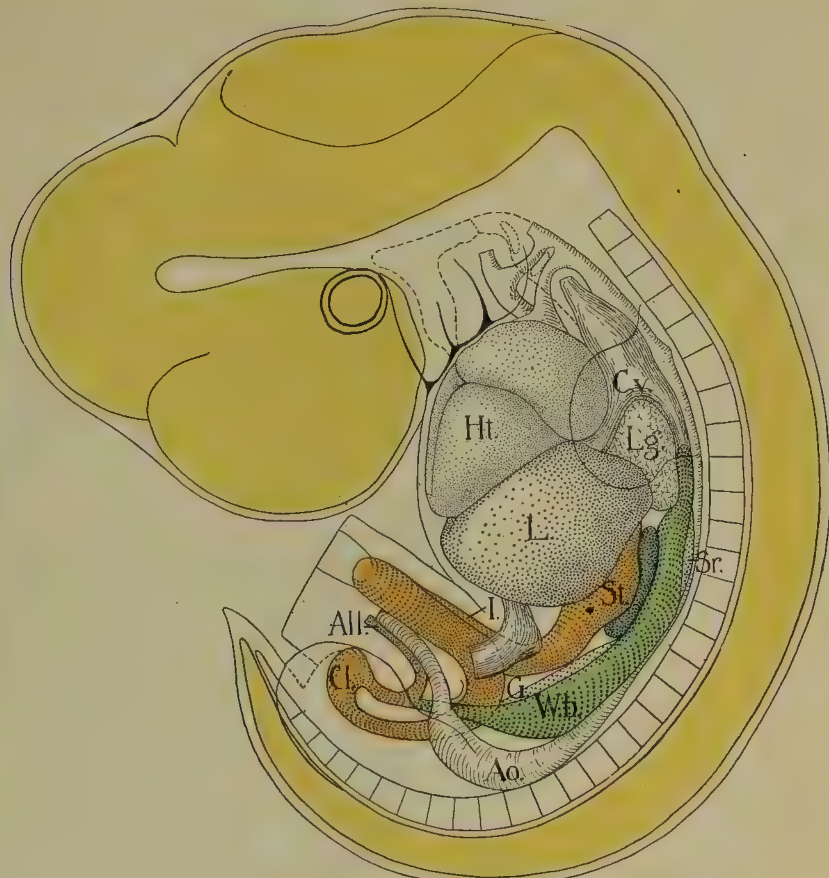


FIG. 49.

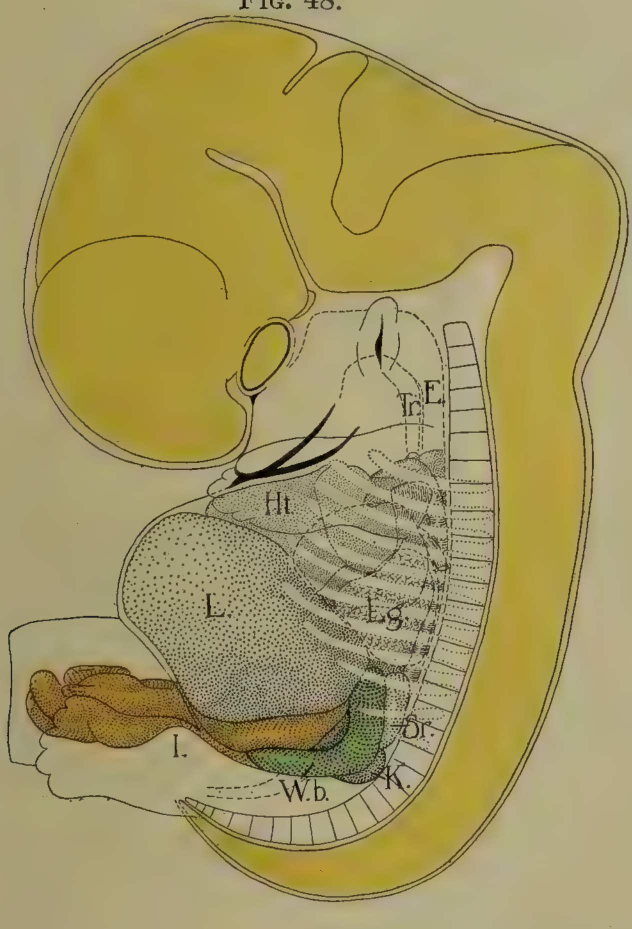


FIG. 50.

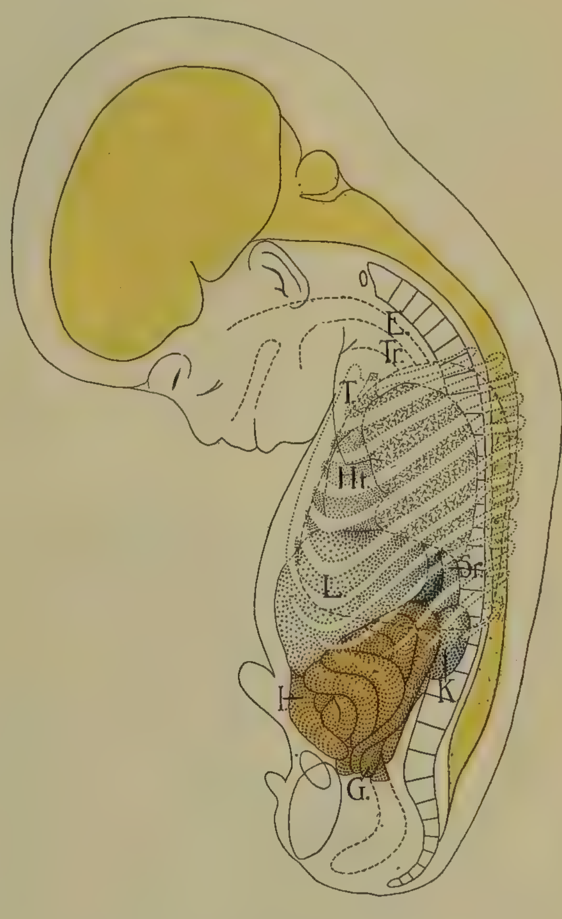


FIG. 51.

FIGS. 48, 49, 50, 51, 52 and 53.—A SERIES OF RECONSTRUCTIONS AND DISSECTIONS ILLUSTRATING THE GROWTH AND TOPOGRAPHY OF THE VISCERA IN THE DEVELOPMENTAL PERIOD. All specimens drawn to the same crown-rump length.

Fig. 48, embryo 4.2 mm. long. (Modified from His.) Fig. 49, embryo 11 mm. long. (Modified from Jackson.) Fig. 50, embryo 17 mm. long. (Modified from Jackson.) Fig. 51, fetus 65 mm. long. (Modified from Jackson.) Fig. 52, newborn 51 cm. long. Fig. 53, adolescent. (Based on drawings and casts of His and Symington.) Nervous system, yellow; gastro-intestinal tract, red; spleen, blue; Wolffian body, green. All., allantois. Ao., aorta. Bl., bladder. Cl., cloaca. C.V., cardinal veins. E., esophagus. G., genital gland. Ht., heart. I., intestine. K., kidney. L., liver. Lg., lung. Ph., pharynx. Sr., suprarenal gland. St., stomach. U., uterus. W. b., Wolffian body.

of organs. The capacity of the stomach at birth is about 30 cc. It rises rapidly to about 90 or 100 cc. at the end of the first month and thereafter increases more slowly to 250 to 300 cc. at the end of the first year.

The development of the intestines.—With the separation of the archenteron from the yolk-sac the intestinal tract is established as a short and relatively straight tube extending from the stomach swelling to the cloaca. This tube in its rapid elongation is thrown into three main or primary loops and a number of secondary ones. The primary loops are: (1) the gastroduodenal loop which forms the upper portion of the duodenum; (2) the enterocolic or umbilical loop which gives rise to the distal portion of the duodenum, the jejunoileum, and the cecum, ascending colon and a part of the transverse colon; and (3) the left colic loop which forms the remainder of the large intestine. The gastroduodenal loop is short and simple needing no further description. The umbilical loop first lies in the median sagittal plane of the body. It consists of a cranial and a caudal limb and a yolk-stalk arises from its summit which projects into an extension of the body-cavity, the umbilical celom. A slight swelling on the caudal limb marks the position of the cecum and the division between small and large intestines. In its further growth the umbilical loop turns on its axis and its caudal

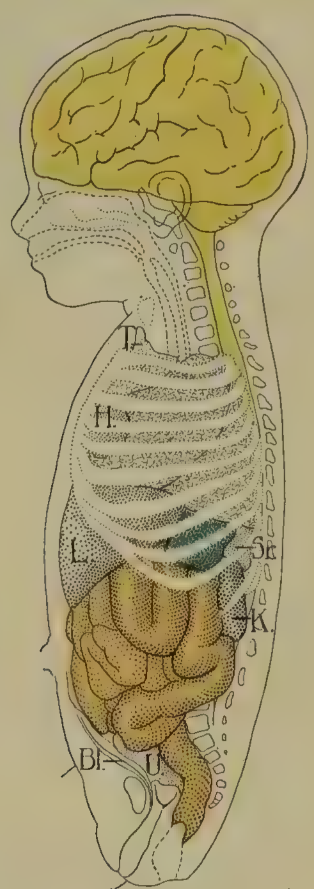


FIG. 52.

FIG. 53.

FIGS. 52 and 53.—SEE CAPTIONS ON PAGE 47.

limb is carried first to the left, then anteriorly and later to the right of the proximal one, carrying the cecum with it. The development of the coils of the small intestine (see page 1254) takes place partly in the abdominal and partly in the umbilical celom. During the middle of the fourth month they return rather suddenly to the abdominal cavity and following this the first part of the colon and the cecum pass ventrally over the small intestines to lie in the right hypochondriac region below the liver. Later the cecum descends into the right iliac fossa to a level a little below that occupied in the adult. Its final position is acquired in early childhood after a slight ascent which is probably associated with the postnatal growth of the lumbar region.

The left colic loop is formed by the bending of the lower part of the intestinal tube to the left side of the abdominal cavity some time after the formation of the other primary intestinal loops. Secondary curves in this loop form the left colic (splenic) and sigmoid flexures. For further details on the development of the intestines, see p. 1268.

The cecum and vermiform process (appendix).—The formation of the swelling which represents the cecum was mentioned above. After the rotation of the umbilical loop the cecal swelling is extended as a finger-like projection from the ventral surface of the gut. A small diverticulum which represents the vermiform process arises from the apex of this projection in the third fetal month (fig. 55). The vermiform process grows rapidly, reaching its full relative length (as compared to the length of the intestine) by the middle of fetal life. In the fourth month the cecal projection is bent at right angles to the main axis of the segment of the intestine from which it arises and the ileocecal valve is formed by invagination of the terminal portion of the walls of the ileum at this point. At birth the cecum is relatively small. Its lower end becomes directly continuous with the vermiform process without a sharp line of demarcation and the cecal sacculations are generally absent. The appendix usually lies directly below the cecum at this time, or is bent upward at an acute angle along its medial margin. The

development of the cecal sacculations and the formation of a distinct cecal fundus usually takes place in early childhood (generally in the third or fourth year).

The rectum and anal canal.—The rectum is formed from the dorsal portion of the cloaca which is separated from the urogenital sinus by the formation of the urorectal septum. At the same time the posterior part of the cloacal membrane is separated from the anterior portion

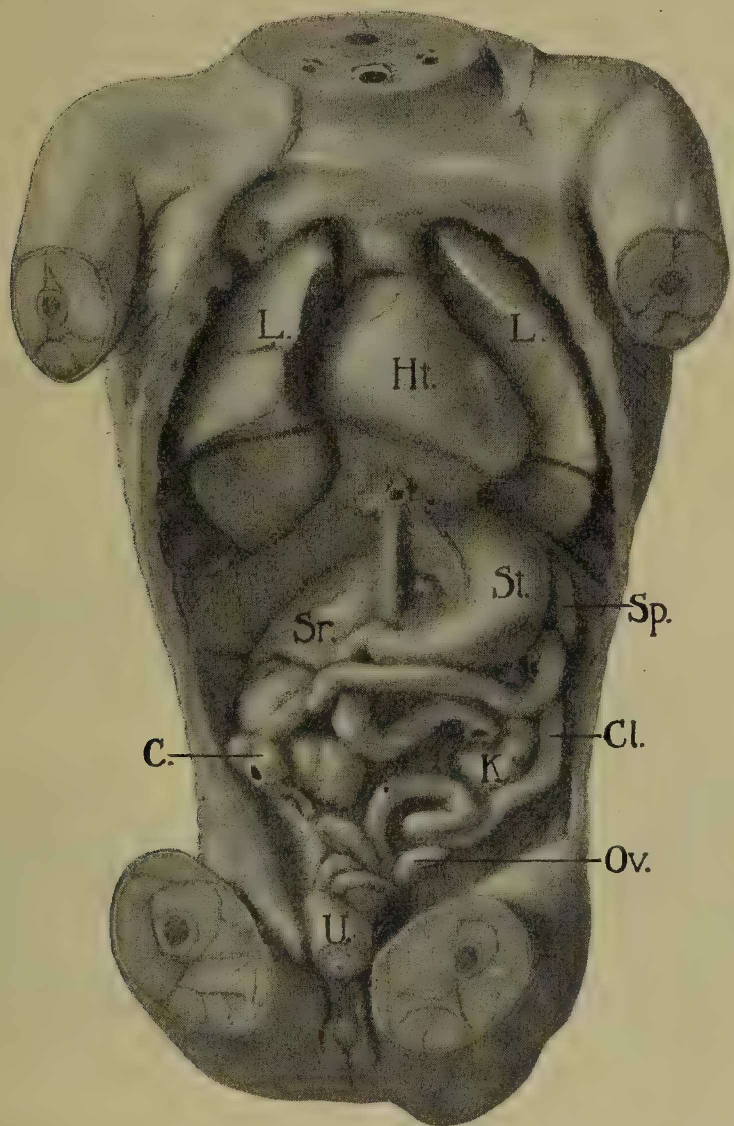


Fig. 54.—Dissection of the Thoracic and Abdominal Viscera of a Fetus of the Fifth Month.

C., cecum. Cl., colon. Ht., heart. K., kidney. L., lungs. Sp., spleen. Sr., suprarenal gland. St., stomach. U., umbilicus. Ov., ovary.

and forms the *anal plate* which is later invaginated forming the anal canal. The rectum and anal canal are separated until comparatively late in the development by the *anal membrane* which lies at the level of the future anal valves. A want of rupture of the anal membrane is known as congenital atresia of the anus.

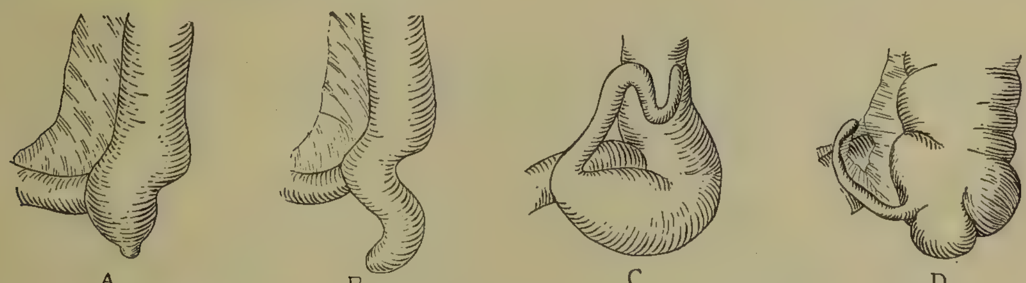


Fig. 55.—Four Stages in the Development of the Cecum and Vermiform Process. (After Kollmann and Paterson.)

A, embryo at the end of the second month. B, fetus of the third month. C, child ten weeks after birth. D, child of 5 years.

Growth of the intestines.—The growth of the intestines in the early part of prenatal life is very rapid. At birth they form about 1.5 per cent. of the body as compared with 0.75 per cent. in maturity. The absolute length of the intestines at birth is usually between 350 and 400 cm. (12 to 14 feet). The intestinal tract grows about 50 per cent. in length in the first year. Thereafter the increase is much slower, the length in the adult being about 2.5 times that of the newborn.

In the early part of the embryonic period the large intestine forms nearly one-half of the length of the intestinal tract. But by the fourth fetal month it is reduced to about one-fifth of the total length of the intestines and this ratio is maintained throughout the remainder of life, except for a period of increase in the length of the colon in the latter fetal months due to its distension by meconium.

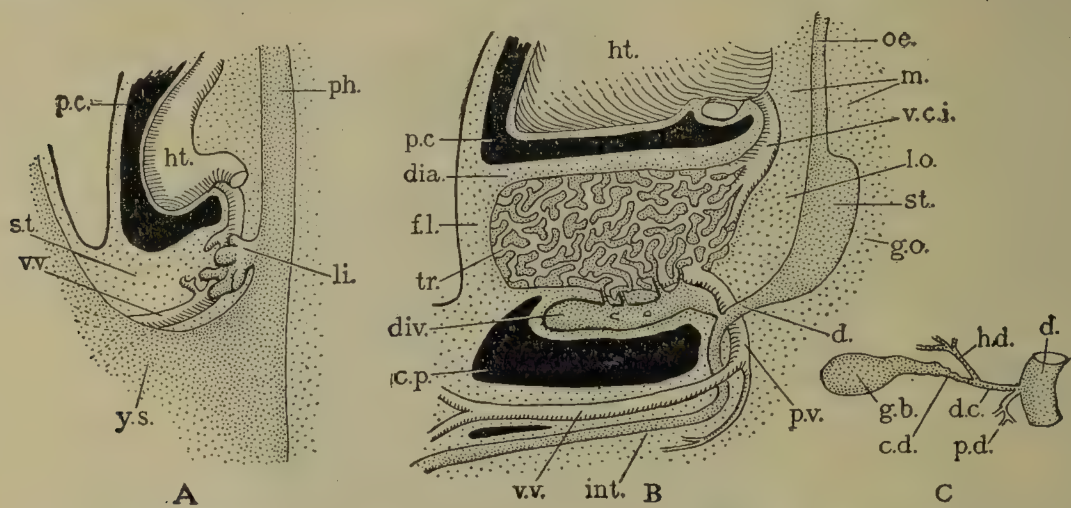


FIG. 56.—DIAGRAMS OF THE DEVELOPMENT OF THE LIVER. (After Lewis.)

A, the condition in a 4.0 mm. human embryo. B, a 12 mm. pig. C, the arrangement of ducts in the human adult. c.d., cystic duct. c.p., cavity of the peritoneum. d., duodenum. d.c., ductus choledochus. dia., diaphragm. div., diverticulum. f.l., falciform ligament. g.b., gall-bladder. g.o., greater omentum. h.d., hepatic duct. ht., heart. int., intestine. li., liver. l.o., lesser omentum. m., mediastinum. oe., esophagus. p.c., pericardial cavity. p.d., pancreatic duct. ph., pharynx. p.v., portal vein. st., stomach. tr., trabecula. v.c.i., vena cava inferior. v.v., vitelline vein. y.s., yolk-sac.

The liver.—The liver arises in the third week as a thickened area in the floor of the posterior part of the foregut (figs. 42A, 48, 56, 67). This area forms a small, thick-walled pouch in which may be recognized an anterior hepatic and a posterior cystic portion. The cystic part forms the common bile-duct, the gall-bladder and cystic duct, and probably the main hepatic ducts. The hepatic portion gives rise to a large number of cellular cords which anastomose freely interdigitate with the neighboring veins, and form the parenchyma of the liver. Certain of these cords, which lie close to the developing portal veins, form the minor hepatic ducts. For further details on the development of the liver, see p. 1288 and figs. 976, 1030.

The liver grows with great rapidity in the embryonic period forming over 7 per cent. of the body in the second and third fetal months. After this time the relative weight declines

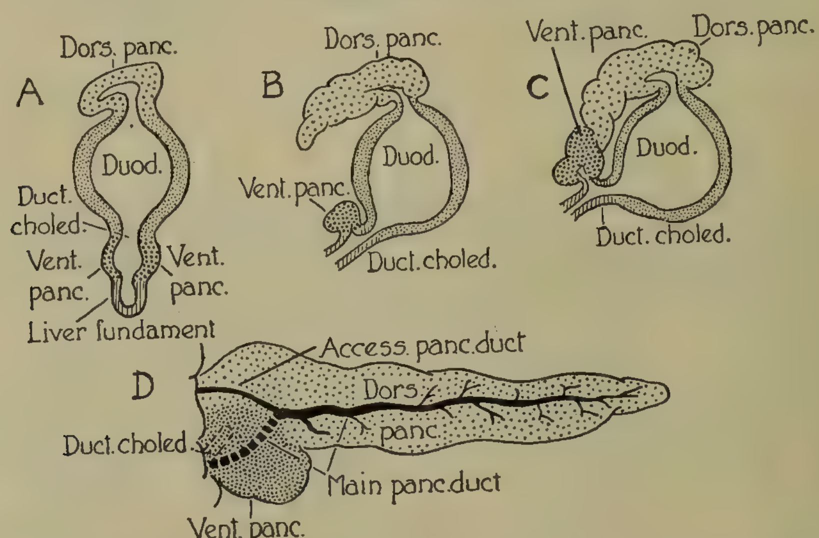


FIG. 57.—A, B, C, DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE PANCREAS. (After Laguesse.) D, DIAGRAM ILLUSTRATING THE EMBRYONIC CONSTITUENTS OF THE ADULT PANCREAS. (After Charpy.)

to about 4 per cent. at birth, 3 per cent. in childhood and 2.5 per cent. in maturity. The post-natal growth of the liver in absolute weight follows the general course of the splanchnic viscera and the total increase between birth and maturity is about 13-fold. In fetal life the gall-bladder is small in proportion to the liver, being more or less buried in its substance, but it grows rapidly in infancy and the adult relation between these structures is established by the end of the second year.

The pancreas.—The pancreas (fig. 57) arises in the fourth week from two thickenings of the wall of the posterior part of the foregut. The first of these to appear is the dorsal pancreas which is formed from the roof of the primitive duodenum caudal to the fundament of the stomach. The second or ventral pancreas, which is sometimes a paired structure, arises from the

floor of the gut at the cephalic end of the liver-pouch. Both diverticula differentiate into proximal stalks and distal expanded portions, the former forming the main ducts of the gland and the latter giving rise to the minor ducts and alveoli. Both pancreatic diverticula turn to the right in their growth and, passing around the right side of the intestine, come in contact near the point of origin of the ventral pancreas. Later, in connection with the rotation of the intestinal tube, the pancreas is shifted to the left of the duodenum. A fusion of the two elements takes place through the anastomosis of their main ducts. In later life the ventral pancreas is represented by the proximal portion of the main pancreatic duct and the lower part of the head of the pancreas. The remainder of the parenchyma of the gland, the accessory pancreatic duct (when present) and the distal portion of the main duct are derived from the dorsal pancreas. The relation of the pancreas to the primitive mesentery is shown in figs. 976 and 1033.

The pancreas grows relatively slowly until the sixth fetal month when it enters on a period of more rapid growth which extends well into the first year of postnatal life. The organ increases in weight nearly 30 times in postnatal life. Its general course of growth is that of the splanchnic group of viscera.

THE RESPIRATORY SYSTEM

Early development of the respiratory system.—The entodermal fundament of the respiratory system arises in the third week as a median groove in the hind part of the floor of the pharynx. The cranial portion of this groove, which represents the larynx, remains attached to the pharynx while the caudal portion grows downward as a respiratory bud which represents the trachea and the lungs (figs. 42B, 48, 58). The free end of the respiratory bud is expanded into a rounded vesicle which immediately bifurcates into right and left branches or lung-buds.

FIG. 58.—RECONSTRUCTION OF THE LUNG OUTGROWTHS OF EMBRYOS OF (*A*) 4.3, (*B*) 8.5, AND (*C*) 10.5 MM.

Ap, Pulmonary artery; Ep, eparterial bronchus; Vp, pulmonary vein; I, second lateral bronches; II, main bronchi.—(His.)

The larynx.—The cranial end of the respiratory groove forms a T-shaped cleft which is bounded anteriorly by a transverse ridge, the fundament of the epiglottis, and laterally by paired arytenoid swellings which represent the cuneiform and corniculate tubercles and the aryepiglottic folds (fig. 59). The epithelial surfaces of the arytenoid swellings soon fuse, forming a plate which obliterates the upper part of the respiratory groove. The cavity of the larynx is reestablished in the second month by the disintegration of the central cells of this plate. The ventricle and ventricular and vocal folds are formed by lateral extensions of the laryngeal cavity in this region.

The laryngeal cartilages are differentiated in the mesenchyma surrounding the epithelial tube of the larynx. Their chondrification begins in the second fetal month but is not completed until shortly before birth. The derivation of the thyroid cartilage is considered in connection with the development of the branchial skeleton (pp. 32, 45).

The larynx is relatively large in the fetus and newborn. At birth the absolute vertical dimensions are a little less and the transverse dimensions a little more than one-third those of the adult (fig. 60). Three phases can be recognized in the postnatal growth of the larynx: (1) a period of general rapid growth from birth to 2 or 3 years: (2) a succeeding period to prepuberty in which growth proceeds rather slowly although there are some alterations in form: and (3) a second period of rapid growth (most noticeable in males) in later childhood and adolescence. Sexual differences are said to appear in the larynx in the third year and after this time the male larynx is larger than the female. The larynx gradually descends in the neck during the fetal period and childhood.

The trachea.—The trachea is formed from the portion of the respiratory bud lying between the laryngeal groove and the lung-buds. The tracheal cartilages and musculature develop in the second month from the mesenchyma surrounding the tube, and the tracheal glands first appear towards the close of the third month. The length of the trachea is nearly tripled between birth and maturity. The diameter of the trachea increases 4 or 5-fold after birth.

The lungs.—The lining of the bronchial tree and the alveoli (air-cells) of the lungs is formed by the repeated division of the lung-buds and their branches (fig. 58). While the terminal branches of the bronchial tree arise from the larger stems by typical dichotomous division the

main trunks are formed by monopodial division, straight or but slightly curved while the smaller arise as side branches from them. From an early stage the lung-buds are asymmetrical, the right being larger than the left and directed more caudally. The early branching of the buds is also dissimilar, the right bud forming two side buds (representing the bronchial rami or the upper and middle lobes), the left bud forming but one (representing the bronchus of the upper lobe).

The formation of alveoli from the tips of the terminal branches of the bronchial tree begins in the sixth fetal month. Their number grows rapidly but they increase little in size before birth. At birth, with the establishment of respiration the alveoli expand vigorously, their lining epithelium being reduced from a columnar to a squamous type. Aside from the possible growth of a few air-cells from the walls of the terminal bronchioles there are no new alveoli formed after birth. The size of the alveoli, however, continues to increase throughout life, even to extreme old age.

The visceral *pleura* is formed from the splanchnic mesoderm of the parietal part of the celom which carries the lung-buds as they push their way into this cavity, and the stroma of the lung is probably derived from cells of this layer. The connective tissue of the lung is extremely abundant in the early part of the fetal period but the relative amount is greatly reduced in the last fetal months by the increase in the number of alveoli and still more so by the expansion of the alveoli at birth.

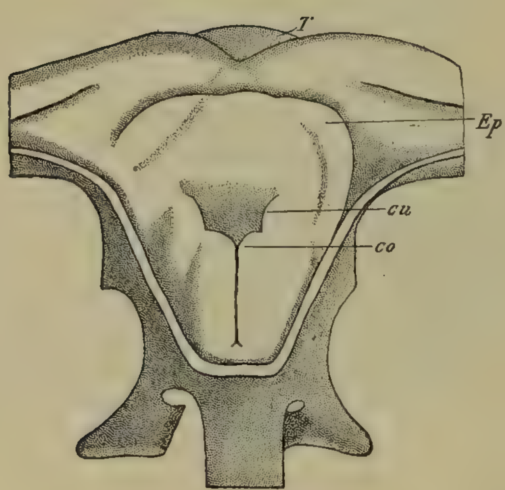


FIG. 59.

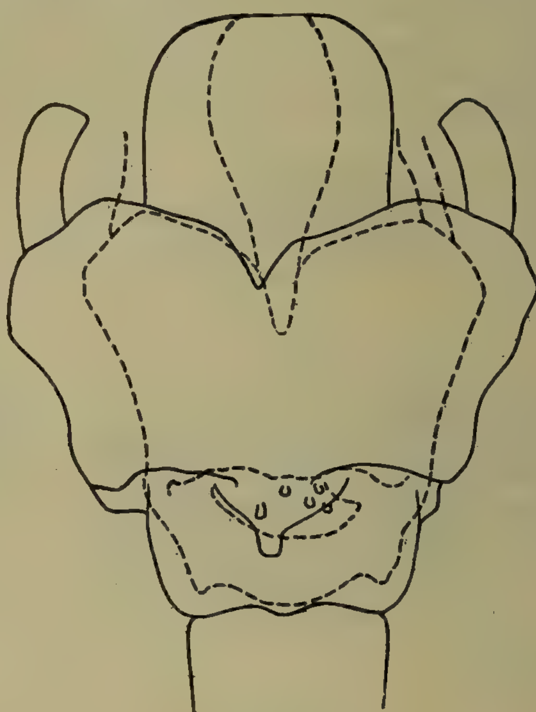


FIG. 60.

FIG. 59.—RECONSTRUCTION OF THE OPENING INTO THE LARYNX IN AN EMBRYO OF TWENTY-EIGHT DAYS. Seen from behind and above, the dorsal wall of the pharynx being cut away. (From McMurrich after Kallius.) co, Cornicular, and cu, cuneiform tubercle. Ep, epiglottis. T, unpaired portion of the tongue.

FIG. 60.—OUTLINE DRAWINGS OF THE LARYNGES OF AN ADULT AND A NEWBORN. Reduced to the same size and superimposed, showing the differences in proportions at birth and in maturity. Adult in dotted line; newborn in solid line.

The lungs are formed in the upper cervical region but in their development they descend at first rapidly and then more slowly into the thoracic cavity. There is little change in the position of the lungs in infancy but a slow descent in childhood.

The lungs reach their highest relative weight in the fourth fetal month when they form about 3.3 per cent. of the body. In the newborn they form about 1.7 to 2.0 per cent. and in the adult about 1 per cent. of the body-weight. The growth of the lungs in absolute weight during postnatal life follows the scheme of the splanchnic group of organs.

The nose and paranasal sinuses.—The formation of the nasal pits, development of the external nose, and establishment of the hard palate have already been considered (p. 42). In the early part of the second month the nasal fossæ are represented by the two nasal pits which open to the surface of the face through the embryonic nares (fig. 17) and are separated medially by the primitive nasal septum. They communicate with the oral sinus through the primitive choanæ (fig. 43).

The floor of the definitive nasal fossæ is formed by the fusion of the palatine shelves of the maxillary processes. During this change the primitive choanæ are merged in the nasal fossæ and the definitive choanæ are formed, eventually assuming their final position between the posterior ends of the nasal fossæ and the nasopharynx. At the same time the lower parts of the nasal fossæ are completely separated by the union of the lower margin of the nasal septum with the upper surface of the fused palatine shelves (fig. 43).

The agger nasi and inferior concha arise as processes from the lateral walls of the nasal fossa and the conchæ above them from both the medial and lateral walls of the upper parts of the fossæ. The conchæ are developed in part by the actual outgrowth of shelves from the wall and in part by the formation of grooves which limit these processes. The formation of the

conchæ begins in the seventh week. For further details on the development of the nose, see p. 1311.

When the definitive nasal fossæ are first established they are quite short anteroposteriorly but their height and breadth are relatively great. During fetal life the length of the chambers grows more rapidly than the height and at birth the fossæ are relatively long, broad and low. The height of the fossæ increases nearly one-half in infancy but grows much more slowly thereafter. At 7 years it is about twice and in the adult 2.5 to 3 times as great as in the newborn. Apparently the length of the nasal fossæ is about doubled in the first decade and increases little thereafter. The breadth of the nasal cavity, on the other hand, increases very slowly in early childhood.

The *paranasal sinuses* arise as evaginations of the nasal mucous membrane in the latter part of the third and in the fourth fetal months. Their subsequent history is considered in connection with their adult anatomy (p. 1305).

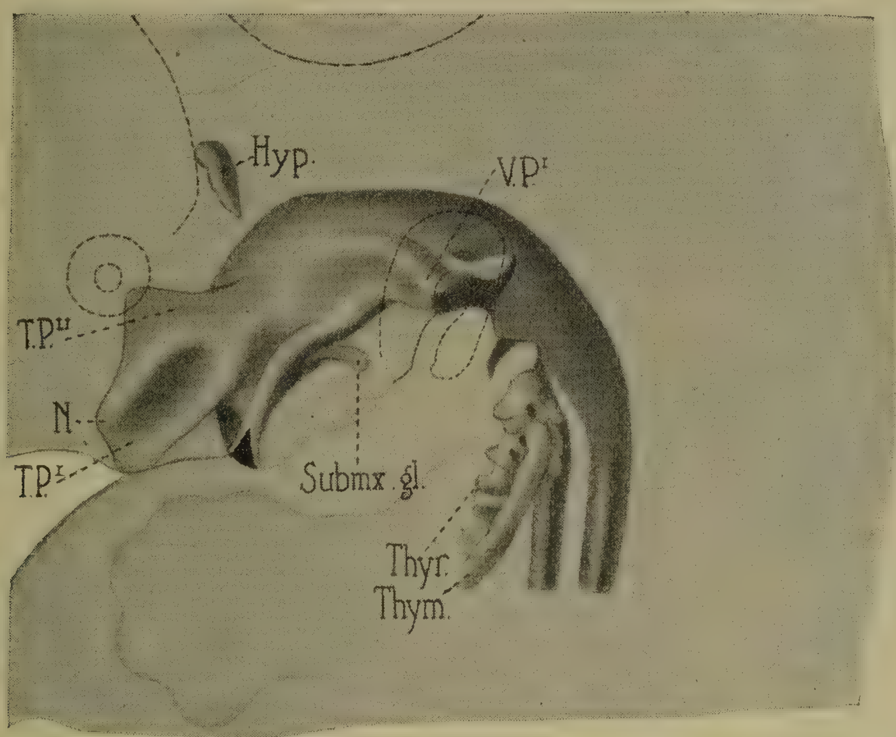


Fig. 61.—Lateral View of a Model of the Nose and Pharynx of an Embryo of 6 Weeks. (After Sudler.)

Hyp., anterior lobe of the hypophysis. N., nasal cavity. Submx.gl., submaxillary glands Thym., thymus. Thyr., thyroid. T.P[1]., inferior concha. T.P[2]., middle concha. V.P., first branchial (pharyngeal) pouch.

THE UROGENITAL SYSTEM

All three germ-layers are involved in the formation of the urogenital system. The mesodermic contribution is derived from the intermediate mesoderm, the entodermal from the caudal ends of the cloaca and allantois, and the ectodermal mainly from the cloacal membrane.

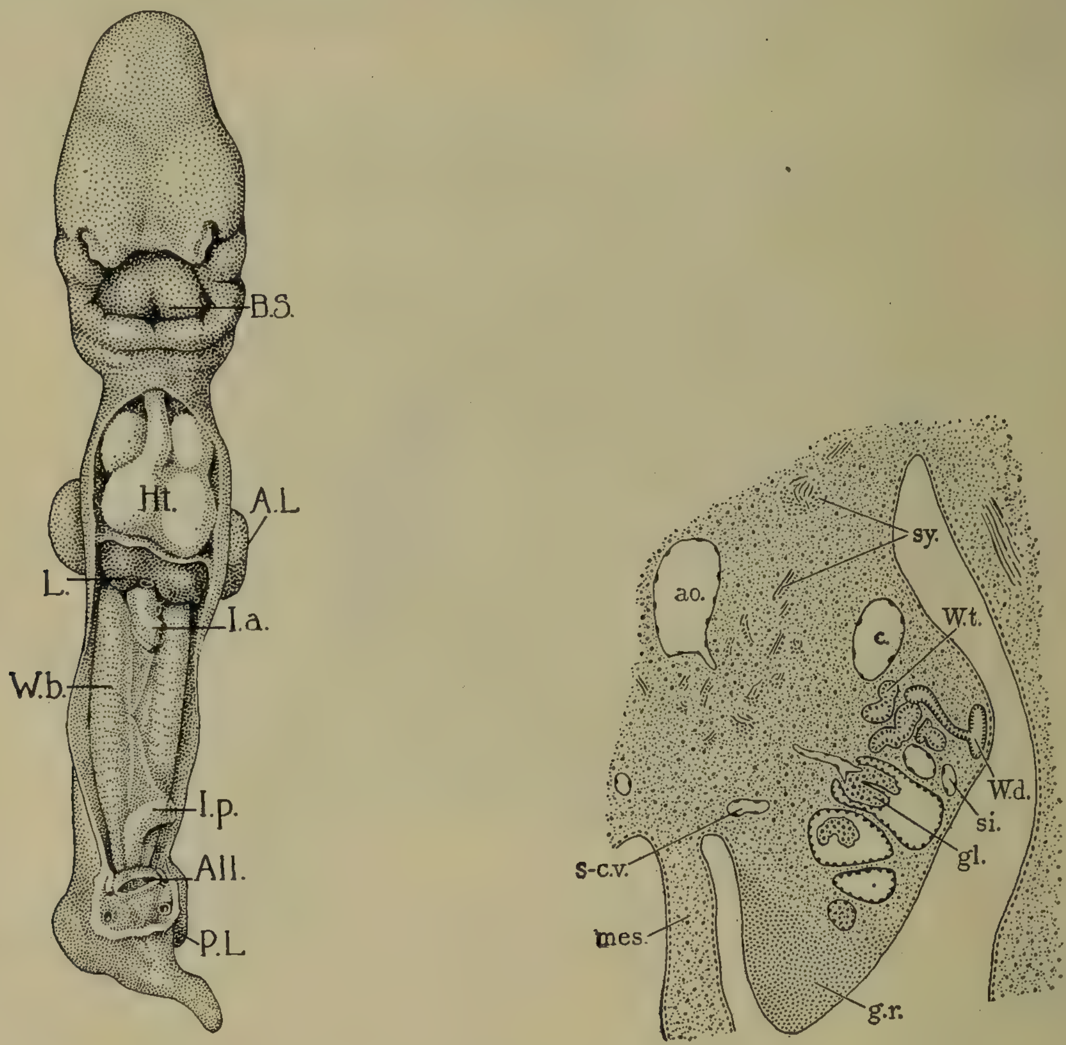
The excretory portion of the urogenital system is derived entirely from the intermediate mesoderm. In man, as well as in other mammals, and in reptiles and birds, there are formed successively in the embryo three sets of excretory organs or kidneys. The first of these, the pronephros or head-kidney, is a rudimentary structure even in the embryo and disappears completely except for its duct. The second, the mesonephros or Wolffian body, becomes a functional excretory organ in the embryo, but later degenerates with the exception of certain portions which are retained as parts of the male genital system and others which remain as vestigial structures. The third, the metanephros, remains as the permanent kidney.

The pronephros.—The pronephros arises as a series of outgrowths from the intermediate cell-mass of the cervical region. These sprouts develop into tubules which connect medially with the body-cavity and end blindly laterally. The blind ends of the tubules are directed caudally and growing backward fuse with one another forming a solid cord. The pronephros is a transitory structure and by the fifth week all of its tubules have degenerated; but the longitudinal cord formed from them persists, acquires a lumen, and, growing backward, connects with the lateral wall of the cloaca. It is now called the Wolffian duct.

The mesonephros and the Müllerian ducts.—The mesonephros arises as a series of tubules from the intermediate mesoderm of the lower cervical, thoracic, and the greater part of the lumbar region. These tubules become disconnected from the intermediate cell-mass, their lateral ends joining the Wolffian duct while their medial extremities are expanded into cup-shaped vesicles which enclose a capillary tuft derived from arterial sprigs which pass to them from the aorta. When fully developed the Wolffian or mesonephric tubules form a pair of large masses projecting from the dorsal wall of the abdominal cavity on either side of the mesentery (figs. 48–50, 62A). These masses, the Wolffian bodies, reach their greatest development in the sixth or seventh week and thereafter undergo a rapid involution, except for certain parts which are retained in connection with the genital glands.

At the time when the Wolffian body has almost reached its highest development the peritoneum near its cranial end on the medial surface is invaginated forming a second longitudinal duct, the Müllerian duct, which lies parallel with the Wolffian duct. The Müllerian ducts grow posteriorly and join the urogenital sinus. In the lower part of their course the Müllerian ducts lie side by side. They subsequently fuse into a single tube in this region and open into the urogenital sinus through a single ostium. Their upper parts, which are associated with the Wolffian bodies, remain paired and separate.

The metanephros.—The metanephros or permanent kidney is formed from the metanephric bud (primitive ureter), which is an outgrowth from the Wolffian duct, and from a thickened



A B

FIG. 62.—A, DISSECTION OF AN EMBRYO OF THE FIFTH WEEK, SHOWING THE WOLFFIAN BODY. (After Coste.)

A.L., anterior limb-bud. All., allantois. B.S., buccal sinus. Ht., heart. I.a., cranial limb of umbilical loop of the intestine. I.p., caudal limb of umbilical loop of the intestine. P.L., posterior limb-bud. W.B., Wolffian body.

B, TRANSVERSE SECTION OF THE WOLFFIAN BODY OF A HUMAN EMBRYO 10 MM. LONG. (After Lewis.)

ao., aorta. c., posterior cardinal vein. gl., glomerulus of Wolffian tubule. g.r., genital ridge. mes., mesentery. s.c.v., subcardinal vein. si., sinusoid. sy., sympathetic nerves. W.d., Wolffian duct. W.t., Wolffian tubule.

mass of mesenchyma, the metanephric blastema, derived from the lower part of the intermediate mesoderm. The metanephric bud arises from the lower part of the Wolffian duct in the fourth week. It grows backward and upward behind the Wolffian body where its distal end encounters and becomes imbedded in the metanephric blastema. The distal end forms the renal pelvis while the proximal portion remains as the ureter. The renal tubules are formed in part from the renal pelvis and in part from the metanephric blastema, the former giving rise to the straight and arched collecting segments and the latter to the remainder of the tubule. The metanephric blastema also forms the stroma of the kidney. The renal tubules are formed in a series of 14 to 18 generations, the last formed tubules occupying the periphery of the kidney. All of the renal tubules have been formed at birth and the subsequent increase in the renal parenchyma (about 90 per cent. of the total growth) takes place entirely through tubule hypertrophy.

The position of the kidneys changes greatly during development. Starting in the sacral region they gradually pass into the abdominal region in the second month. In later fetal life they are shifted downward so that their lower poles are usually in the pelvis at the time of birth, but in infancy there is commonly a second upward shifting of the kidneys. The later changes in the position of the kidneys are probably passive, dependent on the growth of the posterior wall of the trunk.

The kidneys form about 0.7 per cent. of the weight of the body at birth. They decrease to about 0.46 per cent. in maturity, their total postnatal increase being about 14-fold. Their growth in absolute weight follows the general course of the splanchnic group of organs.

The urogenital sinus.—In young embryos the hindgut and the allantois unite in a common cloaca. This chamber is joined on either side by the Wolffian ducts and its ventral wall is formed, in part, by the cloacal membrane. The cloaca becomes divided, in the frontal plane, by the rectourethral septum into a dorsal (posterior) rectum and a ventral (anterior) urogenital sinus. This partition extends to the cloacal membrane which is differentiated into a ventral portion, associated with the later development of the urogenital sinus and a dorsal (posterior) part which forms the anal canal (see p. 42). The Wolffian ducts remain connected with the urogenital sinus when the cloaca is divided, and the ureters which spring from the Wolffian ducts separate from them and acquire independent openings in the urogenital sinus cranial to the ostia of the Wolffian ducts. At this time also the Müllerian ducts form a connection with the sinus medial to the openings of the Wolffian ducts.

The urogenital sinus is later differentiated into three segments. The upper portion (pars vesicalis) is an expanded chamber receiving the ureters and continuous with the allantois cranially. The middle portion (pars urethralis) is a short tube into which the Müllerian and Wolffian ducts open. The lower segment (pars phallica) is widely expanded and is floored by the ventral portion of the cloacal membrane.

The *pars vesicalis* forms the bladder. Its lining epithelium is of entodermal origin except in the region of the future trigone which is derived from the mesoderm of the proximal ends of the ureters. The connection of the allantois with the bladder is lost in the second fetal month and the cranial third of the bladder is obliterated in fetal life, remaining as a fibrous band, the urachus. At birth the bladder is mainly an abdominal organ, its base lying behind the sym-

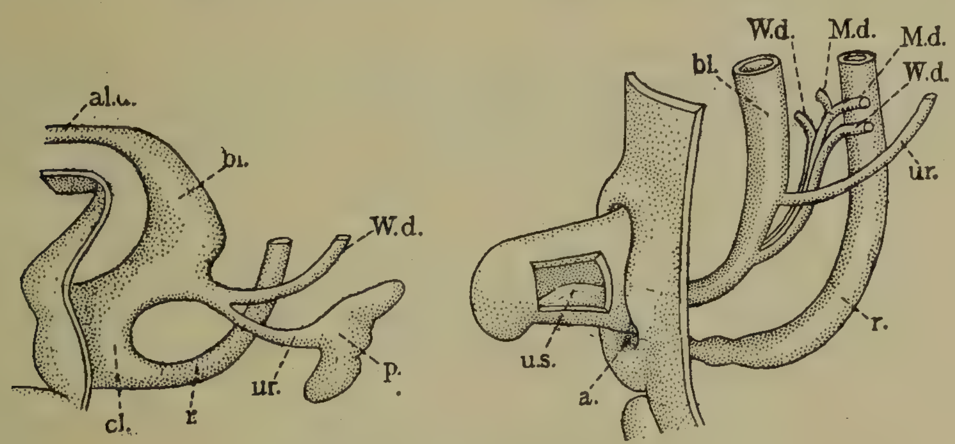


FIG. 63.—DEVELOPMENT OF THE UROGENITAL SINUS. (From Lewis after Keibel.)

A, embryo 11.5 mm. long (4½ weeks). B, embryo 25 mm. long (8½ to 9 weeks). a, anus. al.d., allantoic duct. bl., bladder. cl., cloaca. M.d., Müllerian duct. p., pelvis of kidney. r., rectum. ur., ureter. u.s., urogenital sinus. W.d., Wolffian duct.

physis pubis and its apex extending halfway to the umbilicus, the long axis of the contracted organ being almost vertical at this time. During postnatal life the bladder shifts backward and downward in the pelvis. Three stages can be recognized in this process; a period of rapid descent in infancy and early childhood, a stationary phase in middle and later childhood, and a final period of slow descent in adolescence.

The *pars urethralis* forms the entire urethra in the female and the proximal portion of the urethra in the male. In the third fetal month the pars urethralis gives rise to a series of longitudinal folds from which are formed the prostatic tubules of the male and the corresponding but rudimentary paraurethral (Skene's) glands of the female. All of the prostatic glands are formed by the middle of fetal life.

The *pars phallica* enlarges in the second fetal month, encroaching on the pars urethralis and forming a shallow vestibule into which the urethra and the Müllerian ducts open independently. In its further development (which is considered in connection with external genitalia) the pars phallica is converted into the distal part of the urethra in the male and the vestibule in the female. A pair of evaginations from the lower part of the pars phallica in the fourth fetal month gives rise to the bulbovestibular glands in the female and to the bulbourethral glands in the male.

The external genitalia.—The formation of the external genitalia takes place through the development and transformation of a series of external elevations at the margins of the cloacal membrane. Each of these structures consists of a central core of mesenchyma covered by an outer layer of the ectoderm of the perineal region. A median elevation, the cloacal tubercle, is formed at the anterior end of the cloacal membrane in the fifth or sixth week. This is differentiated into an apical phallus, the genital eminence, and a basal portion, the genital tubercle, which surrounds the root of the phallus and extends caudally on either side of the cloacal membrane as the paired genital swellings. At the same time, the cloacal membrane forms a deep urethral groove, the lips of which are converted into a second pair of longitudinal ridges termed the genital folds, which lie mediad to the genital swellings. The urethral groove between them is converted into a longitudinal slit which connects the vestibule of the urogenital sinus with the exterior.

In the female the phallic part of the cloacal tubercle forms the clitoris while the basal portion forms the mons pubis cranially and the labia majora caudally. The median slit becomes the rima pudendi and the genital folds at its margins the labia minora.

In the male the phallic portion of the cloacal tubercle forms the greater part of the penis. The genital folds are not so fully developed in the male but the margins of the urethral groove bend medially over this depression and fuse along the median line converting it into the proximal urethra. The anterior extremity remains open as the external urethral orifice. The genital swellings disappear in the male, being replaced by an unpaired scrotal swelling. The details of this phase of development are described in more detail in the section on the Urogenital System p. 1382.

Fig. 64.—Diagrams of the External Genital Organs. (A) of a male embryo. (B) of a female embryo. (After Lewis.)

a., anus. g., glans clitoridis and glans penis. g.f., genital folds. g.g.f., genital swellings. r., raphe. u.s., urogenital sinus.

Origin of the testis and ovary.—In their earlier stages no differences can be recognized between the ovary and testis. The undifferentiated sex-gland appears as a ridge on the medial side of the Wolffian body, extending from the middle thoracic through the abdominal region. This ridge consists of a covering epithelium and an inner solid core formed by the ingrowth of this covering. Two types of cells may be recognized in the gland, those having their origin from the epithelium of the body cavity, and larger and less numerous germ-cells whose origin in man is uncertain.

Development of the testis and its ducts.—In the transformation of the indifferent genital gland into the testis the inner part of its epithelial core is converted into a network of solid cords, and the outer part forms a layer of dense mesenchyma which underlies the covering epithelium and represents the tunica albuginea testis. The network of solid cords is converted into the tubuli contorti (seminiferous tubules), the tubuli recti, and probably a portion of the rete testis.

With this differentiation of the genital gland the Wolffian body is also greatly modified. A number of the upper mesonephric tubules become connected with the rete testis and form the efferent ducts of the testis. The tubules above and below this group lose their connection with the Wolffian duct and remain as vestigial structures, certain of the upper ones forming the appendix testis and possibly the appendix epididymidis, and the lower ones the paradidymis. The Wolffian duct remains in its entirety as the ductus epididymidis, the ductus deferens, and the ejaculatory duct. The seminal vesicles arise as outgrowths of the ejaculatory duct. The Müllerian duct degenerates in the male, except for its lower extremity which remains as the prostatic utricle (the homolog of the vagina) and for its upper or cranial end which may give rise to the appendix epididymidis (fig. 1141).

Development of the female genital tract.—In the female the core of the genital ridge forms the stroma of the ovary, the cells of the general covering epithelium give rise to the follicular cells, and the germ-cells which lie in the epithelium develop into the primitive ova (see fig. 1039).

The early changes in the Wolffian body resemble those of the male. The upper tubules degenerate with the exception of one or two which remain as the cystic *appendices vesiculosi* of the adult. The middle group of tubules form the *epoöphoron* (fig. 1127), a structure homologous with the efferent ducts of the testis but without function, which persists and increases in size until maturity. The lower group of tubules undergo a more complete involution although remnants of them persist in postnatal life as the *paroöphoron* (the homolog of the paradidymis). The Wolffian duct in the female loses its connection with the urogenital sinus but portions of it may be retained as the longitudinal duct of the epoöphoron or the duct of Gartner (homolog of the ductus deferens and ductus epididymidis).

The Müllerian duct is retained in its entirety in the female, the unpaired portion forming the uterovaginal canal and the paired portions the uterine tubes (fig. 1141). For the development of the broad ligament, see fig. 1125.

Descent of the testis and ovary.—In the latter part of the second fetal month the testes extend along the posterior wall of the trunk from the thoracic to the sacral region. In the third month they are found in the iliac fossæ, from the fourth to the seventh month at the level of the future internal abdominal ring, and in the eighth month they usually pass into the scrotum (fig. 65). The causes of the descent of the testes are obscure. Much of the early change in position is due not to the actual shifting of the organs but to the involution of their cranial parts. The later changes may be due in part to the contraction of the gubernaculum testis, an associated ligament of the fetal testis which contains smooth muscle.

The passage of the testes through the inguinal canal is preceded by the invasion of the solid scrotum by a pocket of peritoneum, the saccus vaginalis, which later partially surrounds the testis as the tunica vaginalis. The connection between the saccus vaginalis and the abdominal peritoneal cavity is usually patent in the newborn, being commonly closed in the first 6 months after birth. For further details, see p. 1373.

The ovaries, like the testes, shift from an abdominal to a pelvic position in the early part of fetal life (fig. 54), although their final position is usually acquired in childhood. In their passage the axes of the ovaries are shifted first from the longitudinal to the transverse plane of the body and finally into the sagittal plane. The canal of Nuck, the homolog of the saccus vaginalis, is found in the labia majora in the female fetus. It is generally open at birth but is obliterated in early infancy.

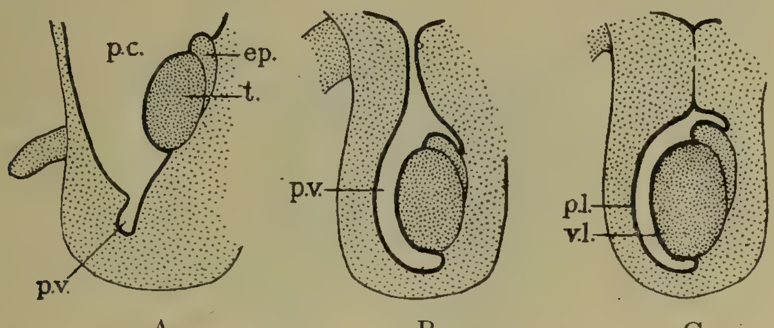


FIG. 65.—DIAGRAMS OF THE DESCENT OF THE TESTIS. (From Lewis after Eberth.) ep., epididymis. p.c., peritoneal cavity. p.v. processus vaginalis. t., testis. p.l., parietal layer of the tunica vaginalis. v.l., visceral layer of the tunica vaginalis.

The growth of the male genital organs.—The male organs of generation follow without exception the scheme of growth of the genital group of organs. They are characterized by rather rapid increase in the later fetal months and this phase may extend into the first months of postnatal life. Thereafter there is little change in their absolute weights until the prepuberal period, when a stage of rapid growth begins which may extend through adolescence into early maturity. Most of the male generative organs increase over thirty-fold in absolute weight in the postnatal period, being relatively heavier in the adult than in the newborn. However, the relative size of the testes is probably greater at the close of the embryonic period than at any subsequent time.

The growth of the female genital organs.—All of the female genital organs grow rapidly in fetal life and are relatively large at birth. In postnatal life the growth of the vagina, uterine tubes, and epoöphoron seem to follow the usual course of the genital organs. The postnatal growth of the ovaries is extremely irregular, the weight being influenced by the development of the ovarian follicles, a process which is active in childhood as well as in maturity. The uterus in the neonatal period undergoes a marked reduction in weight and length—a change which has been attributed to the withdrawal of a placental hormone at the time of birth. After this initial decrease there is little change in the size of the organ until the prepuberal period when it again enters on a phase of active growth. The adult dimensions are probably attained by puberty in the majority of cases. The paroöphoron does not increase in size after birth.

THE CELOMIC CAVITY

The general plan of the development of the celom as a cavity formed between the splanchnic and somatic layers of the lateral mesoderm has been outlined in connection with the development of the mesoderm (p. 14). In the higher mammals, including man, the celom first makes its appearance in the region of the heart as irregular clefts in the mesoderm on either side of the body. These spaces unite with one another by the formation of a communication which crosses the midline of the body below the heart. The common cavity formed by this fusion is known as the pericardial celom (fig. 66). The pleuroperitoneal portion of the celom is formed by the caudal extension of the celom in the lateral plates of the mesoderm on either side of the body. The peritoneal celom communicates freely with the extraembryonic celom at the margins of the embryonic disk.

A single peritoneal cavity is formed from the two lateral ones as the embryo separates from the embryonic disk, and the ventral abdominal wall is formed. During this process the abdominal portion of the archenteron is enclosed between the right and left layers of splanchnic mesoderm which are reflected upon it from the dorsal and ventral abdominal walls. These layers remain dorsal to the archenteron as the dorsal mesentery. They also remain ventral to the archenteron from the end of the cavity to the umbilical region as the ventral mesentery. Caudal to the umbilicus, however, the ventral mesentery disappears and the right and left peritoneal cavities become confluent. The formation of the ventral body-walls also separates the peritoneal cavity from the extraembryonic celom, although an extraembryonic extension of the peritoneal cavity, the *umbilical celom*, remains in the root of the umbilical cord through the embryonic period.

The separation of the peritoneal, pericardial and pleural cavities.—The final divisions of the celom are separated by the formation of the diaphragm and the lateral walls of the middle mediastinum. As will be seen from figs. 66 and 67, the pericardial celom communicates with the peritoneal portion of the celom only by a pair of lateral passages, the *parietal canals*. These channels are separated in the midline by the anterior part of the yolk-stalk and by the vitelline-umbilical trunks which pass along this structure to reach the heart. The median partition formed by these structures with their covering of splanchnic mesoderm is called the *septum transversum* (figs. 67, 68) and is the fundament of the greater part of the diaphragm. In the later shifting of the septum transversum the cranial parts of the parietal canals become funnel-shaped spaces which are invaded by the lung-buds and which form the fundaments of the

pleural cavities. The pleural cavities become separated from the pericardial cavity by the *pleuropericardial membranes* which arise from the dorsal and lateral walls of the parietal cavity enclosing the phrenic nerve. The caudal openings of the pleural cavities into the peritoneal cavity become closed by the *pleuroperitoneal membranes* which arise from the dorsal margin of the septum transversum and extend dorsolaterally to unite with the dorsal abdominal wall (fig. 68).

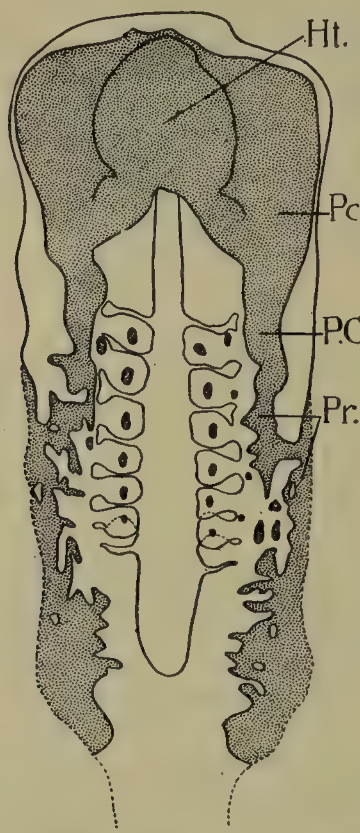


Fig. 66.—Dorsal View of a Reconstruction of an Embryo about 2 mm. Long, Showing the Extent and Divisions of the Embryonic Celom. (After Dandy.)
Ht., heart. P.c., pericardium. P.C., parietal (pleural) canal. Pr., peritoneal cavity.

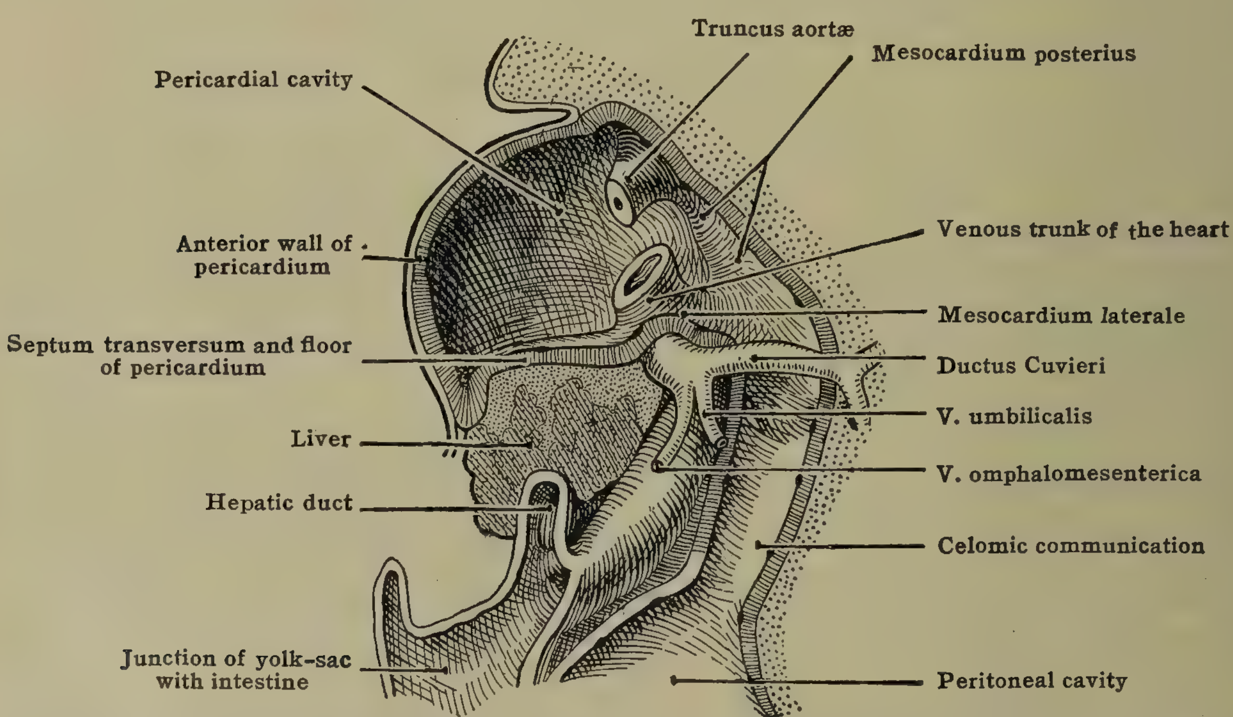


Fig. 67.—Sagittal Section Showing the Primitive Pericardial and Celomic Communication, Septum Transversum, Liver, etc., in a Human Embryo of 3 mm. (After Kollmann, from a model by His.)

The fundament of the diaphragm is formed in the upper cervical region and rapidly shifts caudally in the embryonic period. The musculature of the diaphragm is derived from premuscle masses which are formed in the cervical region.

The further history of the peritoneum is considered with its adult anatomy (p. 1232). The development of the tunica vaginalis is outlined in connection with the descent of the testes (p. 56). For relations to hernia, see p. 1273.

THE DUCTLESS GLANDS

The several varieties of ductless (endocrine) glands have little in common in their germ-layer origin, in the method of their early development, or in the course of their subsequent growth.

The thyroid gland.—The thyroid gland appears in embryos of the third week as a shallow median depression of the floor of the pharynx at the level of the first and second branchial pouches (fig. 42*A*). This outgrowth is converted into a solid mass which for a variable period remains connected with the pharynx by a solid stalk, but which eventually becomes detached and migrates into the region of the neck occupied by the definitive thyroid gland (cf. p. 1420). The solid mass is broken into a number of fenestrated epithelial plates from which the thyroid follicles are developed. Colloid appears in the thyroid follicles about the third fetal month. The disappearance of the colloid at birth and also the desquamation and partial destruction of the follicular epithelium have been described, but are of doubtful significance.

The thyroid assumes its bilobed form at an early stage (fig. 46). Its stalk may persist in part as the pyramidal lobe of the gland and portions of it occasionally remain as isolated thyroid masses in the upper cervical region or in the base of the tongue. The foramen cecum of the tongue presumably marks the point of its pharyngeal attachment.

At birth the thyroid weighs about 2 grams and its weight increases 10 to 15-fold in postnatal life. The postnatal changes in weight follow the course of the visceral group of organs.

The parathyoid glands.—The parenchyma of the parathyroid glands is formed from the thickened lateral walls of the dorsal extremities of the third and fourth pharyngeal pouches (fig. 46, Ep. III and Ep. IV). These masses become detached from the pouches in the second month and then migrate to their adult position. For further details, see p. 45.

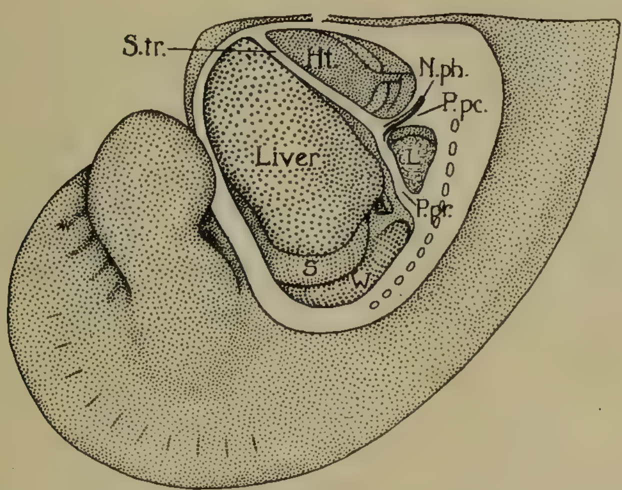


Fig. 68.—Lateral View of an Embryo 11 mm. Long, Showing the Pleuroperitoneal (P. pr.) and the Pleuropericardial Membranes (P. pc.). (After Mall.)

Ht., heart. L., lung. N.ph., phrenic nerve. S., stomach. S.tr., septum transversum. W, Wolffian body.

The pineal body.—The pineal body (epiphysis cerebri) arises in the fifth week as a diverticulum from the caudal extremity of the roof of the diencephalon (fig. 677). The distal portion of this pouch becomes the body of the epiphysis. The proximal portion remains as the stalk. Ingrowths of connective tissue from the pia mater later divide the body of the organ into lobules. At birth the structure is relatively large and by 12 years it has obtained its full size. Structural involution of the pineal body begins about the sixth or seventh year and is practically complete by puberty.

The hypophysis cerebri.—The anterior or glandular lobe of the hypophysis cerebri (pituitary body) is formed from the extremity of Rathke's pouch from the oral sinus, while the posterior or neural lobe is formed from a part of the infundibular depression in the floor of the forebrain. These two structures come in contact in the fourth week. The extremity of Rathke's pouch soon becomes detached and partially incloses the neural portion. In the second month the walls of Rathke's pouch are differentiated into cords and tubules which form the trabeculæ and acini of the hypophyseal parenchyma and obliterate the greater part of its central cavity. The infundibular portion undergoes less extensive changes. The greater part of the stalk of Rathke's pouch usually disappears but a portion of its lower part probably forms the *pharyngeal hypophysis*, a constant glandular mass resembling the anterior lobe of the hypophysis and located in the region of the pharyngeal tonsil (see fig. 1164).

The hypophysis weighs about 0.12 grams in the newborn and its mass increases 5 or 6 times between birth and maturity. The curve of the postnatal increase in the absolute weight of the hypophysis is shown in fig. 28. It is characterized by a rapid rise in infancy and early childhood and a slow but steady growth thereafter to maturity.

The thymus.—While a part of the thymus is of branchial origin and the organ is commonly classed with the ductless glands, both its finer structure and the course of its growth indicate a close relationship with the lymphoid organs. In man the thymus first appears as a ventrally and medially directed downgrowth of the walls of the third pair of branchial pouches (fig. 46). Usually the lower portion of the third pouch is converted into a long epithelial tube the lumen of which is soon obliterated. Its walls are reduced to a reticular network whose meshes are invaded by numerous lymphocytes. The thymic (Hassall's) corpuscles are formed by the secondary aggregation of reticular cells of entodermal origin. For further details, see p. 1424.

In its growth the thymus follows the typical course of a lymphoid organ (fig. 28). At birth it forms about 0.42 per cent. of the body. This relative weight drops to 0.12 per cent. in later childhood, 0.09 per cent. in adolescence and 0.05 to 0.02 per cent. in early maturity. The absolute weight rises from about 13 grams at birth to about 38 grams at puberty and then declines. The weight of the thymus is at all periods subject to great individual variation. After birth the parenchyma forms a constantly decreasing proportion of the thymus.

In the fetus the thymus occupies the anterior part of the superior mediastinum and often a little of the lower cervical region. Its thoracic portion is usually widely expanded coming in contact with the anterior chest wall over a considerable area. With the establishment of respiration at birth the gland is pressed between the expanding medial borders of the lungs and moulded into the more elongate form which is characteristic of infancy and childhood (figs. 1152, 1153).

The chromaffin bodies.—The cells of the various masses of chromaffin tissue (aortic bodies, carotid bodies, cardiac bodies, etc.) have their primary origin in the neural crest (see p. 827) and form a part of the stream of cells which migrate to the ventral side of the vertebral column. These walls give rise both to cells of the sympathetic ganglia and to the chromaffin cells, the distinction between the two becoming evident in the latter part of the second month. The chromaffin bodies form prominent structures in the fetus and newborn, the largest being the aortic bodies which are located on either side of the abdominal aorta (fig. 1160). After infancy they undergo partial involution.

The suprarenal glands.—The suprarenal glands have a dual origin, the medulla being formed of chromaffin tissue (vide supra) and the cortex from the lining of the celom. The cortex appears in the fourth week as buds of celomic epithelium which project from the root of the mesentery into the loose mesenchyma. These form a compact isolated mass of epithelial cords lying on either side of the aorta. The medulla is formed by the migration of chromaffin cells into the center of the mass of cortex. This process begins in the second month and continues through the greater part of the fetal period. For further details, see p. 1428.

The suprarenals follow a peculiar growth-cycle (fig. 28). Growing rapidly in fetal life they acquire an average weight of about 7 grams at birth. During the period of the newborn they undergo a rapid decrease to about one-third of their natal weight. There is little increase in weight in infancy or early childhood but apparently a rapid phase of growth in middle or later childhood and a slower gain thereafter. The relative weight of the suprarenals is approximately 0.46 per cent. of the body-weight from the fourth fetal month until birth. Following the postnatal decrease it drops to about 0.15 per cent., rising again to about 0.2 per cent. in the adult. The neonatal decrease of the suprarenals is caused by the involution of the middle and inner cortical zones, which are not regenerated from the outer zone until after the middle of the first period of childhood.

THE SKIN AND APPENDAGES

The skin.—The epidermal portion of the skin is formed from the surface ectoderm of the embryo while the dermis is derived from the underlying mesenchyma. In an early stage the epidermis consists of two layers, a surface layer of flattened cells, the periderm, and a basal layer of columnar germinative cells. The layers of the epidermis recognizable in the adult skin do not appear until about the middle of the of fetal life. The dermis becomes distinguishable from the underlying tela subcutanea in the third month but its division into reticular and papillary layers does not occur until late in fetal life. The hair-follicles are formed from solid downgrowths of the germinal layer of the epidermis. The first appear at the close of the second month but the general hair-coat does not form before the fourth month. New hair-follicles are formed until birth and probably for some time thereafter. The first hairs or fetal lanugo are soon shed, the process beginning before birth, and a second shedding of the infantile hair, including the hair of the eyelashes and crown, takes place about the end of the first year. After this time there is a constant hair-change but no definite periods of shedding can be recognized. The sebaceous glands arise as lateral outgrowths of the developing hair-follicles. The sudoriferous glands (sweat glands) are formed as solid downgrowth of the epithelium in the fourth or fifth months. All of the sudoriferous glands are formed in fetal life. For further details on the development of the skin, see pp. 71, 74.

The areas occupied by the nails are marked out on the dorsal surface of the digits in the early part of the third month. The epithelium at the proximal margin of the nail-area is invaginated forming the proximal or posterior nail-fold which projects into dermal mesenchyma, and smaller folds are formed at the lateral margins of the nails. The middle cells of the invagination form the horny layer of the nail and the lower cells form the germinative layer. The upper cells or periderm form a superficial covering, the *eponychium*, which is later thrown off except for a narrow proximal margin which persists through life. The dermal mesenchyma underlying the epithelial nail forms the nail-bed. For the growth of the nails, see p. 75.

The mammary glands.—In the fourth week a thickening of the surface ectoderm, the mammary line, is formed on either side of the trunk extending from the anterior to the posterior limb-bud. The portion of the mammary line in the region of the future mammary gland forms a solid mass of epithelium, the mammary hillock. The lactiferous ducts develop as outgrowths from the basal portion of the mammary hillock and the minor ducts and alveoli of the gland are formed through the further growth and subdivision of the lactiferous ducts. For further details, see p. 84.

Soon after birth a slight secretion (witch's milk) is formed in the lactiferous ducts of the mammary glands of both male and female infants. Ordinarily this secretion ceases by the close of the third postnatal week. There is little change in the structure of the mammary gland in childhood but in the latter part of the prepuberal period in the female there is a rapid growth of the gland parenchyma together with an increase in the adipose and elastic tissue.

References on developmental anatomy.—*Embryology:* Keibel and Mall, Human Embryology (2 vols.); McMurrich, Development of the Human Body; Bryce, Quain's Anatomy, 11th ed., vol 1; Keith, Human Embryology and Morphology; Broman, Normale und abnorme Entwicklung des Menschen. *Growth:* Minot, Age, Growth and Death; Jackson, Amer. Jour. Anat., vol. 9; Anat. Record, vol 3; Retzius, Biol. Untersuch., vol. 11; Dufestel La Croissance; Scammon, The Measurement of the Body in Childhood, The Measurement of Man. *Postnatal Development:* Bardeen, Carnegie Contributions to Embryology, No. 49: Ballantyne, Introduction to the Diseases of Infancy; Symington, The Topographical Anatomy of the Child; Scammon, Outline of the Anatomy of the Infant and Child, Abt's System of Pediatrics, vol. 1; Peter, Wetzel und Heiderich, Handbuch der Anatomie des Kindes; Gundobin, Die Besonderheiten des Kindesalters.

SECTION II

THE SKIN AND MAMMARY GLANDS

By CHARLES R. STOCKARD, M.D., Ph.D., Sc.D.

PROFESSOR OF ANATOMY IN THE CORNELL UNIVERSITY MEDICAL COLLEGE

THE SKIN

THE bodies of all animals present a modified surface layer enclosing and protecting their more delicate inner parts. The existence of the individual largely depends upon the integrity of this limiting envelope and through it exchanges between the environment and the individual must take place. In the lowest animals such a modified surface layer is known as the ectoplasm, perisarc, theca, coat, etc. while in man and higher animals it is the skin. When an area of skin is destroyed the fluids of the body flow out freely and the elements of the environment invade the exposed parts. If the destruction of skin be too extensive, the individual is unable to maintain itself and actually disintegrates into the environment. On the basis of such a conception, the skin becomes one of the most important and complicated organs of the body, both as to structure and as to functions.

The human skin, or **common integument** [integumentum commune], covering the entire surface of the body and blending with the epithelial lining of the inner tubes at their orifices is so constructed as to maintain wide physical and chemical differences between the internal structures on the one side and the external environment on the other. At the same time the skin permits exchanges of fluids and, through special modifications, supplies all sensory communication and appreciation of the surrounding world.

The *primary function of the skin* is protective, but in addition and in connection with this function it supplies the mechanism for regulating or maintaining the body-temperature, the sensory apparatus for receiving impressions, widely distributed glands for the secretion of sweat and sebum, local glands secreting waxes and the milk-glands on which the existence of the race has depended. The skin also possesses slight powers of excretion, respiration and absorption. Its outer layer further gives rise to the hair and nails which are protective in nature.

The receptor portions of the organs of special sense are developmental modifications of the embryonic skin. Thus all means of acquaintance with the world about must depend primarily upon skin-organs. And finally the stimuli received by the organs of special sense are conveyed to the central nervous system, the brain and spinal cord, which in evolution and embryonic development represent a modified portion of the embryonic skin or ectoderm. The skin of animals, broadly speaking, is the protective and sensory sheath enclosing the body.

Layers.—The skin consists of two principal layers. The outer layer, **epidermis** or scarf-skin, contains no vessels and is derived from the ectoderm. This is truly the protecting layer and from modifications of it the hair, nails and skin-glands as protective organs are derived, although these may later extend deep into the underlying tissues (fig. 69). Immediately below this outer epithelial epidermis lies the **corium** (cutis, derma) or connective tissue skin. This is richly supplied with blood and lymph-vessels and from these the epidermis is nourished. Sensory end-organs and nerves are also very abundant in the corium. Further details of structure of the corium and its relation to the surface patterns of the epidermis

are described later. The corium passes imperceptibly into a deeper, looser connective tissue layer, the **tela subcutanea** or superficial fascia, which serves to connect more or less loosely the corium or skin proper to the deep fascia or underlying tissues.

Thickness.—In general the skin on the more exposed dorsal or extensor surfaces of the body and extremities is thicker and less sensitive than on the ventral or flexor surfaces, yet on the palms and soles it is thicker than in any dorsal region except the neck and interscapular back region. At the same time the palm and sole skin is highly sensitive. The average thickness is from 1 to 2 mm.; but over the tympanic membrane and eyelids it may be less than 0.5 mm., while on the back it may reach almost 5 mm. in thickness.

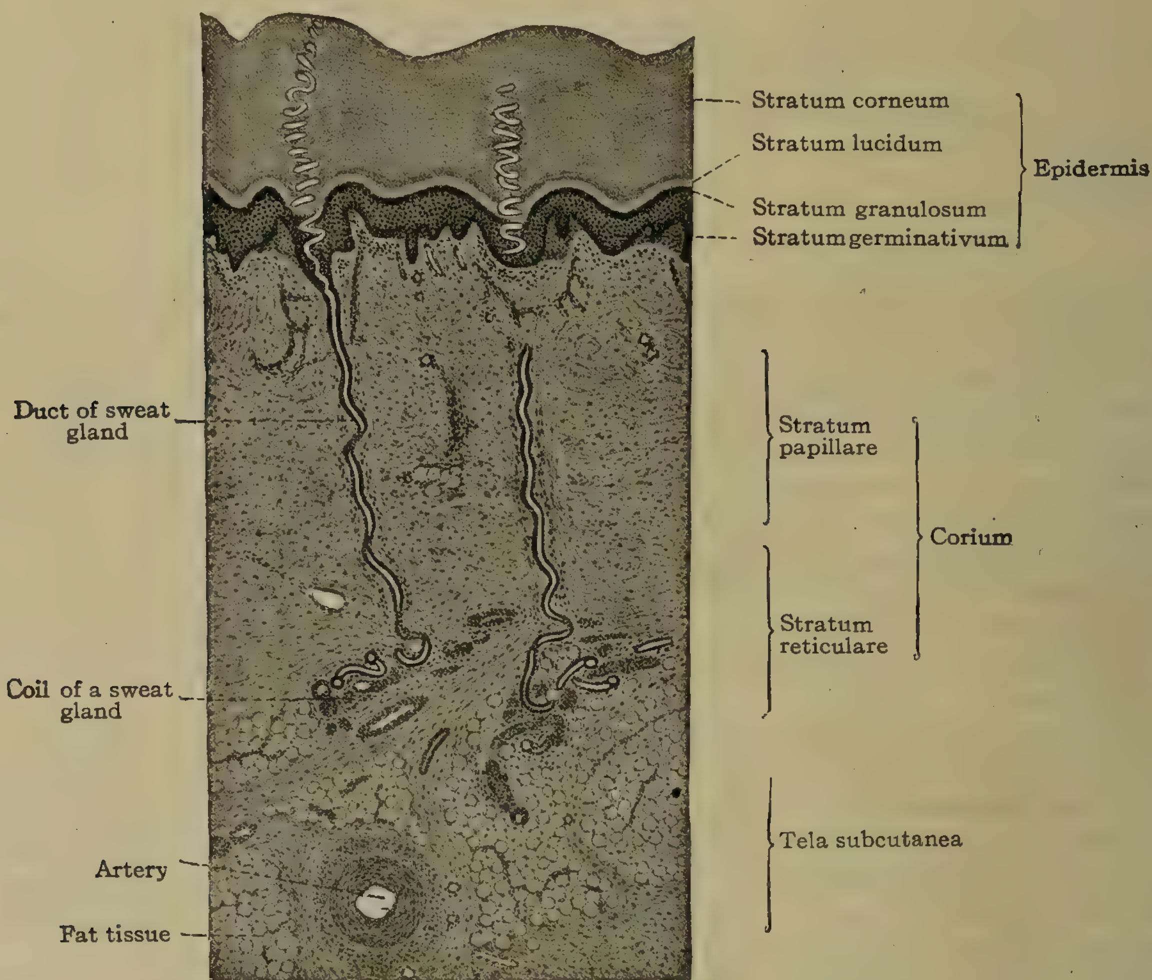


FIG. 69.—VERTICAL SECTION OF THE SOLE OF THE FOOT OF AN ADULT. ×25. (Lewis and Stöhr.)

The **color** of the dorsal skin and also of the dorsal hair, which includes the head-hair, is darker than the ventral skin and ventral hair, such as the beard. An individual may have black crown hair and a lighter or red beard but rarely, if ever, the reverse arrangement.

The color of the skin has considerable general significance and the races of mankind are roughly separated on such a basis into Caucasian or white, Mongolian or yellow, Malay or brown, Indian or red, Ethiopian or black. The hair and eye-color are very dark brown or black in all races except the white. This race of mankind alone shows golden or flaxen hair and blue eyes. The color of the skin varies with the amount of melanin pigment present in the deepest layers of the epidermis, being black in the negro where it is most abundant and decreasing in the different races to the scantest amount in the blonde Caucasian. The blood in the cutaneous vessels also affects the color of the skin, giving the pinkish complexion to the albino and blonde; in the brunette often producing a dark color below the eyes and about the lips. The influence of the blood on skin-color is readily appreciated by noting the blueness of the lips and fingers when very cold, the scarlet flush of anger, and the pallidness of fear.

The skin of blondes on exposure to strong sunlight or cutting winds becomes red, and usually shows later irregular pigmented spots or *freckles*. Darker individuals become uniformly pigmented or *tanned* on exposure. Both tan and freckles are more or less transient and generally disappear when the body is no longer exposed.

Complete absence of pigment from the skin gives the condition known as albinism. Partial absence of pigment or white spots at times occur; if congenital the condition is known as leukoderma, if acquired it is called vitiligo.

Young children of darker races, e. g., Japanese and Chinese, occasionally present a bluish pigmentation known as 'blue Mongolian spots' of the skin over the sacral, coccygeal and ischial regions. This also occurs rarely in white children. The appearance is due to the presence in the corium of spindle-shaped or stellate pigment cells, chromatophores, resembling the pigment cells of the choroid layer of the eyeball. Similar cells are found distributed generally in the corium of monkeys' skin and their occurrence in man has been thought to be of possible phylogenetic significance.

The **elasticity and strength** of the skin are due to the corium, and this layer when tanned or cured gives leather. The skin is more elastic or stretchable over certain regions than others and this property varies in different individuals. The skin is more lightly attached to underlying parts in certain regions, and is here very movable. Its elasticity is well shown under these conditions. If an arm be firmly grasped with the hand it will be found that the skin may move up and down over the underlying muscles as if it were a sleeve. The degree of mobility of the skin is appreciated in surgical operations.

The infinite folds and irregularities on the surface of the skin along with its loose under attachment and elastic nature render it *distensible* to a considerable

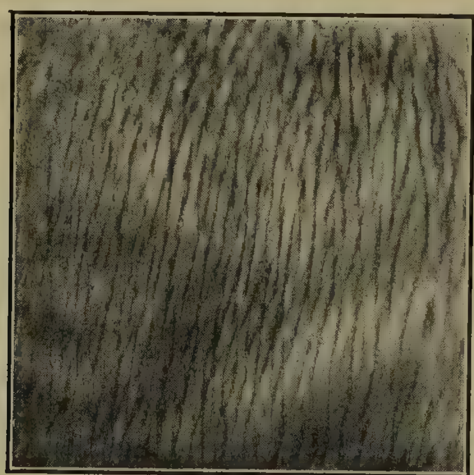


FIG. 70.—FROM A PHOTOGRAPH OF THE SUPERFICIAL FURROWS ON THE BACK OF THE HAND. (× 1.)

extent. Roughly speaking, the skin of an individual is sufficiently extensive to cover a body of much larger size. Under certain conditions a leg, for example, may swell to double the usual size but the skin stretches to cover it. The skin over such a swollen part is smoother and more glistening than usual, since the minute folds and patterns are obliterated or smoothed out by the expansion. When increase in size is gradual such as normally occurs during pregnancy the skin area may be stretched to four or five times its previous extent. In these cases the skin is often injured and short parallel, slightly reddish streaks occur which after reduction in size become the silvery white lines, or striæ seen in the abdominal skin of a woman who has borne children.

The **surface-area** of the skin corresponds approximately to the surface of the body and naturally varies with the size of the individual. It has been variously estimated at from 10,500 to 18,700 sq. cm. for a medium-sized adult male. For the area in children, see p. 25.

Folds and furrows.—The skin presents elevations and depressions due to the fact that it follows more or less closely the contour of the underlying structures, but in addition to this it possesses certain elevations and depressions peculiarly its own. These are found on the skin in various parts of the body. Some are permanent, others only temporary. Large permanent **folds** which include all the layers of the skin are seen, as the prepuce of the penis and the pudendal labia. The most marked depression is the **umbilical fovea.** Other conspicuous folds and furrows are seen in the neighborhood of the lips and eyelids. Certain other less permanent folds and furrows are produced by the action of the joints, **joint-furrows,** and of the muscles of expression of the skin, **'wrinkles.'**

Other minute folds and furrows which affect only the epidermis and the superficial layer of the corium are seen in various places. These are represented by the numerous fine superficial creases, unassociated with elevations, forming rhomboidal and triangular figures over almost the whole of the surface of the skin (figs. 72, 73). They are especially numerous on the dorsal surface of the hands (fig. 70). The fine curvilinear ridges [cristæ cutis] with inter-

vening furrows [sulci cutis] arranged in parallel lines in groups on the flexor surface of the hands and feet are also of this type. They form patterns characteristic for each individual and permanent throughout life.

Among the projections are the large permanent folds of skin such as the **labia pudendi**, the **preputium penis**, the **frenula preputii clitoridis**, and **labiorum pudendi**, and less marked ridges as the median **raphe** of the perineum, scrotum and penis, and the **tuberculum labii superioris.** Of a somewhat different sort are the **touch pads** [toruli tactiles] of the hands and feet. Among the larger depressions in addition to the **umbilical fovea**, is the **coccygeal foveola**, and a considerable number of well-marked permanent furrows found in various places, such as the **nasolabial** and **mentolabial sulci**, the **philtrum labii superioris**, the **infraorbital sulcus**, and the **infraorbital** and **supraorbital palpebral sulci.** There are numerous **articular furrows** on both the flexor and extensor surfaces produced by the action of the joints, and associated with intervening folds of skin, particularly on the dorsal surface. They are especially noticeable on the hands.

Variations of the **palmar joint-sulci** are due to variations in opposition of the thumb and the use of the fingers and the relative arrangement of the thumb and fingers and joints. They are of importance as indicating topographically the position of the joints, their relation to which has been made clearer by means of the X-ray. Two or three of these are seen on the palmar surface of the wrist; two lower down and usually close together, and one less well marked, a little higher upon the forearm (fig. 74). None of these corresponds exactly to the wrist-joint. The lowest 'precisely crosses the, arch of the os magnum in the line of the third metacarpal bone' (Tillaux), and is not quite 1.8 cm. (¾ in.) below the arch of the wrist-joint. It is about 1.2 cm. (½ in.) above the carpometacarpal joint line, and indicates very fairly the upper border of the transverse carpal (anterior annular) ligament.

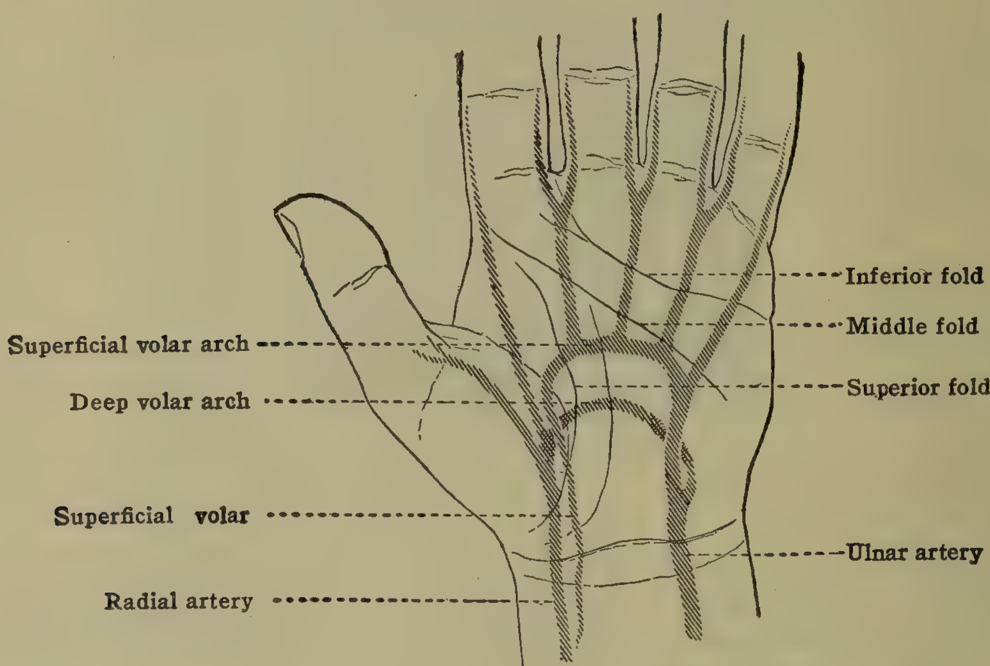


FIG. 71.—RELATION OF THE FOLDS OF THE PALM TO THE VOLAR ARCHES. (Modified from Tillaux.)

Of the many creases in the skin of the palm, three require especial notice. The first starts at the wrist, between the thenar and hypothenar eminences, and, marking off the former eminence from the palm, ends at the lateral border of the hand and at the base of the index-finger. The second fold is slightly marked. It starts from the lateral border of the hand, where the first fold ends. It runs obliquely medially across the palm, with a marked inclination toward the wrist, and ends at the lateral limit of the hypothenar eminence. The third, lowest, and best marked of the folds starts from the little elevation opposite the cleft between the index and middle fingers, and runs nearly transversely to the ulnar border of the hand, crossing the hypothenar eminence at the upper end of its lower fourth. The first fold is produced by the adduction of the thumb; the second, mainly by the bending simultaneously of the metacarpophalangeal joints of the first and second fingers; and the third by the flexion of the three medial fingers. The second fold, as it crosses the third metacarpal bone, about corresponds to the lowest part of the superficial volar arch. The third fold crosses the necks of the metacarpal bones, and indicates pretty nearly the upper limits of the synovial sheaths for the flexor tendons of the three lateral fingers. A little way below this fold, the palmar aponeurosis breaks up into its four slips, and midway between the fold and the webs of the fingers lie the metacarpophalangeal joints. Of the transverse folds across the fronts of the fingers, corresponding to the metacarpophalangeal and interphalangeal joints, the highest is placed nearly 18 mm. (¾ in.) below its corresponding joint. The middle folds are multiple for all the fingers, and are exactly opposite to the first interphalangeal joints. The distal creases are single, and are placed a little above the corresponding joints. There are two single creases on the thumb corresponding to the two joints, the higher crossing the metacarpophalangeal joint obliquely. The free edge of the web of the fingers, measured from the palmar surface, is about 1.8 cm. (¾ in.) from the metacarpophalangeal joints. (Treves.)

The folds and furrows brought about through the action of the skin muscles run at right angles to the muscle fibers and are more or less transitory at first but become more permanent through repeated or long-continued action. They are represented by the **wrinkles** of the fore-

head, the lines of expression of the face, the transverse wrinkles of the scrotum and the radiating folds around the anus. The more superficial **cristæ cutis** and **sulci cutis** are arranged in groups within and around the touch pads, on the volar surface of the hands and the plantar surface of the feet (figs. 72, 73). The cristæ of each group are parallel. They correspond to the rows of papillæ of the corium. Since the patterns of the cristæ and sulci are characteristic for the individual, and permanent from youth to old age, they have been classified in a number of types and are important as a means of identification.

There are also a great number of minute depressions which mark the points where the hairs pierce the surface and where the glands open. These are popularly known as **pores**. Under the influence of cold and emotion the hair muscles contract and cause a slight elevation of the

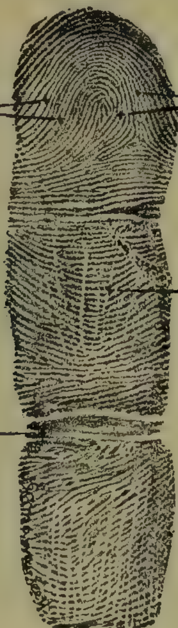


Fig. 72.—Finger Print (Natural Size) Showing Cristæ and Sulci.

Fig. 73.—Diagram Showing the Arrangement of the Principal Cristæ of the Thumb

skin at the point where the hair emerges. This roughened appearance of the skin is generally known as 'goose-flesh.'

A complex wrinkling of the skin appears in old age, or in the course of exhausting diseases, as a result of loss of elasticity and from absorption of the cutaneous and subcutaneous fat. Rounded depressions called **dimples** are produced by the attachment of muscle-fibers to the deep surface of the skin, as on the chin and cheek, and are made more evident by the contraction of these fibers. Others are produced by the attachment of the skin by fibrous bands to bony eminences, as the elbow, shoulder, vertebræ, and posterior iliac spines. They are best seen when the subcutaneous adipose tissue is well developed.

Structure of the corium.—The superficial layer of the corium is of fine, close texture, free from fat, and forms a multitude of eminences called **papillæ**

Fig. 74.—From a Photograph of the Skin Ridges and Papillæ of the Palm of the Hand. Epithelium Completely Removed Above; Partly Removed Below. (× 5.)

corii (figs. 74, 75) which project into corresponding depressions on the deep surface of the epidermis. For this reason this part of the corium although but indistinctly separated from the deeper layer is called the **corpus papillare.**

Some of the papillæ contain vessels, others include nerves, hence they are known as vascular or tactile papilæ. They are very closely set, varying considerably in number in different parts of the body from 36 to 136 to a square millimeter. It has been estimated that there are about 150 million papillæ on the whole surface.

The deeper layer of the corium, the **tunica propria** (stratum reticulare), is composed of coarse loose bands of fibrous tissue intermingled with small fat lobules. The fibrous and elastic tissue is arranged for the most part in intercrossing bundles nearly parallel with the surface of the skin.

The bundles running in some directions are usually more strongly developed and more numerous than those in others, but the direction of the strongly developed bundles varies in different parts of the body. In general those are best developed which have a direction parallel with the usual lines of tension of the skin, hence it results that wounds of the skin tend to gape most at right angles to these lines. The bundles take a direction nearly at right angles to the long axis of the limbs, and on the trunk run obliquely, caudally, and laterally from the spine (figs. 76, 77). On the scalp, forehead, chin, and epigastrium, equally strong bundles cross in all directions, and a round wound, instead of being linear as elsewhere, appears as a ragged or triangular hole. The arrangement of the connective tissue bundles influences the arrangement of the blood-vessels of the skin.

The quantity of *subcutaneous fat* varies considerably in different parts of the body. It is, for instance, entirely absent in the penis, scrotum, and eyelids. When it is abundant, the subcutaneous layer is known as the *panniculus adiposus.*

In some situations, as in the caudal portion of the abdomen and in the perineum, the connective tissue is so arranged that the panniculus may be divided into layers, so that a superficial and a deep layer of the superficial fascia may be recognized. The fat is well developed over the nates, volar surface of the hands and plantar surface of the feet, where it serves as pads or cushions; in the scalp it appears as a single uniform lobulated layer between the corium and the aponeurosis of the epicranial muscle; and on other parts of the surface it is

Fig. 75.—Papillæ of the Corium after Maceration. From Retouched Photograph Epithelium Removed by Maceration. (× 25.)

somewhat unequally distributed and shows a tendency to accumulate in apparent disproportion in some localities, as on the abdomen, over the symphysis pubis, about the mammæ in females, etc. Everywhere except on the scalp it may undergo rapid and visible increase or decrease under the influence of change of nutrition.

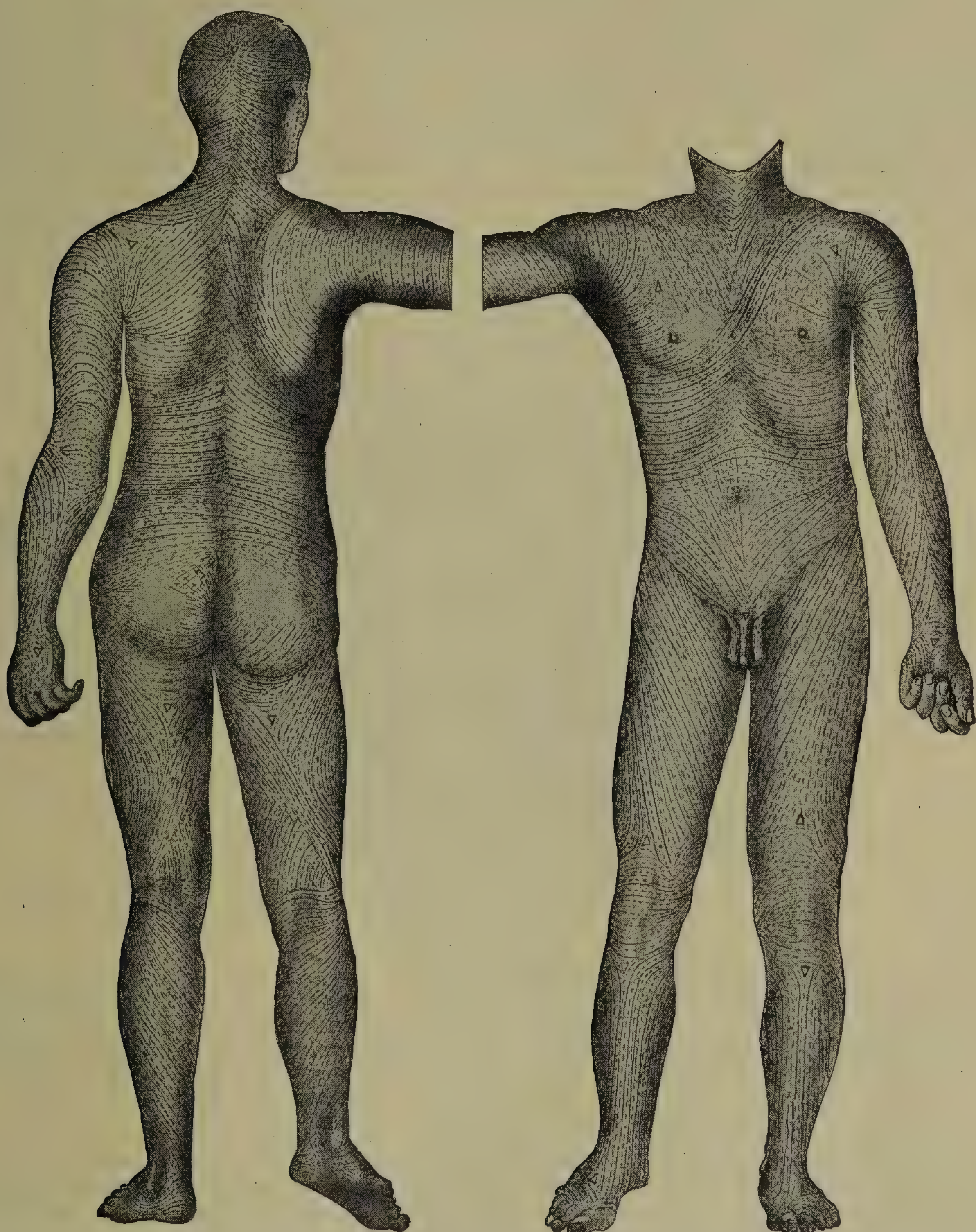
The scalp.—The importance of the scalp is best seen from an examination of its layers (fig. 78). These are—(1) skin; (2) subcutaneous fat and fibrous tissue; (3) the epicranius (occipitofrontalis) muscle and aponeurosis; (4) the subaponeurotic layer of connective tissue; (5) the pericranium.

The first three layers are connected and move together. The thick skin, supported by the dense fibrous subcutaneous layer and epicranial aponeurosis, is well adapted to protect the underlying cranium from the effects of trauma, and in this connection the mobility of the first three layers on the subaponeurotic areolar tissue is important. A scalp wound does not gape widely unless it involves the epicranial aponeurosis, in which case it involves the subjacent 'dangerous area' of the scalp, so-called because pus in this layer may spread widely underneath the scalp and even give meningeal infection by spreading through the diploic or emissary veins. In the process of scalping (whether performed by the knife or by the hair being caught in machinery), separation takes place at this subaponeurotic layer which is loose, delicate and devoid of fat. The numerous sebaceous glands frequently give rise to retention cysts in the scalp.

Skin of the leg.—The proneness of the skin to dermatitis in the lower third of the medial and front aspect of the leg as a result of varicose veins is well known. The close contiguity of the periosteum to the skin here accounts for the difficulty in healing chronic ulcers whose callous base has become fixed to the periosteum, and the frequency with which the upper fragment of a fractured tibia perforates the skin.

Skin-muscles.—In the subcutaneous tela and the corium muscle fibers are found in larger or smaller groups. These are of two kinds, striated and unstriated (smooth) fibers.

Subcutaneous planes of *striated muscle* are relatively scanty in man when compared with the great panniculus carnosus of the lower mammalia. This is mainly represented by the platysma in the neck which has both its origin and part of its insertion in the skin. Closely



Figs. 76 and 77.—Diagrams Showing the Arrangement of the Connective Tissue Bundles of the Skin on the Anterior and Posterior Surfaces of the Body. (After Langer.)

associated with this are the muscles of expression of the face and the palmaris brevis muscle which have one end terminating in the deep surface of the skin. The epicranial muscle is also considered by some to belong to this group.

Smooth muscle fibers are scattered through the corium collected into bundles in the neighborhood of the sebaceous glands and the hairs. They are described in connection with these latter (p. 73). In addition to these muscles are found in the scrotum as the dartos, in the perineum, around the anus, and beneath the papilla and areola of the mammary gland.

Bursæ mucosæ subcutaneæ.—In some situations where the integument is exposed to repeated friction over subjacent bones or other hard structures its movements are facilitated by the development of sac-like interspaces in the sub-

cutaneous tissue, the **subcutaneous mucous bursæ.** They are similar to the more deeply placed bursæ which are found in relation with muscle tendons. Their occurrence is quite variable. In some individuals they are numerous, in others very few. They have a considerable practical importance from the fact that they may become greatly swollen.

The most constant subcutaneous mucous bursæ are the following:

Bursa anguli mandibulæ; B. subcutanea prementalis, between the periosteum and soft parts over the tip of the chin; **B. subcutanea prominentiæ laryngeæ** over the ventral prominence of the thyroid cartilage of the larynx (often found in the male); **B. subcutanea acromialis,** between the acromion and the skin; **B. subcutanea olecrani,** beneath the skin on the dorsal surface of the olecranon; **B. subcutanea epicondyli humeri lateralis,** found beneath the skin over the lateral epicondyle of the humerus (occasional); **B. subcutanea epicondyli humeri medialis,** between the skin and the medial epicondyle of the humerus (more frequent); **B. subcutanea metacarpophalangea dorsalis,** between the skin and the dorsal side of the metacarpophalangeal joints (occasional especially the fifth); **B. subcutanea digitorum dorsalis,** beneath the skin over the proximal finger-joints; and rarely over the distal finger-joints; **B. subcutanea trochanterica,** between the skin and the great trochanter of the femur; **B. subcutanea præpatellaris,** beneath the skin covering the caudal half of the patella; **B. subcutanea infrapatellaris,** between the skin and the cephalic end of the ligamentum patellæ; **B. subcutanea tuberositatis tibiæ** ventral to

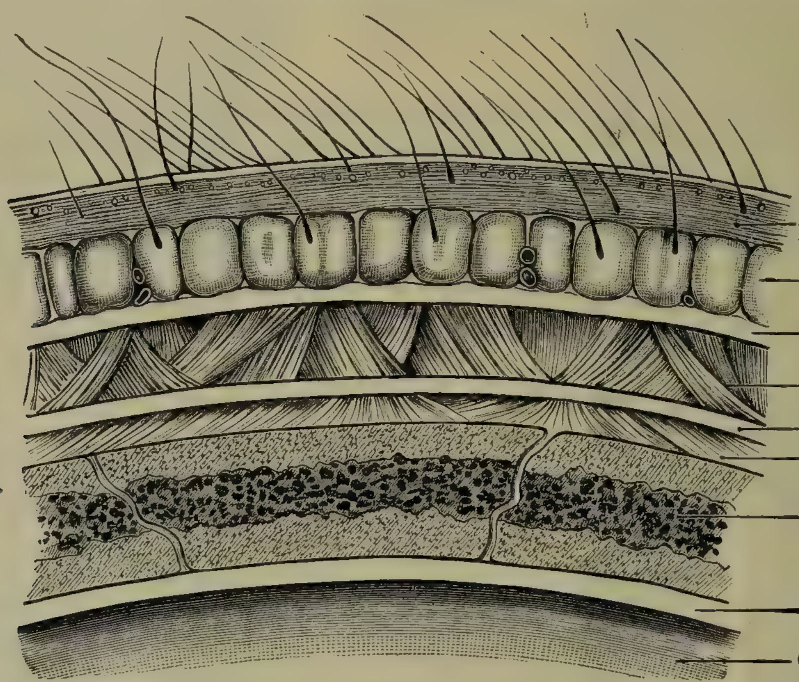


FIG. 78.—DIAGRAM OF SECTION THROUGH THE SCALP AND CRANIAL WALL. (Tillaux.)

the tibial tuberosity, covered by skin or by skin and crural fascia; **B. subcutanea malleoli lateralis,** between the skin and the point of the lateral malleolus; **B. subcutanea malleoli medialis,** between the skin and medial malleolus; **B. subcutanea calcanea,** in the sole of the foot between the skin and the plantar surface of the calcaneum; **B. subcutanea sacralis,** beneath the skin which covers the lumbodorsal fascia and the region between the sacrum and coccyx.

Blood-vessels of the skin.—The corium and subcutaneous tela are richly supplied with blood-vessels. The cutaneous arteries are as a rule perforating branches from the deeper arteries supplying the muscles and underlying tissue of the region. There are, however, a number of arteries directly supplying the skin, though all of these are small except some of the arteries of the scalp. The skin of the trunk is supplied by branches from the intercostal arteries in a metameric fashion. The areas supplied by certain groups of vessels and the directions which the arteries follow in the skin show much regularity.

The arteries enter the corium from the underlying fascia and there break up into a network of minute vessels supplying the hair-follicles, glands and all cutaneous tissues. The veins of the skin usually accompany the arteries and lead back to the larger underlying vessels. Other veins of considerable size, particularly noticeable on the extremities run in the fascia immediately beneath the skin and independent of the arteries. These large vessels are described in the general section on the veins (p. 739).

Lymphatics of the skin.—The cutaneous lymphatic vessels are found in the skin of all parts of the body but are more abundant in certain places. The lymph-vessels of the skin are developmentally among the first lymph-vessels to appear. The larger vessels and glands of the subcutaneous tela will be found described in connection with the general lymphatic system Section VII. In the corium the lymphatics from the papillæ form a **subpapillary network** which opens into a **subcutaneous plexus** connected with the larger lymph-vessels of the subcutaneous tela. There are no lymph-vessels in the epidermis, but this is supposed to be supplied by the lymph in the tissue spaces between the cells and these spaces connect indirectly with the lymph-vessels.

The nerves.—The skin has one of the richest nerve supplies of the body. The nerves are in greater proportion in those parts which are most sensitive. The various skin-areas are supplied

by specific (segmental) nerves with much greater regularity than in the case of the arteries. The nerves supplying adjoining areas overlap so that there is an intermediate space supplied by both. The variations consist in an extension of one area and a corresponding contraction of an adjoining area. The distribution of the nerves in the skin shows, especially on the trunk and neck, a marked metameric arrangement (see fig. 850).

With the exception of the nerves to the sudoriferous and sebaceous glands, the skin-muscles and blood-vessels, all the cutaneous nerves are sensory. They have diverse modes of termination. Some end in the subcutaneous tela; others, the greater number, terminate in the corium; still others extend to the epidermis. Some of the sensory organs of the skin are shown in fig. 79.

Development of the skin.—The ectoderm of the embryo is at first a single layer of cells but it soon becomes two-layered, the outer layer being very different in form from the uniformly regular underlying cells. This outer layer, *epitrichium or periderm,* is present only in the embryo and fetus and is cast off. The cells of the deeper layer of ectoderm multiply and form a many-celled stratified epithelium. The ectodermal cells also give rise to the hairs, nails, various types of skin-glands, and enamel-organs of the teeth.

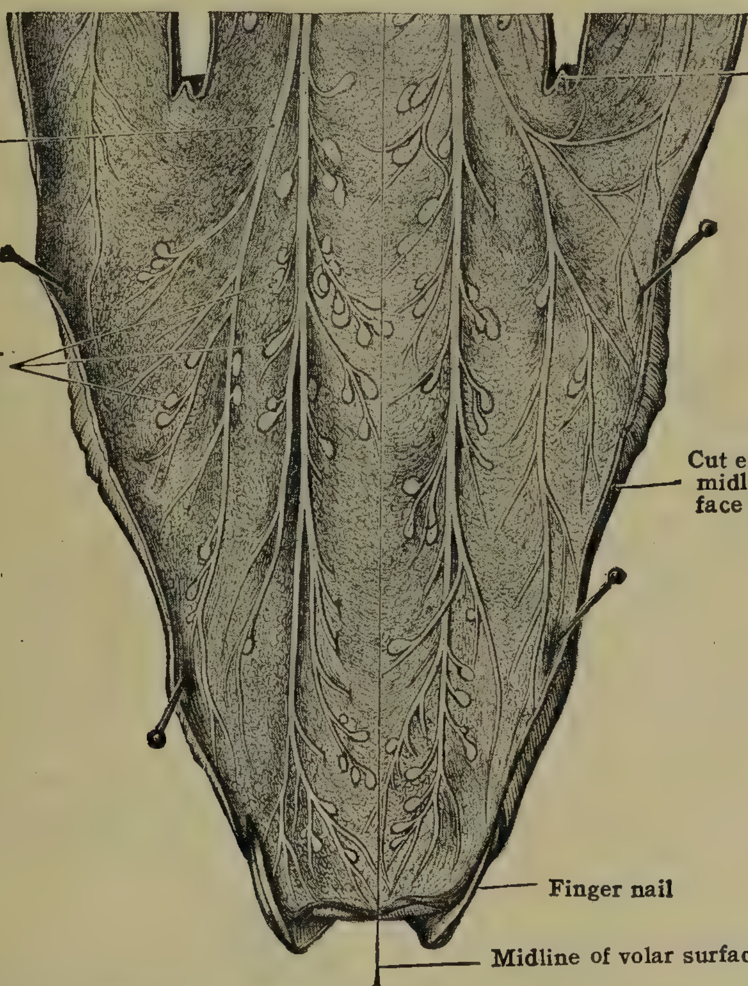


Fig. 79.—Cutaneous Nerves of the Middle Finger and Lamellous (Pacinian) Corpuscles. (From Toldt's Atlas.)

The stratified epithelium becomes differentiated into several more or less clearly marked layers due to changes taking place in the cells as they near its outer surface. The lower cells continue to multiply throughout life as the *stratum germinativum.* Cells above this stratum deposit granules in their protoplasm and form the *stratum granulosum.* These cells on reaching a more superficial position become cornified and constitute the *stratum corneum.* This cornified layer is continuously desquamated or thrown off and replaced from the deeper cells. Such is the continuous wear and tear of the outer surface of the body and its means of regeneration.

The *corium* or connective tissue skin is mesodermal in origin and differentiates from the cells of the dermo-muscular plate of mesoderm immediately underlying the embryonic ectoderm. It forms the matrix which receives the down-growths from the epidermis, hair-follicles, glands, etc. and serves by means of its rich vascular supply to nourish all the skin organs and parts.

Old age changes.—With advanced age the skin becomes thinner, less elastic and in certain regions the papillæ of the corium almost completely disappear. The cutaneous and subcutaneous fat becomes absorbed and the thin inelastic skin wrinkles over the wasted parts. The epidermis becomes smoother, with finer markings less pronounced, and takes on a sleek, shiny, often scar-like appearance. The hair becomes rough and fails to maintain its general directions. The function of the skin-glands is impaired and scaling often occurs. These changes give to the skin of the aged an entirely different feel and texture from that of the vigorous adult.

THE APPENDAGES OF THE SKIN

The appendages of the skin include: (A) the hairs; (B) the nails; (C) the cutaneous glands; and (D) the mammary glands.

A. THE HAIRS

The **hairs** [pili] over the general body surface are less developed in man than in any other primate. However, in localized areas such as the scalp the hair becomes more highly developed than in other mammals and may grow to several meters in length. Where well developed they in themselves serve as a protective organ and moreover through their connection with the nervous system they become in a measure organs of special sense. They are strong, flexible, somewhat elastic, and poor conductors of heat. They cover the entire surface of the body with the following exceptions: The flexor surfaces of the hands and feet; the dorsal bends and sides of the fingers and toes; the dorsal surfaces of the distal phalanges of the fingers and toes; the red borders of the lips; the glans and inner surface of the prepuce of the penis and clitoris; the inner surface of the labia majora; the labia minora and the papilla mammæ.

The **size and length** of hairs vary greatly not only in different parts of the body but also in different individuals and races. In certain situations the hairs are especially long and large and are designated by special names (such as the capilli, barba, hirci, and pubes).

Strong, well-developed short hairs are found in connection with the organs of sense forming the eyebrows, **supercilia**, the eyelashes, **cilia**, at the entrance to the external acoustic meatus, **tragi**, and at the nares, **vibrissæ**. Upon the extensor surfaces of the extermities, upon the chest, and in other situations in some individuals, especially in adult males, the hairs are also longer and stronger than upon the rest of the body, where they are, as a rule, short, fine and downy. The first hairs appearing in the fetus are very fine, and are called **lanugo**.

Excess of long hairs, **hypertrichosis**, may involve the whole hairy surface of the body as seen in the exagerated cases of hairy men and bearded women exhibited as freaks. This condition may be inherited and affect several individuals in the same family. Local areas of long hairs also occur as over nævi and upon the sacrum. Local congestion due to inflammation, irritation, or pressure may cause hypertrichosis. In women, hair upon the upper lip or other parts of the face may be an inherited peculiarity and due to some abnormality of the ovaries, or other endocrine glands. It is also not uncommon after the menopause.

In **color** the hairs may be either blonde, brown, black, red, or some gradation of these colors. The color varies with the race, and also with the individual, and according to age. It is due to pigment in the cells of the hair but is also influenced by the amount of air between the cells.

Greying and whitening of the hair are due not only to a decrease of pigment but also to an increase in the amount of air between the cells. Sudden blanching of the hair is thought to be due almost entirely to an increase in the quantity of this contained air. Whitening of the hair is physiological in old age and not infrequent in younger persons. This may be an inherited peculiarity or may follow mental overwork, nervous shock, or prolonged disease. Local blanching is also seen as the result of disease.

The hair may be straight, waved, curled, or frizzled in varying degree. Here also there is not only an individual but also a racial variation, as instanced in the curled or crinkled hair of the African negro and the straight hair of the American Indian. The curliness is caused by the form and manner of implantation in the skin. Straight hairs are round or oval in transection and curled hairs are more flattened. The root of curled hair has been observed in certain instances, as in the negro, to have a curved course in the skin which may account in a measure for its curliness.

The hairs are *arranged* singly or in groups of from two to five and, except those of the eyelashes, are implanted at oblique angles to the surface of the skin. The directions in which the hairs point are constant throughout life for the same individual. They are arranged in tracts in which the hairs diverge from a center in whorls, the **vortices pilorum**.

These vortices are found constantly in certain definite regions and apportion the whole hairy surface. The centers of vortices are found at the vertex (sometimes double) upon the face, around the external auditory meatus, in the axilla, in the inguinal region, and sometimes on the lateral surface of the body. These are all paired except as a rule the first. Where adjoining vortices come together the hairs are arranged in lines along which they all point in nearly the same direction, only slightly diverging, forming the **hair streams, flumina pilorum**. In other lines and places the hairs point in coverging directions such as at the umbilicus and over the tip of the coccyx.

The structure of the hair.—Each hair consists of a **shaft** [scapus pili] (fig. 80) projecting from the free surface of the skin to end (unless broken or cut) in a

conical tip [apex pili], and of a **root** [radix pili], imbedded in the case of the lanugo hair in the corium and of the larger hairs at various depths in the subcutaneous tela. Surrounding the root is a downgrowth of the skin known as the **follicle** [folliculus pili].

The root of the hair at its deepest parts swells to from one and one-half to three times the diameter of the shaft forming thus the **bulb** [bulbus pili] (fig. 80). The bulb is hollow and a vascular connective tissue process, the hair **papilla** [papilla pili] (figs. 80, 81) extends from the deepest part of the follicle into the cavity in its base. The follicle consists of an external connective tissue portion, the **theca folliculi,** formed by the corium, and an internal epithelial portion belonging to the epidermis and divided into two portions, the **inner** and **outer root-sheaths** (fig. 80).

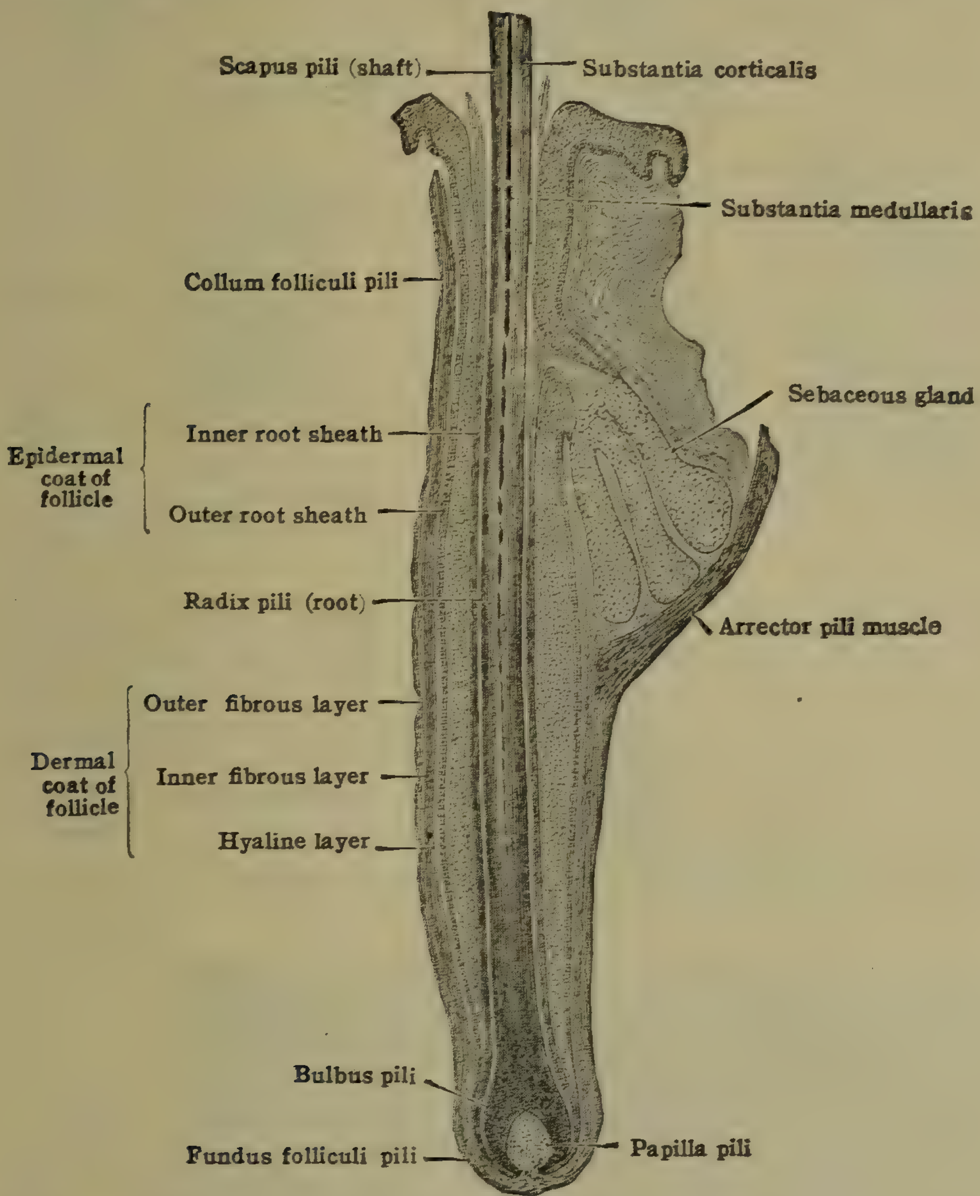


FIG. 80.—LONGITUDINAL SECTION OF A GROWING HAIR OF THE HEAD. (×30.) (From Toldt's Atlas.)

At the junction of the outer and middle thirds of the follicle of most of the hairs, the ducts of usually two or more sebaceous glands connect with the space between the hair and its follicle (figs. 80, 82). Immediately beneath this is the narrowest part of the follicle, the neck [collum folliculi pili], especially important as the position of the nerve ending of the hair.

Many of the hairs have in connection with their follicle round or flat bundles of unstriped muscle fibers, the **arrectores pilorum** (figs. 80, 82). These are situated on the side toward which the hairs point, their deep ends being attached to the hair-follicle beneath the sebaceous glands, which they more or less embrace; and their superficial ends connect with the papillary layer of the skin. Contraction of the arrectores not only causes the hairs to become more erect and the skin around them to project somewhat causing 'goose flesh,' but also compresses the sebaceous glands which are situated between the follicle and muscle and helps to empty the glands of their secretion.

The blood supply of the hairs.—The hair-follicles are surrounded by a capillary network of arteries connected with those of the corium and the papillæ are also supplied with loops of arteries.

FIG 81.—LONGITUDINAL SECTION OF A HAIR READY TO FALL OUT, WITH FOLLICLE FOR NEW HAIR. (×30.) (From Toldt's Atlas.)

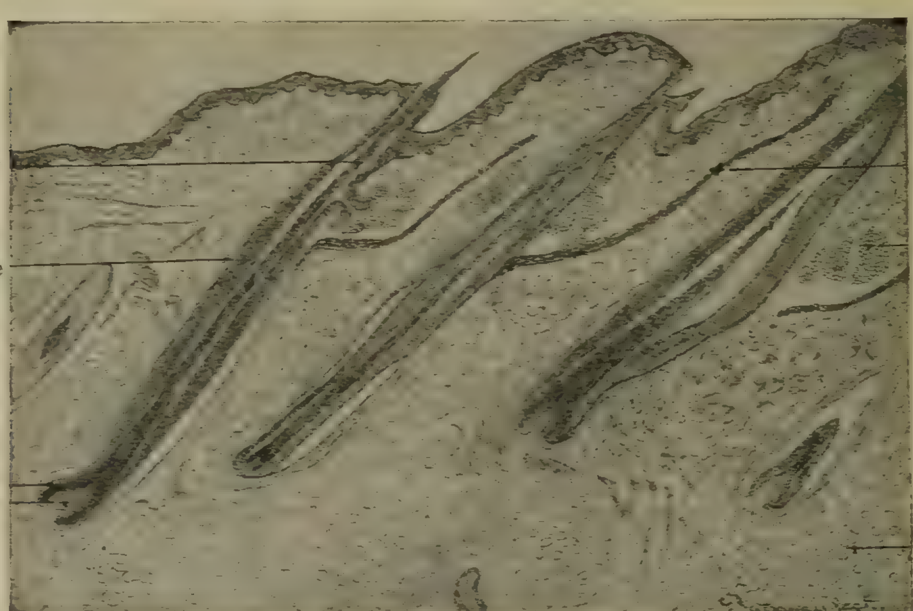


FIG. 82.—VERTICAL SECTION OF THE SKIN FROM SCALP. (×20.)

The nerves of the corium supply branches to the hairs. Some of these branches enter the papillæ, others surround the follicle at its neck and are distributed among the cells of the outer root sheath.

Development.—The hairs are developed from the epidermis by thickenings and downgrowths into the corium of plugs of epithelium. The deepest parts of these plugs become swol-

len to form bulbs and from these the hairs are produced. The central cells of the epithelial downgrowths disintegrate producing the lumen of the follicle. The hairs continue to grow from the deeper cells and protrude from their follicles between the fifth and seventh fetal months. Abnormally they may be scanty at birth and rarely entirely absent, **alopecia.** The lanugo hairs which cover all the hairy parts of the body at birth are soon shed and replaced by new hairs in the old follicles. Throughout life also the hairs are being constantly shed and replaced by new ones. This is accompanied by cornification of the bulb and fibrillation of the deep end of the hair (fig. 81). Thinning of the hair and baldness occur when the shed hairs cease to be replaced. This is common in old age and a premature baldness appears to run in certain families. The rate of growth is normally from 1 to 1.5 cm. per month, but is subject to variation.

B. THE NAILS

The **nails** [ungues] are thin, translucent, horny epidermic plates upon the dorsal surfaces of the distal phalanges of the fingers and toes. Through their hardness they serve as protective organs not only by covering the nerve-endings and other delicate structures of the skin; but also by acting as natural weapons.

FIG. 83.—DORSAL SURFACE OF ISOLATED FINGER-NAIL. (× 1.) (From Toldt's Atlas.)

FIG. 84.—FINGER-NAIL AND NAIL BED.

On the fingers they form useful tools. They are four-sided plates presenting a distal free border [margo liber], which overhangs the tips of the fingers, an irregular, sharp proximal edge [margo occultus], and on each side a somewhat thinned border [margo lateralis] (fig. 83).

Each nail is composed of an exposed distal part, the **body** [corpus unguis], and a proximal covered part, the **root** [radix ungius], (figs. 83–85), which ends in the margo occultus. The nail is at a slightly deeper level than the surrounding skin which overhangs the root and the lateral margins in a fold, the **nail-wall**

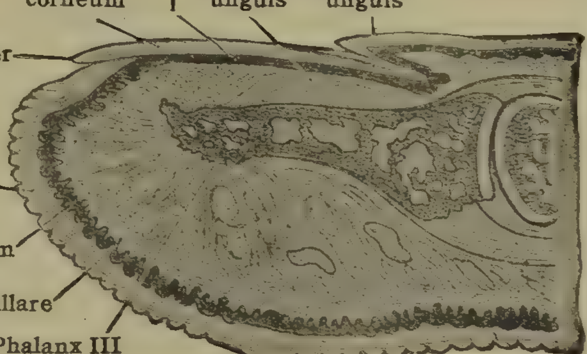


FIG. 85.—LONGITUDINAL SECTION THROUGH THE TIP OF THE MIDDLE FINGER. (×2.) (From Toldt's Atlas.)

[vallum unguis] (figs. 84, 85). The epidermis of the free edge of the nail-wall, especially proximally, is thickened and often appears as a ragged edge. At a deeper level than the above and extending somewhat more distally is a variably developed thin parchment-like membrane, the **eponychium,** closely attached to the superficial surface of the nail. The groove which is formed between the vallum and the underlying nail bed is known as the **sulcus matricis unguis.** This lodges the root and lateral margins of the nail and is deepest in the center of the root, becomes shallower toward the lateral margins, and finally disappears entirely toward the free border of the nail (fig. 85).

The **stratum corneum unguis** (fig. 85) which forms the principal thickness of the nail, presents fine longitudinal lines on the free dorsal surface The deeper surface of the nail, the **stratum germinativum unguis,** is a soft epithelial layer. Both these layers are transparent, excepting a semilunar area near the root, the **lunula** (figs. 83, 84), which is opaque whitish in color. Beneath the stratum germinativum is the fibrous **nail bed** [matrix unguis], corresponding to the corium and presenting well-marked longitudinal ridges, the **cristæ matricis unguis** (fig. 84).

Blood-supply of the nails.—The arteries are numerous in the matrix beneath the body of the nail but fewer beneath the root. They pass from the deep parts of the nail bed toward the surface, running in the main longitudinally and sending anastomosing branches to the papillæ.

The **nerves** beneath the nail are abundant and terminate in free sensory endings and in special end organs of several sorts.

Development of the nails.—For an account of the development of the nails, see p. 60.

Growth of the nails.—The nail grows in length and thickness by multiplication of those cells of the stratum germinativum which are situated between the margo occultus of the root and the distal border of the lunula. The older cells are pushed distally and toward the surface by the deeper cells. As a result the nail becomes gradually thicker from the occult border as far as the distal margin of the lunula. Over the rest of the nail bed no thickening appears to take place. The rate of growth is faster on the fingers than on the toes and varies with age, season, and the individual. When the nail is torn off, or detached through inflammation, it may be regenerated if the cells of the stratum germinativum have not been destroyed.

Congenital hypertrophy of the nails sometimes occurs, but absence or imperfect development is rarely seen. The white spots so frequently seen in the nail are caused by air between the cell layers due usually to injury or impaired development.

C. THE CUTANEOUS GLANDS

The **glands of the skin** [glandulæ cutis] are of two kinds: **glomiform glands** and **sebaceous glands.** The *glomiform* ('skein-like') glands [glandulæ glomiformes] are of four types: sudoriferous, ciliary, ceruminous and circumanal glands.

The **sudoriferous glands** [glandulæ sudoriferæ] or sweat-glands are modified simple tubular glands which secrete the *sweat* [sudor]. They are found in the skin of all parts of the body except that part of the terminal phalanges covered by the nails, the concave surface of the concha of the ear, the labia minora, and the inferior part of the labia majora in the female and the surface of the prepuce and the glans penis in the male.

The *number* of sweat glands found in different parts of the body varies greatly. There are very few on the convex surface of the concha and on the eyelid. They are also rather scanty on the dorsal surface of the trunk and neck, more numerous on the ventral surface of these parts and on the extensor surfaces of the extremities, still more numerous on the flexor surfaces and most numerous on the volar surface of the hands and plantar surface of the feet. They vary from less than 57 to more than 370 to the square centimeter.

Each gland (figs. 69, 86) consists of a secretory portion or **body** [corpus gl. sudoriferæ], and an excretory **duct** [ductus sudoriferus], which opens on the surface of the skin by a mouth visible to the unaided eye, the so-called 'pore' [porus sudoriferus]. Occasionally the duct opens into a hair-follicle.

The bodies of the glands are irregular or flattened spherical masses, yellowish or yellowish red in color and somewhat transparent. They vary in size from .06 to 4 mm. or more with a mean diameter of .2 to .4 mm., the largest being found in the axilla. They are formed of the irregularly many times coiled terminal part of the gland tube. The bodies of the glands are situated in the deeper part of the corium or in the subcutaneous tela.

The ducts, beginning as several coils bound up with those of the bodies, extend often in a straight or slightly wavy course nearly at right angles to the surface as far as the epidermis. This they pierce as spiral canals of from two to sixteen turns, more marked where the epidermis is thickest (fig. 69), and opened on the surface by somewhat widened funnel-shaped mouths. The ducts pass between the papillæ of the corium and open on the summits of the cutaneous cristæ where these are present. The diameter of the ducts is distinctly smaller than that of the secreting part of the glands, and this is true of the lumen also.

The degree of development of the sweat-glands varies with the situation, the individual, and also racially, as instanced by their great development in the negro. In rare cases sweat glands are completely absent from the human skin. The general body-skin of a number of mammals contains no sweat-glands. The glands are smaller in the aged than in the young.

The sudoriferous glands in the axillary region seem to be in some way connected with the sexual function for although a large number persist as small glands, others undergo further development beginning about the ninth year in the female and at puberty in the male. These glands in places form almost a continuous layer and are formed of large partly branched tubules with high secreting cells. The reddish color of the sweat in the axillary and some other regions, especially in certain individuals, is probably derived from the pigment-granules which are found in the glands here. The oil in the secretion lubricates the skin and keeps it soft and supple.

Vessels and nerves.—The sudoriferous glands are supplied from the deep cutaneous plexus by an abundant network of arteries which surround and penetrate between the coils of the gland-tubules. There is an enclosing network of nerve-fibers some of which have been traced to the gland cells.

Development.—The sudoriferous glands are seen first in the fourth or fifth fetal month. The anlages resemble closely those of the hair, but the cells are not so loosely packed. They project down as solid plugs which become long, slender, and tortuous rods. In the seventh fetal month the rods begin to develop a lumen in the deeper parts, which also now begin to coil. A lumen soon develops also in the superficial parts and joins that in the deeper part of the gland. The outer of the two layers of epithelium in the ducts becomes transformed at its transition into the gland proper into the myoepithelial layer.

The **ciliary glands** [gl. ciliares; Molli] are modified sudoriferous glands of the branched tuboalveolar type. They have simpler coils but are larger than ordinary sweat glands. They are situated in the eyelids near their free borders and open into the follicles of the cilia or close to them (see Section IX).

The **circumanal glands** [gl. circumanales] are found in a circular area about 1.5 cm. wide which surrounds the anus, a short distance from it.

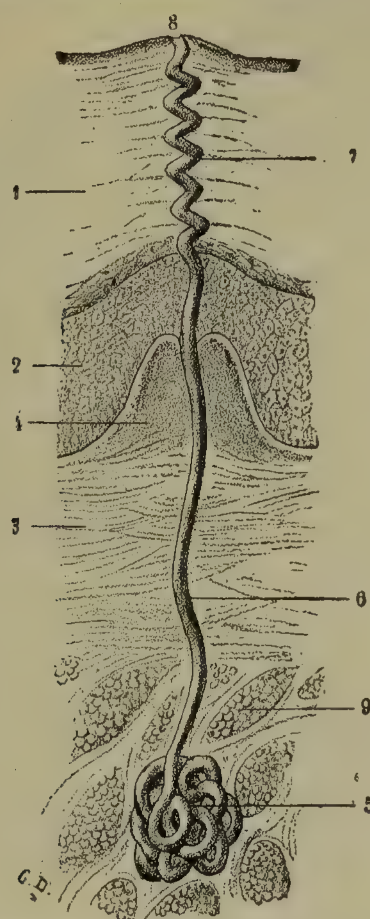


Fig. 86.—Vertical Section of the Palmar Skin Showing an Isolated Sudoriferous Gland. (Testut.)

1, Stratum corneum; 2, Malpighian layer; 3, corium; 4, papilla; 5, body of sudoriferous gland; and 6, 7, its excretory duct; 8, orifice of duct on surface; 9, subcutaneous fat.

These glands are several times the size of the ordinary sweat glands and resemble the glands found in the axilla, their secretion likewise having a strong odor. They are branching tubular glands. The other kinds of glands which are found in this same area are ordinary sweat glands, glands with straight ducts, with saccules and secondary alveoli, and tuboalveolar glands.

Ceruminous glands [gl. ceruminosæ] are glomiform glands somewhat modified from the sudoriferous type. They are branched tuboalveolar glands with relatively large lumina in the coils and narrow short ducts, and occur only in the external acoustic (auditory) meatus.

They are very abundant on the dorsal and superior part of the acoustic meatus in the region of the cartilaginous part, where in the adult most of them open on the surface of the skin close to hairs. Others open into the hair-follicles as they all do in the fetus and child. Their secretion, the **cerumen**, is, when freshly secreted, a fluid or semifluid oily material of a yellowish-brown color, which on exposure to the air becomes solid like wax.

The **sebaceous glands** [gl. sebaceæ] are simple branched or unbranched alveolar glands distributed over nearly the whole surface of the body. Nine-tenths of them are closely associated with the hairs, into the follicles of which

they empty (figs. 80, 81), and are therefore absent from certain of the non-hairy parts of the body, as the flexor surfaces of the hands and feet, the dorsal surfaces of the distal phalanges of the fingers and toes. On the other hand, a few are found, usually much modified, opening independent of the hair-follicles, as at the angles of the red margins of the lips, around the nares, around the anus, and the *tarsal* (Meibomian) glands in the eyelids. Modified sebaceous glands are also found upon the mammary papilla and areola in the female, and in some cases upon the superficial surface of the glans and the surface of the prepuce of the penis, here known as **preputial glands;** also a few very small ones may be found upon the labia minora, the glans and prepuce of the clitoris.

The sebaceous glands vary in size in different situations and also in individuals and races. They range from .2 to 2.2 mm. long and nearly as broad. Among the smallest are those of the scalp. The largest are found on the alæ of the nose and on the cheeks where their ducts are visible to the unaided eye. They are also large on the mons pubis, labia majora, scrotum, about the anus and on the mammary areola. Smaller glands are also found associated with these large ones. The size of the glands is independent of the size of the hairs with which they are associated but the number of glands depends upon the size of the hair. On small hairs one or more glands are always found and on large hairs there may be a whole wreath of from four to six separate glands opening into the hair follicle.

The **number** of sebaceous glands has never been exactly estimated, although, it is known that they are less numerous than the sudoriferous glands. This is very evident on the extremities, trunk, and neck, where they bear a relation of 1 to 6 or 8. On the scalp, concha of the ear, and skin of the face they are about equal in number while on the forehead, alæ of the nose, free borders of the eyelids and external genital organs in the female the number of sebaceous glands is greater than the number of sudoriferous glands.

Each sebaceous gland consists of a secretory portion, the **body,** connected with the hair-follicle or the surface of the skin by a wide short **duct.** In the small glands, the body of the gland may consist of a single alveolus but in the larger glands there are from four to twenty of these connected by irregular ducts to a single excretory duct.

The **ducts** open into the hair-follicles near their necks between the inner root-sheath and the hair or upon the surface of the skin. They are always very short, cylindrical, or infundibuliform, and their epithelium is directly connected with that of the outer root-sheath of the hair-follicle or with the epidermis where the hair is wanting.

The glands lie in the superficial layers of the corium and where one or a few are connected to a single hair, they usually open into the hair-follicles on the side toward which the hairs point. Where there are several glands for one hair they may completely surround the hairs like a rosette. The active secretion of the sebaceous glands does not begin before the fifth or sixth year of life. It attains its maximum in the adult and decreases in the aged.

The relation of the arrectores pilorum to the sebaceous glands has been described in connection with the relation of these muscles to the hairs.

Vessels and nerves.—The sebaceous glands are surrounded by a fine capillary plexus of **blood-vessels** closely associated with those of the hairs and skin. Concerning their **lymph-vessels** little is known. The **nerves** of the sebaceous glands are connected with those of the skin and hair but the exact manner of distribution is uncertain.

Development.—The sebaceous glands appear first in the fifth fetal month as single, rarely double, buds on the anlages of the hair-follicles. The distal ends of these enlarged buds become lobulated. In these solid masses of cells lumina for the alveoli and the ducts later are formed, through the fatty degeneration of the central cells. The oily contents of these cells together with the débris and the cast-off surface cells of the epidermis form the **vernix caseosa** on the surface of the fetus.

D. THE MAMMARY GLANDS

The **mammary glands** [mammæ] or breasts are modified cutaneous glands. In the male they remain rudimentary and functionless throughout life, but in the female they are functionally closely associated with the reproductive organs since they secrete the milk for the nourishment of the newborn and are subjected to marked changes at puberty, throughout pregnancy, during and after lactation, and after the menopause.

The two mammæ (fig. 87) are situated on the ventral surface of the thorax one on each side of the sternum. As examined from the surface in a well-developed nulliparous female they appear to extend from the second or third rib to the sixth or seventh costal cartilage and from the lateral border of the sternum to beyond the ventral folds of the axillæ. Separating the two mammæ there is a median area of variable size, the **sinus mammarum.**

In shape they are conical or hemispherical, and in consistency somewhat firm and elastic. The two breasts are seldom equal in size, the left, as a rule

being slightly the larger. Each measures from 10 to 13 cm. in diameter being slightly longer in the direction parallel with the lateral border of the pectoralis major muscle. The **weight** of each gland varies from 140 to 200 grams, or more.

Each mamma presents a ventral and a dorsal surface. The **ventral surface** is free, covered by skin, smooth and convex. It is continuous cephalically, without sharp demarcation, with the ventral surface of the thorax but laterally and caudally it is usually sharply defined (figs. 87, 89). It is most prominent slightly laterocaudal to the center and at this point there is a marked pigmented projection, the **nipple** [papilla mammæ] surrounded by a slightly raised area, also pigmented, the **areola mammæ.** These two structures will be described separately later.

The **dorsal surface** of the mammary gland (figs. 89, 90) is attached and concave. It is in relation in its cephalomedial two-thirds with the fascia over the pectoralis major muscle. In its caudolateral third it extends over the base of

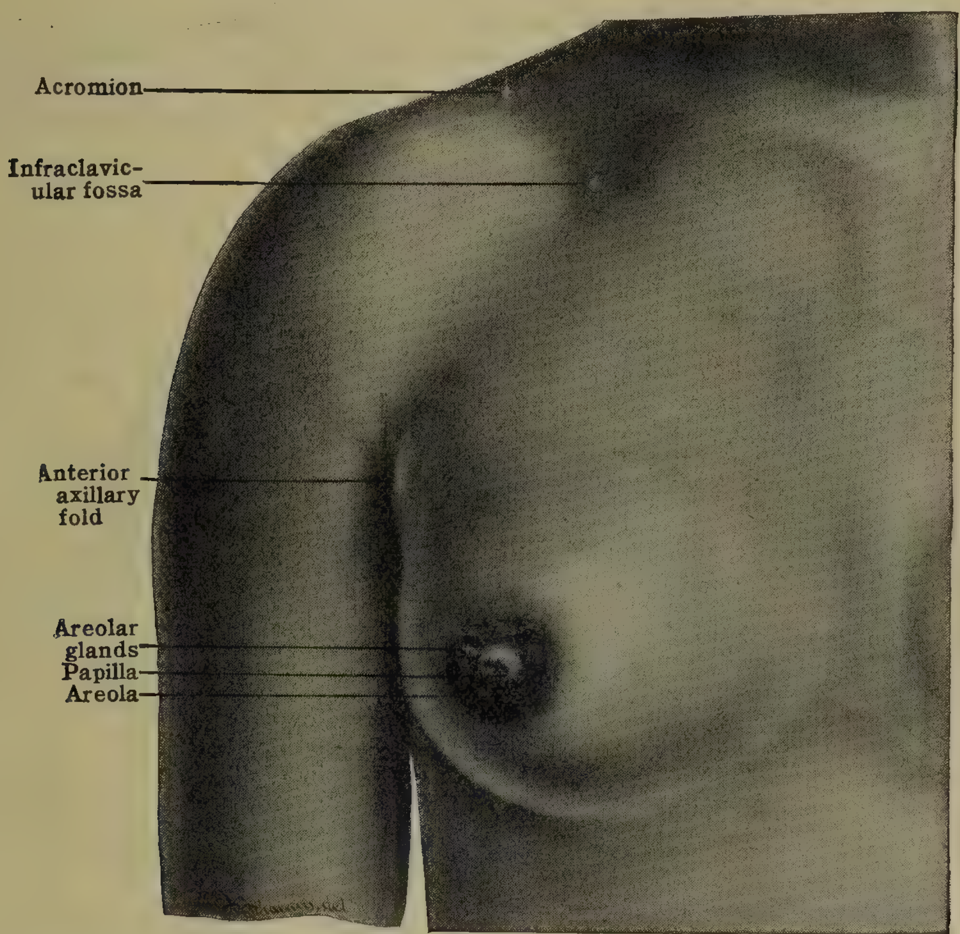


Fig. 87.—The Right Mamma of a Girl 18 Years Old. (Modified from Spalteholz.)

the axillary fossa, where it is in relation with lymphatic glands and with the serratus anterior muscle, and at its most caudal part, sometimes with the external abdominal oblique muscle.

The usual **number** of breasts in the human species is two; rarely is the number reduced, much more often do we find an increase in this number. Each of these conditions is found in both sexes and may be complete or partial. Complete suppression of both breasts, **amastia,** is one of the rarest anomalies and is usually associated with other defects. Complete absence of one is less rare. A more frequent condition is arrest of development, **micromastia,** leading to rudimentary but functionless organs. Absence of the nipple, **athelia,** is much commoner and generally affects both breasts. All grades of the imperfection from complete absence to slightly imperfect nipple may be found. When there is an increase this may include the whole breast, **polymastia,** or just the nipple, **polythelia.** The supernumerary structures [mammæ accessoriæ] may be represented only by a pigmented area indicating an areola; or by a nipple with or without an areola: by a gland with a more or less perfect nipple and areola; or with ducts opening without a nipple; or there may be no opening on the surface. The extra mamma is very rarely perfectly developed and functional. Various observers have found the supernumerary breasts or nipples occurring in from 1 to 7 per cent. of the cases examined and somewhat oftener in males than in females. The extra organs are found more frequently on the left side, usually along a line extending from the axilla toward the genitalia. This corresponds to the position in which the mammæ occur in some other mammals and also to the milk-line of the embryo. Although they are occasionally found in other situations, over 90 per cent. of them are encountered upon the ventral surface of the thorax along the above-mentioned line caudal

and medial to the normal pair of breasts. They are frequently hereditary. It is doubtful whether their possessors are either more fertile or more liable to bear twins.

The **shape** of the breasts varies with the development and functional activity and with the amount of fat. The smooth, somewhat conical breast of the nullipara becomes hemispherical with increase in the amount of fat, while in emaciation it may be reduced to a flattened disk with an irregular surface. After lactation the breasts tend to become more pendulous with marked sulci between them and the thoracic walls, and after repeated pregnancies they may become elongated so as to be almost conical or even have pedunculated bases.

The **size** of the mammary gland in girls remains relatively the same as in the infant up to puberty, when it suddenly increases considerably and continues for a time to enlarge slightly at each menstrual period. There is also a temporary enlargement and soreness at each menstrual period, due perhaps to the increased blood supply. Until the age of puberty the glands measure 8 to 10 mm. in diameter but when they have attained their complete adult development they have increased to 100 to 110 mm. in the cephalomedial, 120 to 130 mm. in the cephalolateral (obliquely from above downward) direction, and 50 to 60 mm. in thickness.

During pregnancy the breasts again increase in size, more especially after the birth of the child. When their full functional activity is established, their volume may be two or three times as great as before pregnancy. After lactation they return again nearly to their former size, which they retain until another pregnancy. After the menopause the useless glands in

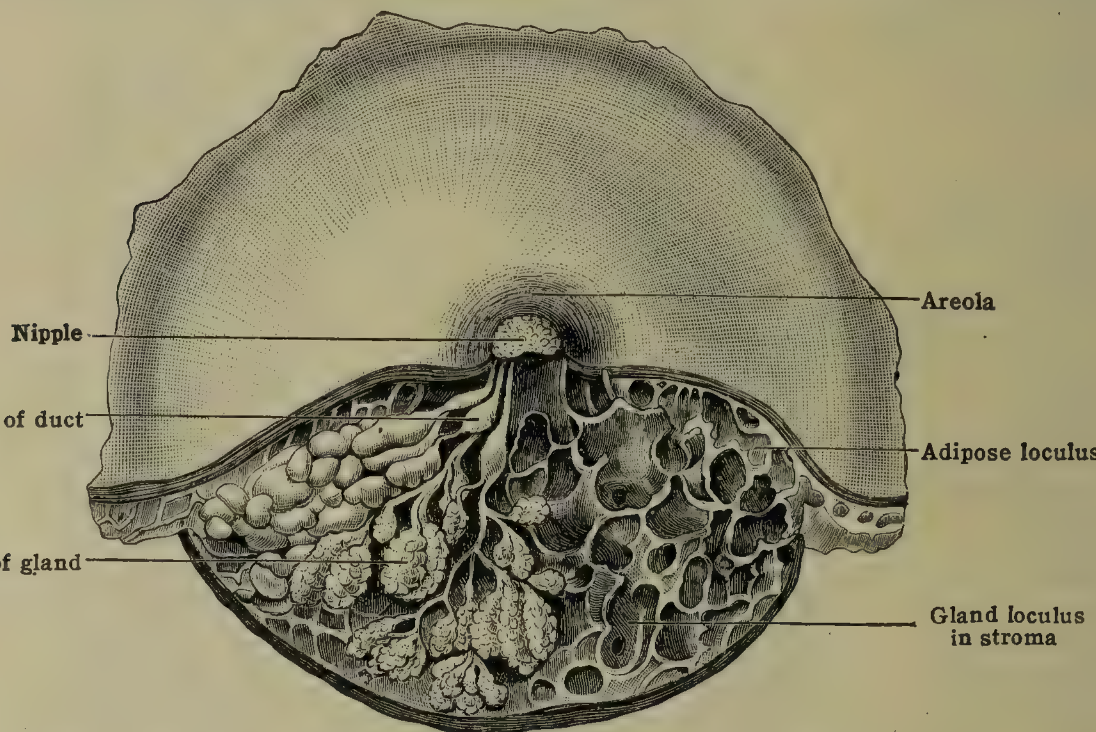


Fig. 88.—The Female Mamma During Lactation. (After Luschka.)

some cases atrophy and are reduced to small discoidal masses. In others, especially in fat individuals, although the secreting tissue disappears, it is replaced by fat so that there is little or no reduction in size. In addition to the above-mentioned variations in size, the breasts are subject to great individual differences, the cause of which is little understood. Large robust women are sometimes seen with small mammary glands, and small women with large glands.

The level of the mammæ varies with the stature; as a rule, in tall women it is more caudal and in short and broadchested women it is more cephalic. The tightness of the attachment to the sheath of the pectoralis major muscle is quite variable, but even when quite loose there is some movement of the breast when the arm is raised. The glandular tissue of that part of the breast which overhangs the axilla may be in direct contact with the lymphatic glands, a relation of clinical importance.

Structure.—The mammary glands are composed of the essential epithelial glandular tissue, the **parenchyma,** the supporting and enclosing connective tissue of the subcutaneous tela, the **stroma,** and the covering cutaneous layer.

Parenchyma.—The essential part of each mamma is a flattened, circular mass of glandular tissue of a whitish or reddish-white color, the **corpus mammæ.** This is thickest opposite the nipple and thinner toward the periphery. The ventral surface of this mass is convex and made uneven by numerous irregular pyramidal processes (figs. 89, 90) which project toward the skin. The dorsal surface, or base, is flat or slightly concave and much less irregular than the ventral surface.

Minute processes of glandular tissue extend from the corpus mammæ into the retromammary tissue, some of them accompanying the septa of the pectoral fascia between the bundles

of muscle fibers of the pectoralis major muscle. Malignant growths of the mammary gland may extend into these septa, a fact to be remembered in surgical removal of the breast. The circumference of the mamma is thick and well defined, more marked caudally than cephalically, but it presents numerous irregular processes which extend beyond the limits apparent from the surface. One of these, known as the axillary process or 'tail' of the gland, is especially large and well marked, extending cephalolaterally into the axillary fossa. There are frequently other large but less-marked projections. The glandular tissue in section appears grayish or pinkish in color, and is firm and resistant in consistency. It is thus readily distinguished from the adipose tissue.

The **corpus mammæ** is not a single structure but is composed of from fifteen to twenty separate **lobes** [lobi mammæ] (fig. 88). These are larger and smaller irregular flattened pyramidal groups of glandular tissue, with their apices toward the nipple and their bases radiating toward the periphery of the gland.

Each lobe has a single excretory **duct** [ductus lactiferus] (figs. 88, 89, 90), which opens by a contracted *orifice* (porus lactiferus) in a depression upon

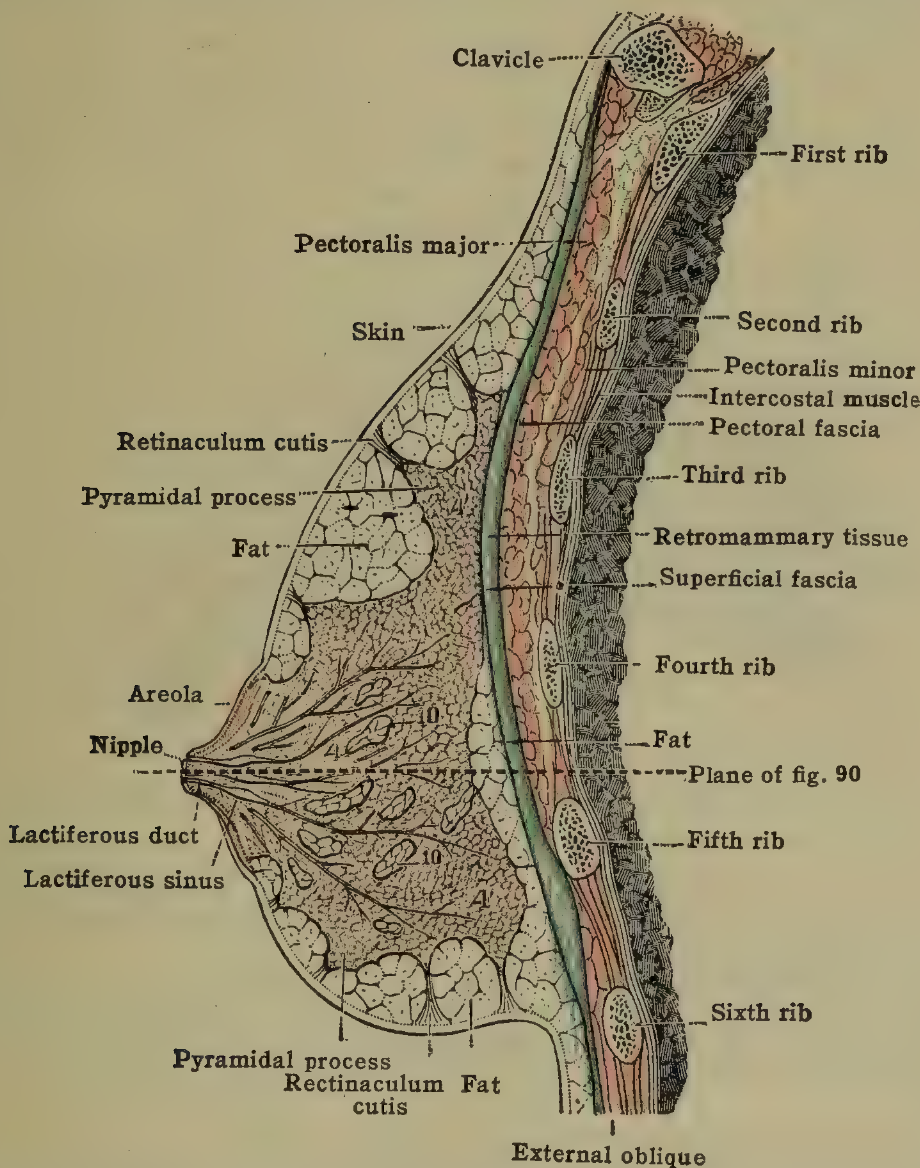


FIG. 89.—SAGITTAL SECTION OF THE RIGHT MAMMA OF A WOMAN TWENTY-TWO YEARS OLD; (Testut.)

the tip of the nipple. When traced from the pore toward the circumference of the gland, the ducts are seen to run first directly dorsally through the nipple, parallel and close to one another. From the base of the nipple they diverge. Each duct is here visible to the unaided eye and measures from 1.5 to 2.5 mm. in diameter. Beneath the areola its diameter increases for a short distance to from 4 to 9 mm., forming thus a reservoir, the ampulla or **sinus lactiferus**, in which the secretion may accumulate for a time. Beyond this dilation the duct continues, gradually decreasing in size as it breaks up into smaller and smaller branches.

There is no anastomosis between the ducts during their course, although at or beneath the pore two or more ducts may join to have a common opening. They possess no valves but when empty their inner surface is thrown into longitudinal plicæ. The ducts have an external coat of white fibrous connective tissue mixed with circular and longitudinal elastic fibers, and an epithelial lining.

Each of the terminal branches of a duct ends in a tubulosaccular, spherical or pyriform **alveolus.** A number of these alveoli which open into a common branch of the duct, when grouped together and bound up with connective tissue, constitute a **lobule** of the gland (lobulus mammæ). A lobe is made up of all the lobules whose ducts join one common excretory duct.

Stroma.—The lobes, lobules, and alveoli are completely covered by a connective tissue sheath too delicate to constitute a distinct capsule. Outside of this the whole gland is embedded in the subcutaneous tela which forms for it a sheath, **capsula adiposa mammæ.** This is particularly well developed on the ventral surface where the fat fills in between the irregularities caused by the lobes and lobules and gives to the surface of the gland its smooth appearance. Within the corpus mammæ there is little fat between the lobules in nulliparæ but much more fat is found here in the stroma in multiparæ. When the fat is absorbed, as it is during lactation and in emaciation, the lobules stand out much more distinctly. There is however, no fat immediately beneath the areola and nipple. The connective tissue is here loosely arranged and allows free motility of the nipple and also permits the more easy distention of the ducts and sinuses during lactation. The connective tissue strands, **retinacula mammæ,** which extend from the apices of the glandular processes on the ventral surface of the mamma are connected to the corium and correspond to the retinacula cutis found in other situations. These are sometimes particularly well developed over the cephalic part of the mamma and have been called the *suspensory ligaments of Cooper.*

The dorsal surface of the mamma is bound to the pectoral fascia by loose connective tissue containing, as a rule, only a small amount of retromammary fat (figs. 89, 90). The attach-

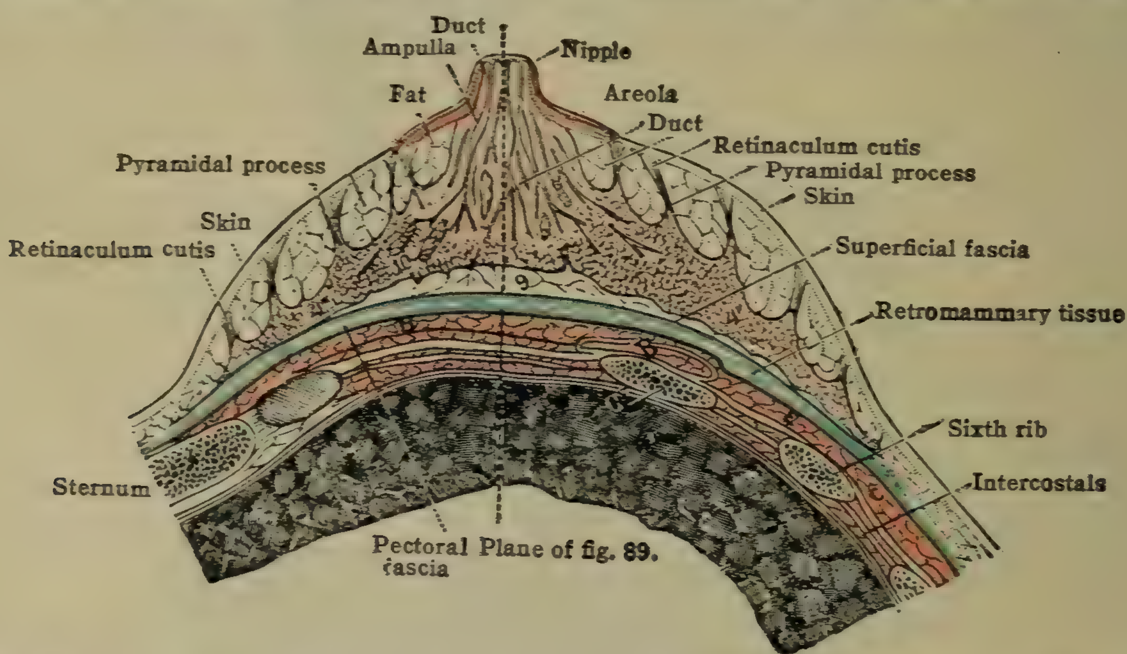


Fig. 90.—Horizontal Section of the Right Mamma of a Woman 22 Years Old. (Testut.)

ment to the sheath of the pectoralis major muscle is at times so loose that the spaces between the connective tissue appear to form serous sinuses, the **retromammary bursæ.** These may be the seat of retromammary abscesses.

A mammary gland may be made up of a larger amount of stroma and a smaller amount of glandular tissue, or the reverse, and therefore a small breast may furnish more milk than a large one. There is also a variation in different parts of the same breast, one lobe or section may have well-developed lobules while in another they remain almost as at puberty, merely branching ducts.

The **skin** covering the ventral surface of the mamma is covered with lanugo hairs associated with sebaceous glands, and contains many sweat glands of the ordinary type. It is so thin that the subjacent veins are readily seen through it. It is closely adherent to the subjacent fatty layer but its flexibility, elasticity, and motility over the deeper glandular tissue permit much stretching during the enlargement which occurs at the time of lactation. In spite of this, **lineæ albicantes** are often produced especially when the breasts have been unusually large. Aside from the above-mentioned particulars it does not differ from the skin of the adjacent part of the thorax, except over the center of the breast where it forms the areola and nipple.

The **areola mammæ** (figs. 87 to 90) is covered by a thin, delicate, pigmented skin. The *color* in young nulliparæ is reddish, the shade varying with the complexion. During pregnancy the color darkens, slightly in blondes, but so as to become almost black in marked brunettes.

This pigmentation serves as one of the signs of gestation. After lactation the color fades, but little pigmentation remaining in blondes, considerable in brunettes. During pregnancy there is sometimes seen extending more or less beyond the areola a less deeply and less uni-

formly pigmented ring, the **secondary areola.** In size, the areola is subject to considerable individual variation and is increased in pregnancy.

The surface of the areola is roughened by a number of slight elevations irregularly arranged. These are due to underlying large sebaceous and rudimentary milk-glands [gl. areolares: Montgomerii], tubercles or *glands of Montgomery.* Projections caused by sebaceous glands are also found in the secondary areola. All of these tubercles enlarge greatly during pregnancy and the glands produce a slight secretion which is discharged through ducts that open on their summits. The sweat glands are few but large, and in addition to the lanugo hairs there are usually several well-developed hairs.

The *corium* of the areola is devoid of fat but contains a well-developed layer of smooth muscle-fibers, the fascicles of which intercross in various directions but may be seen to be mainly of two orders, circular and radial. They are continuous with those of the nipple. The circular fibers are most numerous adjacent to the nipple, where they may form a layer nearly 2 mm. in thickness.

The areola varies greatly in size, measuring from 15 to 60 mm. in diameter. There is some confusion in regard to the areolar glands and the tubercles of Montgomery. Some consider the tubercles to be caused by the areolar glands, others consider them caused by the sebaceous glands. Sebaceous glands undoubtedly cause the projections in the secondary areola. The sudoriferous glands of the areola are large and compound tubular glands with a complicated glomerulus and are considered as transitions between sweat and mammary glands. The sebaceous glands are even more numerous than the sudoriferous and are composed of several lobes. They also have been considered by some as intermediate stages in the formation of mammary glands, but this is improbable. There are ten to fifteen very small areolar glands (though Pinard found an average of but four to each breast), whose structure is essentially identical with that of the principal mammary glands. They have dilations on their ducts and they open on the areola at times in common with a sebaceous gland.

The **nipple** [papilla mammæ] (figs. 87 to 90) in well-developed nulliparæ is situated slightly laterocaudal to the center of the breast and on a level with the fourth rib or fourth intercostal space about 12 cm. from the median line. But its position in reference to the thoracic wall varies greatly with age, individual, and the present and past activity of the gland. The nipple is usually somewhat conical or cylindrical with a rounded fissured tip marked by fifteen to twenty minute depressions into which the lactiferous ducts empty. The average length of the nipple is 10 mm. to 12 mm. The skin is thin, wrinkled, and pigmented like the areola, except over the tip of the nipple where there is no pigment.

The corium of the nipple has many large vascular and nervous papillæ and there is no fat in it. Hairs and sudoriferous glands are absent, but sebaceous glands are present in great numbers. Their secretion here and over the areola serves to keep the skin soft and to protect it from the saliva of the nursing infant. In the deeper layers of the corium smooth muscle-fibers form a loose stratum continuous with that of the areola. This is made up principally of an external circular layer and to a slight extent by an internal layer whose bundles of fibers are parallel with the milk-ducts. Numerous interlacing muscle-fibers connected with these layers and mixed with loose connective tissue, and elastic fibers, but no fat, surround the lactiferous ducts as they pass through the axis of the nipple.

The nipple usually does not project from the surface until the third year. It soon becomes conical but does not attain its full size until shortly after puberty. The size of the nipple is variable, ordinarily in proportion to the size of the gland, but large nipples are sometimes found on small breasts and small nipples on large breasts. During pregnancy the nipple increases in size and becomes more sensitive and more easily erectile. The shape of the nipple in addition to conical or cylindrical may be hemispherical, flattened, discoidal, or slightly pedunculated. Its end may be invaginated or the entire nipple retracted beneath the surface of the gland and projecting only in response to stimuli.

The circular muscle-fibers of the nipple act like those at its base in the areola. By intermittent, rhythmic contractions they tend to empty the lactiferous ducts; by continuous and tight contraction they act as a sphincter. When contracted they also narrow the nipple, make it harder, erect, and more projecting. When the vertical fibers contract they depress the tip of the nipple or they may retract the whole nipple beneath the surface. The muscle of the areola when stimulated puckers the skin toward the nipple causing circular, concentric folds in the skin of the areola.

The **male mammary gland** [mamma virilis]. This develops exactly as in the female. From birth to puberty the glands in the two sexes have a parallel growth and development, but from this time on the glands in the male grow but slightly and reach their full development about the twentieth year.

The corpus mammæ in the adult male measures from 1.5 to 2.5 cm. in diameter and .3 to .5 cm. in thickness. It is whitish in color, tough, and stringy. It is composed of the same number of lobes as in the female but these consist of little more than short ducts with no true acini and may be reduced to mere epithelial or connective tissue strands. The areola and nipple are present and pigmented, but the nipple averages only 2 to 5 mm. in height. The areola has a diameter of 2 to 3 cm. and is covered with hairs. The areolar tubercles may be recognized and the areolar muscle is present. The position of the nipple in relation to the chest-wall is more constant than in the female as the breast is less movable. It is seldom beyond the limits

of the fourth intercostal space or the two adjacent ribs, and averages 12 cm. from the median line. Occasionally the male breast may hypertrophy on one or both sides (**gynecomastia**).

Blood-supply.—The main arterial supply to the mammary gland is from mammary rami of perforating branches of the internal mammary artery (p. 641). Usually that from the second or third intercostal space is especially large. Small branches, external mammary rami, are also supplied to the caudal and lateral segments of the breast by the lateral thoracic artery (p. 646). Some rami from the thoracoacromial or supreme thoracic arteries may reach the cephalo-lateral segment of the breast and small twigs, lateral mammary rami, from the anterior branches of the lateral cutaneous rami of the aortic intercostal arteries (p. 662) supply its deep surface. The veins from a superficial plexus communicating with deeper veins corresponding to the arteries.

The lymphatics.—The lymphatics of the mammæ are extremely numerous, forming rich plexuses and free anastomoses. There is a rich plexus in the skin of the areola and nipple which empties mainly into a subareolar plexus. Deep lymphatics arise in the spaces around the alveoli in all parts of the gland. They anastomose freely with the cutaneous lymphatics and most of these converge toward the nipple where they join the subareolar plexuses. From these plexuses the main lymphatic channels pass outward to communicate with the pectoral, subscapular, axillary and central nodes of the axilla. Metastases or infections from the mammary gland are therefore most likely to be transmitted to the axillary nodes.

There are three subsidiary or secondary lymphatic channels of the breast: (1) Groszman's path passes directly backward through the pectoralis major to communicate with lymph nodes (Rotter's) beneath the pectoralis minor. (2) Lymphatics which follow the perforating branches of the internal mammary to communicate with the mediastinal nodes and pleural lymphatics. (3) The paramammary route of Gerota, which may account for liver metastases and skin metastases in the upper abdominal wall. The lymphatics of the skin also anastomose across the front of the chest. For further details and figures, see p. 792.

The nerves.—The gland proper receives its nerves laterally from the lateral mammary rami of the anterior rami of the lateral cutaneous branches of the fourth to sixth intercostal nerves and medially from the medial mammary rami of the anterior cutaneous branches of the second to the fifth intercostal nerves. The skin over the breast receives in addition to branches from these nerves, branches from the supraclavicular nerves of the cervical plexus. Therefore in painful affections of the breast the pain may be referred to the side of the chest and back (along the intercostal nerve trunks), over the scapula along the medial side of the arm (along the intercostobrachial nerve), or up into the neck. Sympathetic fibers reach the gland but by what course is not yet clear. The nerves are distributed in part to the skin, in part to the plain muscle of the areola and nipple, some to the blood-vessels, and others to the glandular tissue. The secretion is, however, not entirely controlled by nerves as it is influenced also by hormones from other organs brought to it by the blood.

In **removal of the breast** elliptical incision will usually suffice if employed on wide lines and if attention be paid to the following points:—(1) Those details in the surgical anatomy already referred to, especially those bearing on the extensiveness of this organ, and the proportionate difference between seen and unseen disease. (2) The importance of removing in one continuous piece the whole breast, all the skin over it, the costosternal part of the pectoralis major, the pectoralis minor, the axillary fat, and lymphatics.

Development.—In very early embryos the epithelium over an area on the side of the body extending from the forelimb to the hindlimb (or beyond these limits) is seen to be deeper and more cubical, the mammary streak. In this area there is produced by multiplication of cells a ridge, the *mammary line or ridge*. In spots along this line, corresponding to the relative position of the mammary glands in some mammals and the supernumerary mammæ in man, the epithelium thickens. The intervening parts of the line disappear as the spots enlarge to form transient *mammary hillocks*. In man development ordinarily proceeds in but one of these hillocks on each side. The deep surface of the hillock projects into the corium as the superficial surface flattens out and the mesodermic cells of the corium condense around the ingrowth producing the *nipple zone*. Rapid proliferation of the deeper cells produces a *club-shaped stage* from the deeper surface of which small bud-like masses of epithelial cells sprout and extend as solid plugs into the corium. These are the anlages of the true secreting part of the gland and the number of buds corresponds to the number of lobes of the future gland. The sprouts extend beyond and beneath the nipple zone and are supported by closely packed connective tissue cells forming the *stroma zone*. The epithelial buds continue to grow and branch and a lumen is finally produced in the originally solid plugs. The primary epithelial ingrowth degenerates and ultimately disappears. A cavity is produced in it which later connects with the lumina of the gland ducts. The depressed nipple zone becomes elevated above the surface soon after birth.

References for the skin and mammary gland.—*General and topographic:* Quain's Anatomy, 11th ed., vol. ii, pt. 1: Testut, Traité d'Anatomie Humaine, 8th ed.; Poirier-Charpy, Traité d'Anatomie, vol. v; Rauber-Kopsch, Lehrbuch der Anatomie, 9th ed.; Bardeleben, Handbuch der Anatomie, vol. v, pt. 1; Merkel, Topographische Anatomie; Corning, Lehrbuch der topographischen Anatomie. *Development:* Keibel and Mall, Human Embryology. *Skin:* v. Möllendorff's Handbuch der mikroskopischen Anatomie des Menschen; Heidenhain, Anat. Hefte., vol. xxx; Kean (finger-prints), Jour. Amer. Med. Assoc., vol. xlvii; Unna (blood and lymph), Arch. f. mikr. Anat., vol. lxxii; Botezat (nerves) Anat. Anz., vol. xxxiii. *Hair:* Danforth, Archives of Dermatology and Syphilology, 1925; *Nails:* Branca, Annales de Dermat. et Syphilis, 1910; *Mammary glands:* Kerr, Ref. Hand. Med. Sci. (Breast); Pinkus Anatomie der Haut, Berlin, 1927.

SECTION III

OSTEOLOGY

By ROBERT J. TERRY, A.B., M.D.

PROFESSOR OF ANATOMY IN WASHINGTON UNIVERSITY

THE SKELETON

THE skeleton forms the solid framework of the body, and is composed of bones, and in certain parts, of pieces of cartilage. The various bones and cartilages are united at the joints by means of ligaments, and are so arranged as to contribute in giving to the body definite shape, in protecting from injury the delicate organs, and in affording attachment to the muscles by which the various movements are accomplished. The total skeleton is shown in fig. 91.

In its widest acceptance, the term **skeleton** includes all parts of the framework, whether internal or external, and as in many animals there are, in addition to the deeper osseous parts, hardened structures associated with the integument, it is convenient to refer to the two systems as **endoskeleton** and **exoskeleton** or **dermal skeleton**, respectively. All vertebrate animals possess an endoskeleton, and some of them a well-developed exoskeleton also; but in mammals, the external skeleton, when it exists, plays a relatively subordinate part. In the invertebrates the endoskeleton is generally absent and the skeleton when present is external. The exoskeleton is phylogenetically the older and the endoskeleton the more recent form; an example of the transition between the two is presented by the ganoid fishes.

Bones are divisible in regard to form into three classes—**long bones** [ossa longa], **short bones** [ossa brevia], **flat bones** [ossa plana] to which may be added a fourth kind, namely, **irregular bones.** The **long bones,** found in the limbs, in part sustain the weight of the trunk and form a system of levers which, with the muscles attached to them, provide the means of locomotion and prehension. The **short bones,** illustrated by those of the carpus and tarsus, are found mainly where compactness, elasticity, and limited motion are specially required. **Flat bones** confer protection or provide broad surfaces for muscular attachment, as in the case of the cranial bones and the shoulder-blade. Lastly, the **irregular** or **mixed bones** constitute a group of peculiar form, often very complex, which cannot be included under either of the preceding heads. These are the vertebræ and many of the bones of the skull.

The **surface contour** of a bone presents inequalities in the shape of eminences and depressions. **Crests** [cristæ], **spines** [spinæ], **tubercles** [tubercula] and **grooves** [sulci] are directly related to the origin and insertion of muscles; other grooves of crooked and branched form, **canals** [canales] and **holes** (foramina) are adapted to blood-vessels and nerves; smooth **articular surfaces** [facies articulares], cartilage-covered and of various forms such as **heads** [capita], **condyles** [condyli] and **pulleys** [trochleæ] enter into the formation of joints. The surfaces of a bone with the exception of cartilage-covered articular surfaces are closely invested with a tough, fibrous vascular **periosteum** intimately connected with the tendons and ligaments which find attachment on the bone. All bones present a superficial layer of **compact osseous substance** [substantia compacta] which varies in thickness. Within the denser covering there exists a sponge-structure of bony plates and tubes known as the **spongy substance** [substantia spongiosa] which is most abundant in the short and irregular forms: in long bones it is found chiefly in the enlarged extremities. The spongy substance contains the **red marrow** [medulla ossium rubra]. The disposition of the plates of the spongy substance is claimed to correspond to the lines of pressure and tension in most of the bones (fig. 92). The **shaft** [diaphysis] of a long bone contains a spacious **medullary cavity** [cavum medullare] occupied by the fatty **yellow marrow** [medulla ossium flava]; into this space a constant artery (the medullary or nutrient) enters by the so-called **nutrient foramen** [foramen nutricium] of the shaft. The flat bones of the cranial vault have very dense **outer** and **inner tables** [lamina externa; interna] of compact substance; the intermediate layer of spongy substance, channeled for large veins, is known as the **diploë.** In certain parts of the skull the spongy substance is replaced by the air-filled **paranasal sinuses**; this condition being expressed in the term **pneumatic bone** [os pneumaticum].

Vessels and nerves (fig. 93).—It is a characteristic of the vessels of the skeleton that the bones are poor in capillary nets but are furnished with an abundance of fine arterioles. Arteries enter the flat bones at various points. Veins run at first with the arteries, then enter separate bony-walled canals. In the long bones, arteries supply (1) the spongy structure of the extremities, by twigs coming from the articular arteries which branch in the periosteum; (2) the compact bone of the shaft, by vessels of the periosteum; (3) the walls of the medullary cavity and the medulla by the **nutrient artery.** The latter passing through the obliquely directed **nutrient canal** [canalis nutricius], divides on entering the medullary cavity into proximal and

distal branches which at the extremities anastomose with the articular arteries supplying the red marrow and spongy bone. The nutrient artery is accompanied by two **veins**; most of the venous blood of the medulla and spongy bone is returned by large and numerous veins which leave the bone by foramina at the extremities. **Lymph-vessels** are abundant in the periosteum

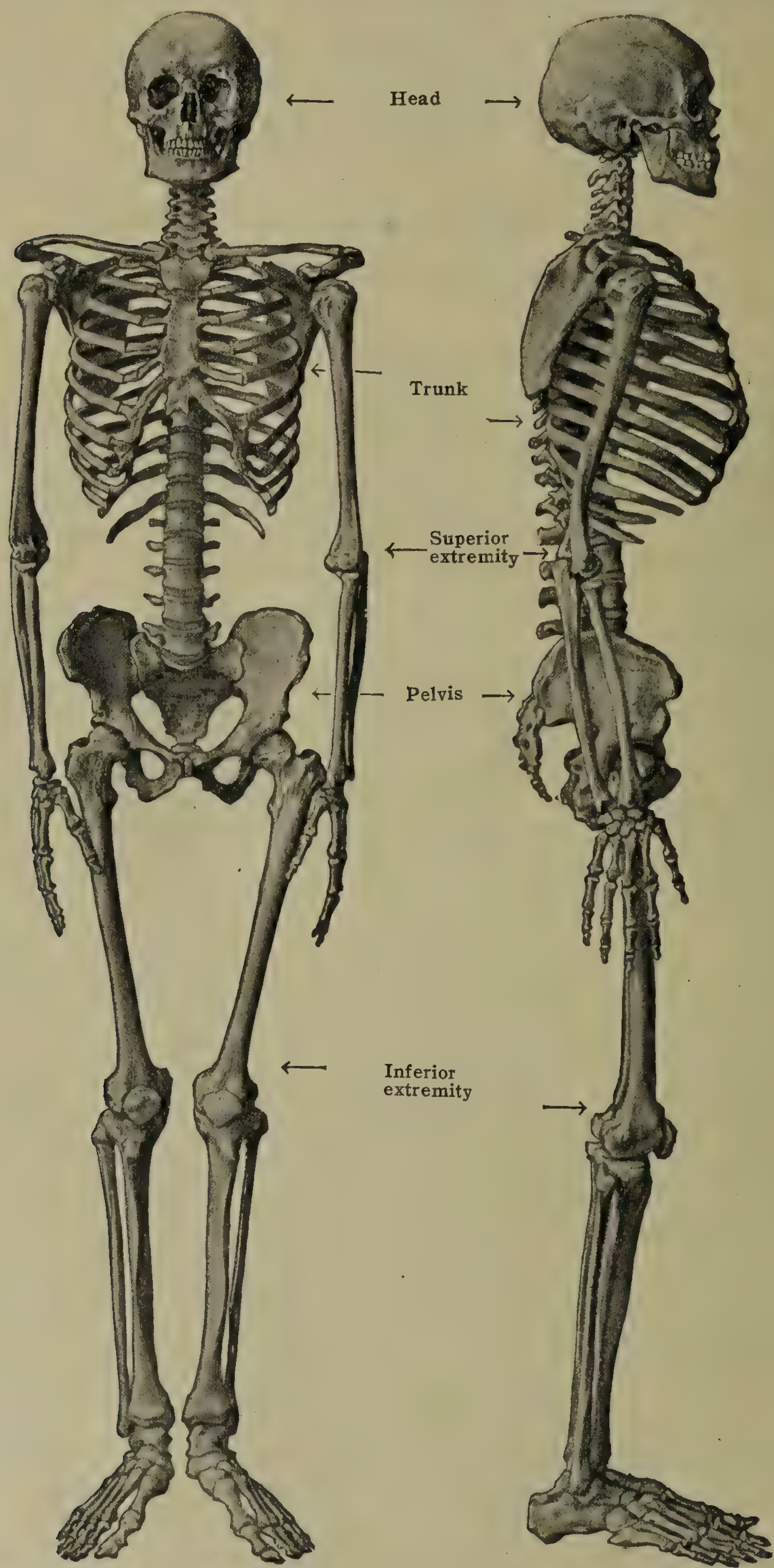


Fig. 91.—The Skeleton as Seen from in Front and from the Right Side. (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

and perivascular lymphatics are present in the Haversian canals. Very little is known concerning the **nerves** which accompany the arteries into bone.

Among the **physical properties** of bone of special interest is that of *elasticity*, which declines in old age, the bones becoming brittle and liable to fracture.

The *strength* of a bone has been determined in various ways with pressure in the direction of its long axis. The femur broke at 263–400 kg.; the humerus at 174–276 kg. (Messerer).

In regard to *hardness*, there is not a great deal of variation generally throughout the skeleton; the petrous portion of the temporal bone is exceptionally hard. The *specific gravity* of bone ranges from 1.87 to 1.97.

The *color* of bones in the living is white tinged very slightly with pink and yellow.

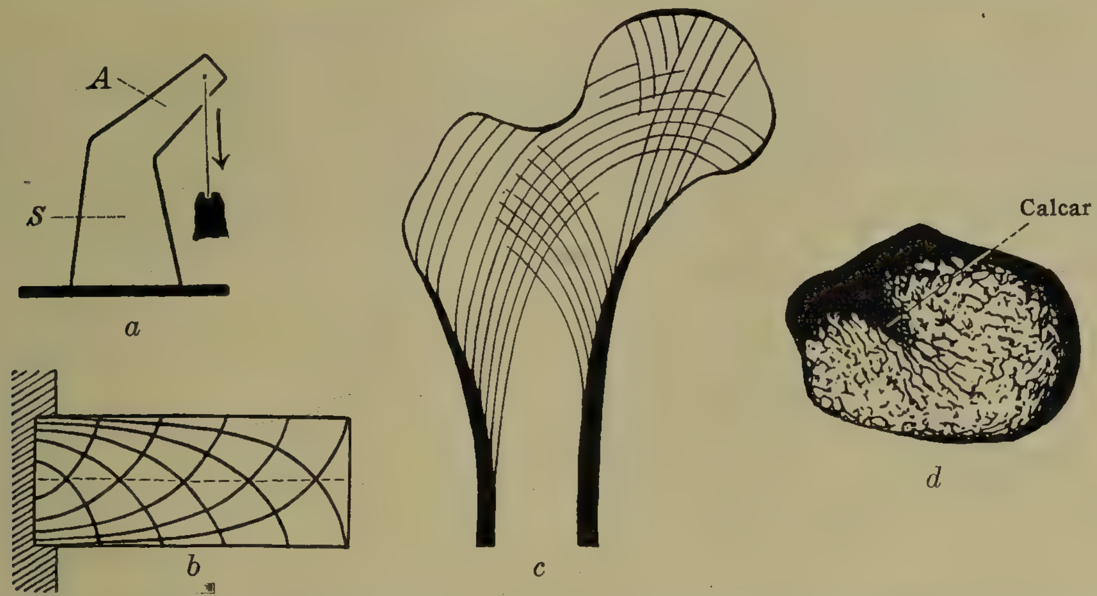


FIG. 92.—MECHANICS OF BONE. (From Braus, Anatomie des Menschen.)
a, Crane of the form of the neck of the femur; *b*, beam set in a wall with trajectories (after H. v. Meyer); *c*, human femur (after Meyer), compact substance black, *d*, transverse section through the neck of the right femur (after Quain's Anatomy).

FIG. 93.—ARTERIAL SUPPLY OF LONG BONES AS SHOWN BY INJECTION OF QUICKSILVER. (After Lexer, Kuliga and Türk, in Braus, Anatomie des Menschen.)
a, Humerus; in the upper end of the bone numerous perforating rami from diaphyseal arteries are seen entering the epiphysis. *b*, metacarpal bone of the thumb.

Burning a bone in the air reduces its weight one-third and the residue consists of earthy salts chiefly phosphate of lime. The mineral matter may be removed from a bone by treating it with an acid; there remains a tough, elastic substance, retaining the form of the original bone and which on boiling yields gelatine.

Like other systems, the osseous framework is subject to **variation.** The bones in developing, are among the last organs to assume their definitive shapes and are directly or indirectly under the environmental influences of all the soft structures. Skeletal variations may or may not represent heritable characters. In the following discussion of the bones, only a few of the more typical and important variations are noted.

The number of bones in the skeleton varies at different ages (see p. 30), some, which are originally quite independent, becoming united as age advances. Classified with respect to the subdivision of the body into trunk (with the head) and limbs, they comprise an **axial skeleton,** which includes the vertebral column, the skull, the ribs, and the sternum, and an **appendicular skeleton,** belonging to the limbs. The following table shows the number of bones usually distinct in middle life, including the auditory ossicles:—

		Bones
Axial Skeleton	The vertebral column	26
	The skull	29
	The ribs and sternum	25
Appendicular Skeleton	The upper limbs	64
	The lower limbs	62
	Total	206

Several of the skull-bones are **compound,** i. e., in the immature skeleton they consist of separate elements which ultimately unite to form a single bone. In order to comprehend the

Fig. 94.—The Tibia and Fibula in Section to Show the Epiphyses.

nature of such bones it is advantageous to study them in the various stages through which they pass in the process of development in the fetus and the child.

It follows, therefore, that to appreciate the **morphology** of the skeleton the mode of development of the bones must be studied, as well as their shapes and relations.

Some bones arise by **ossification** in **membrane,** others in **cartilage.** In the embryo, many portions of the skeleton are represented by cartilage which may become infiltrated by lime-salts—**calcification.** This earthy material is later replaced in a regular manner by true bone—**ossification.** Portions of the original cartilage persist at the articular ends of bones, and, in young bones, at the **epiphysial synchondroses** [synchondrosis epiphyseos], i. e., the planes of junction of the main part of a bone with the independently ossifying parts called **epiphyses.** Long bones increase in length at the **epiphysial cartilages,** and increase in thickness by ossification subjacent to the deeper layers of the investing membrane or **periosteum.** These processes proceed concurrently in the limb-bones of a young and growing mammal.

There is no bone in the human skeleton which, though preformed in cartilage, is perfected in this tissue. The ossification is completed in membrane. On the other hand, there are numerous instances in the skull, of bones the ossification of which begins, and is continued for some time within the original membranous walls of the primordial cranium. Further details of skeletal development and ossification are included in the description of each bone. (For early development, see p. 28.)

The **limb-bones** differ in their development in several important particulars from those of the skull. Some of the long bones have many centers of ossification, but these have not the

same significance as those of the skull. It is convenient to group the centers into two sets, **primary** and **secondary**. The **primary center** of a long bone appears quite early in fetal life, and extends to form the main part, shaft or **diaphysis**. In only three instances does a **secondary** center appear before birth, e. g., the lower end of the femur, the head of the tibia, and occasionally the head of the humerus. Many primary ossific centers appear after birth. When a bone possesses one or more secondary centers, the primary nucleus, as a rule, appears early.

Secondary centers which remain for a time distinct from the main portion form additions to the bone termed **epiphyses** (fig. 94). An epiphysis may arise from a single center, as is the case at the lower end of the femur, or from several, as at the upper end of the humerus. Prominences about the ends of long bones may be capped by separate epiphyses.

The time of the appearance of epiphysial centers and the time of union of the epiphyses with the main bone seem to follow certain rules, thus:—

1. Those epiphyses of a long bone whose centers of ossification appear last are generally the first to unite with the shaft.

2. The epiphysis toward which the nutrient artery is directed is the first to be united with the shaft. It is also found that whereas the increase in length of the long bones takes place at the epiphysial cartilages, the growth takes place more rapidly and is continued for a longer period at the end where the epiphysis is the last to unite. It is claimed that the shifting of the investing periosteum, which apparently results from these two factors, leads to obliquity of the nutrient canal by drawing the proximal portion of the nutrient artery toward the more rapidly growing end. Moreover, when a bone has only one epiphysis, the nutrient artery will be directed toward the extremity which has no epiphysis.

3. The centers of ossification appear earliest in those epiphyses which bear the largest relative proportion to the shafts of the bones to which they belong.

4. When an epiphysis ossifies from more than one center, the various centers coalesce, as a rule, before the shaft and epiphysis consolidate, e. g., the upper end of the humerus.

I. THE AXIAL SKELETON

A. THE VERTEBRAL COLUMN

The **vertebral column** [columna vertebralis] (fig. 112) functions as a pillar for the support of the trunk and as a case for the protection of the spinal cord and

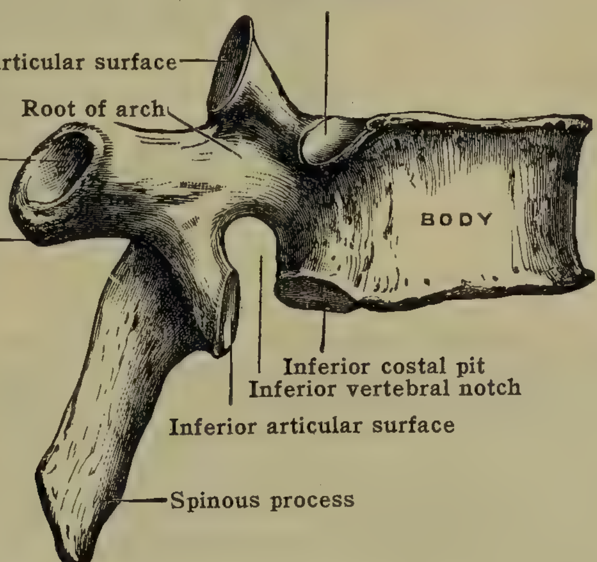


FIG. 95.—A THORACIC VERTEBRA. (Right side.)

nerve roots. It consists of a series of bones called **vertebræ,** closely connected by means of fibrous and elastic structures, which allow of a small amount of motion between any two adjacent members of the series, but which give to the column as a whole a high degree of flexibility. Stability of the vertebral column is secured partly through the form of the individual vertebræ and the form of the entire pillar, but also to a large extent by means of ligamentous connections and muscular control.

In the young subject the vertebræ are thirty-three in number. Of these, the upper twenty-four remain separate throughout life, and are distinguished as **movable** or **true vertebræ.** The succeeding five vertebræ become consolidated in the adult to form one mass, called the **sacrum,** and at the terminal part of the column are four rudimentary vertebræ, which also tend to become united as age advances, to form the **coccyx.** The lower nine vertebræ thus lose their mobility as individual bones, and are accordingly known as the **fixed** or **false vertebræ.** Of the true vertebræ, the first seven, located in the neck, are called **cervical vertebræ** [vertebræ cervicales], the succeeding twelve, in the arch of the

back, **thoracic** or **dorsal vertebræ** [vertebræ thoracales], and the remaining five, in the loins, **lumbar vertebræ** [vertebræ lumbales].

Although the vertebræ of the several regions of the column differ markedly in many respects each is constructed on a common plan. The essential characters are well seen in the vertebræ near the middle of the thoracic region, and it will be advantageous to commence the study of vertebral structure with one selected from this region.

Description of a thoracic vertebra (figs. 95, 96).—The vertebra consists of two essential parts—a body in front and an arch behind.

The **body of the vertebra** [corpus vertebræ] or **centrum** functions in supporting the weight of the trunk. It is a short column of bone, the upper and lower surfaces of which are rough for the intervertebral fibrocartilages, with the margins slightly lipped.

The body is deeper behind than in front, and slightly concave on its superior and inferior surfaces. The circumference is concave from above downward in front and at the sides, convex from side to side, and perforated by numerous vascular foramina. Posteriorly it is concave from side to side and presents one or two large foramina for the passage of blood-vessels

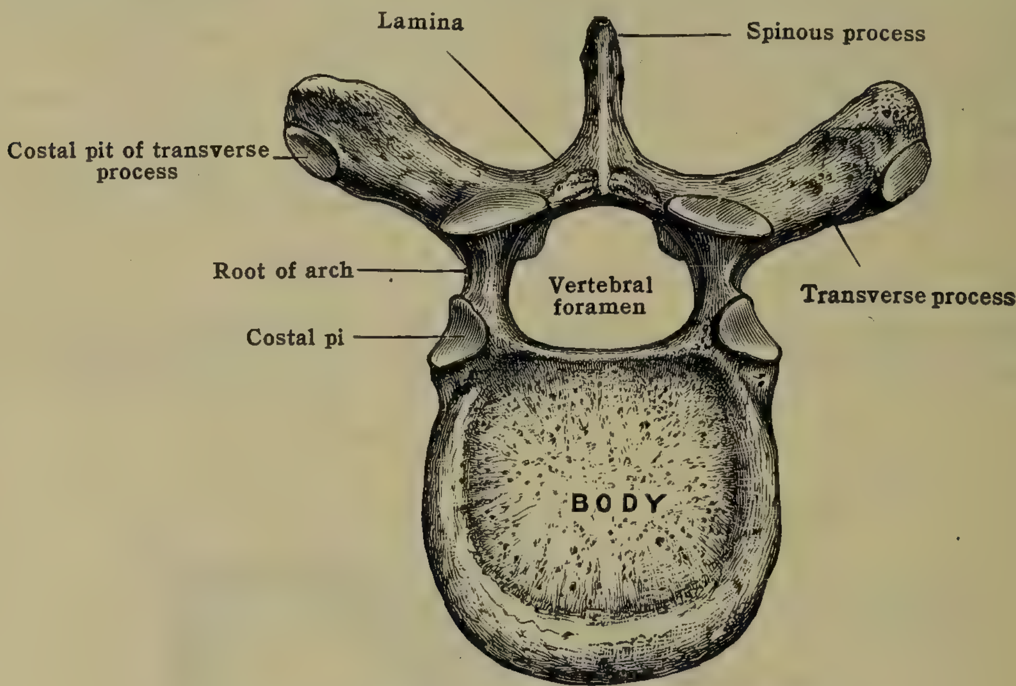


FIG. 96.—A THORACIC VERTEBRA. (Viewed from above.)

to and from the spongy substance of the interior. On each side of the body, at the place where it joins the arch, are two **costal pits** (superior and inferior) [fovea costalis superior; inferior] placed at the upper and lower borders, and when two vertebræ are superimposed, the adjacent costal pits, together with the part of the intervertebral fibrocartilage, form a complete shallow articular pit, nearly circular for the head of a rib.

The **arch of the vertebra** [arcus vertebræ] with the body incloses the vertebral foramen and serves to protect the spinal cord and the roots of the spinal nerves. It is formed by the two roots and two laminæ, and supports seven **processes**—one **spinous**, two **transverse**, and four **articular**. The **roots of the vertebral arch** [radices arcus vertebræ] are two short, constricted columns of bone, projecting backward from the posterior surface of the body. The concavity on the upper and lower borders of each root, of which the lower is much the deeper, is named the **vertebral notch** [incisura vertebralis superior; inferior], and when two vertebræ are in position, the notches form an **intervertebral foramen** [foramen intervertebrale] transmitting the spinal nerves and blood-vessels. The **laminæ** are two broad symmetrical plates of bone which complete the arch posteriorly.

The lamina is rough on the superior border and the lower part of the anterior surface for the attachment of the ligamenta flava which bind together the adjacent vertebræ. The upper part of the anterior surface is smooth, where it forms the posterior boundary of the vertebral canal. When articulated, the laminæ in the thoracic region are imbricated or sloped, the laminæ of the upper vertebra overlapping those of the lower.

The **spinous process** [processus spinosus], is long and three sided, projects backward and downward from the center of the arch and terminates in a slight tubercle. It gives attachment by its prominent borders to many muscles, to the interspinous and supraspinous ligaments.

The **transverse processes** [processus transversus] are two in number and extend laterally and backward from the arch at the junction of the roots and laminæ. They are long, thick columns of bone terminating in clubbed extremities, on each of which is a **costal pit of the transverse process** [fovea costalis processus transversalis] concave for articulation with the tubercle of a rib. The transverse processes, in addition to supporting the ribs, afford attachment to and powerful leverage for muscles.

The **articular processes** [processus articulares superiores; inferiores], two superior and two inferior, project upward and downward opposite the attachments of the transverse processes and form joints between successive vertebræ. The superior are flat and bear **articular surfaces** [facies articulares superiores] which are directed upward, backward, and laterally, and are situated a little in advance of the **inferior articular surfaces** [facies articulares inferiores] which are oval, concave, and directed downward, forward, and medially.

The **vertebral foramen** [foramen vertebrale] is bounded anteriorly by the body, posteriorly and on each side by the arch. It is nearly circular, and is smaller than in the cervical or the lumbar region. When the vertebræ are articulated, the series of vertebral foramina constitute the spinal or **vertebral canal** [canalis vertebralis], in which are lodged the spinal cord and its membranes, the roots of the spinal nerves, the posterior longitudinal ligament and the blood-vessels supplying these structures.

THE CERVICAL VERTEBRÆ

The segment of the vertebral column which forms the axial skeleton of the neck is possessed of a high degree of flexibility, resulting from the peculiar con-

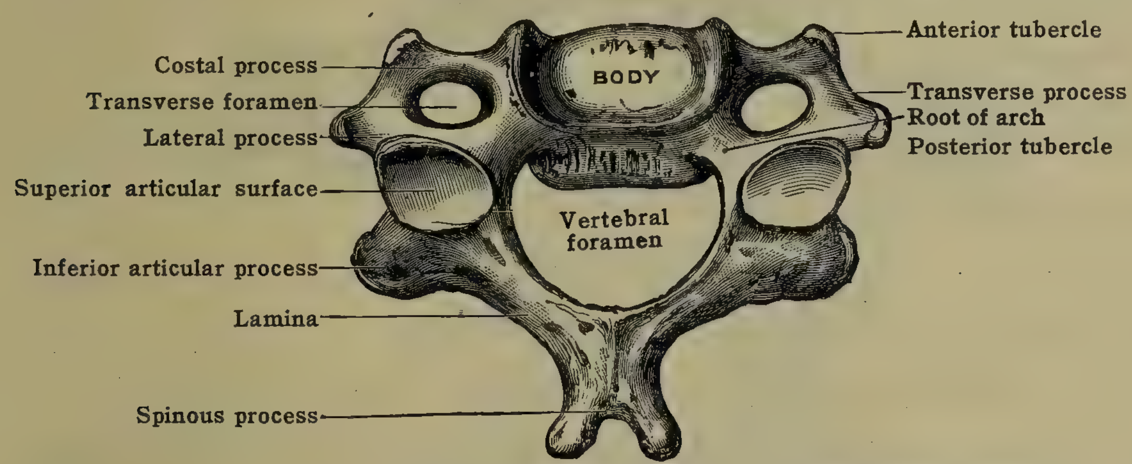


Fig. 97.—A Cervical Vertebra. (Viewed from above.)

formation of its constituent vertebræ and from the special characteristics of the articulations between the individual bones.

A typical cervical vertebra (from the third to the sixth inclusive) presents the following characteristics (figs. 97, 100, 101):—The **body** is smaller than those of other movable vertebræ and, seen from above or below, is of oval shape with the long axis transverse.

The lateral margins of the upper surface of the body are raised into prominent lips, so that the surface is concave from side to side; it is also sloped downward in front. The inferior surface, on the contrary, projects downward in front and is rounded off at the sides to receive the corresponding lips of the subjacent vertebra; it is concave antero-posteriorly and convex from side to side. The partial interlocking of the adjacent bodies provided by these contours, increases the stability of the intervertebral articulations.

The **roots** are directed laterally and backward and spring from the body about midway between the upper and lower borders. The superior and inferior vertebral notches are nearly equal in depth. The **laminæ** are long, narrow, and slender. The **spinous process** is short and bifid at the free extremity.

Articular processes.—Both the superior and inferior articular processes are situated at the junction of the root with the lamina and they form the upper and lower extremities of a short column of bone. The articular surfaces are oblique and nearly flat, the superior looking backward and upward, and the inferior forward and downward.

The **transverse process** presents near its base a circular **transverse foramen** [foramen transversarium] transmitting the vertebral artery, vein, and the associated

vertebral plexus of sympathetic nerves. Moreover, each process presents above a deep **groove for a spinal nerve** [sulcus n. spinalis], and is bifid at its free extremity, terminating in **two tubercles—anterior** and **posterior (of cervical vertebræ)** [tuberculum anterius; posterius, vertebrarum cervicalium].

The **transverse foramen** is characteristic of a cervical vertebra. It is bounded medially by the root, posteriorly by the **lateral process** (which corresponds to the transverse process of a thoracic vertebra), anteriorly by the **costal process** [processus costarius] (which corresponds to the rib in the thoracic region), and laterally by the **costotransverse lamella.** The latter is a bar of bone joining the two processes and directed obliquely upward and forward in the upper vertebræ and horizontally in the lower.

The **vertebral foramen** is triangular with rounded angles; it is larger than in the thoracic or lumbar vertebræ, in adaptation to the cervical enlargement of the spinal cord and the greater mobility of the cervical region of the column.

Peculiar cervical vertebræ.—The various cervical vertebræ possess distinguishing features, though, with the exception of the first, second, and seventh, which are so different as to necessitate separate descriptions, these are largely confined to the direction of the costotransverse lamella, and the size and level of the anterior and posterior tubercles. In the sixth the anterior tubercle is markedly developed and is named the **carotid tubercle** [tuberculum carotis].

The Atlas or First Cervical Vertebra

The atlas (figs, 98, 101), upon which the skull rests, is remarkable in that it lacks a body. It has the form of an irregular ring, and consists of two symmetri-

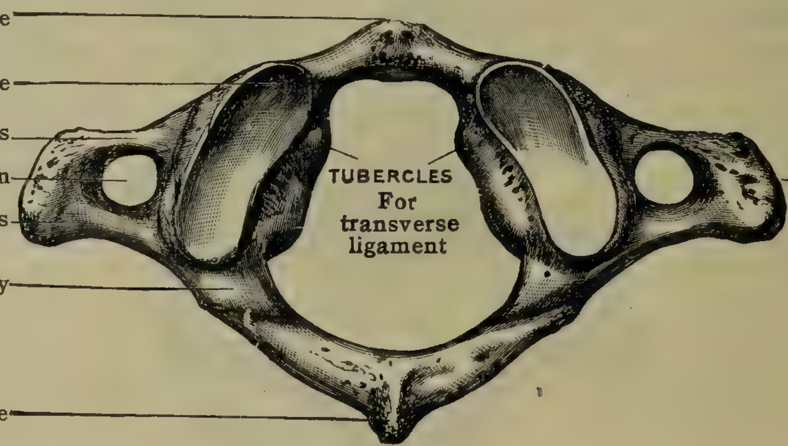


Fig. 98.—The Atlas or First Cervical Vertebra. (Viewed from above.)

cal, thick portions, the **lateral masses** [massa lateralis] united by the **anterior** and **posterior arches** [arcus anterior; posterior]. The lateral masses present **superior articular pits** [fovea articularis superior], for articulation with the occipital condyles, and **inferior articular surfaces** [facies articulares inferiores], meeting the anterior articular surfaces of the epistropheus. The **anterior arch** joins the lateral masses in front and constitutes about one-fifth of the entire circumference of the ring. On its anterior surface it presents a median **anterior tubercle** [tuberculum anterius] for the attachment of the longus colli muscle and the anterior longitudinal ligament, and on its posterior surface a circular **facet** [fovea dentis], concave from side to side, for articulation with the **odontoid process** [dens] of the epistropheus. The upper and lower borders serve for the attachment of ligaments uniting the atlas to the occipital bone and epistropheus respectively.

The **lateral masses** are thick and strong, and extend laterally into the transverse processes. The superior articular pits are elongated, oval, deeply concave, and converge in front in adaptation to the convexities of the occipital condyles. The inferior articular surfaces, circular and concave in the sagittal direction and slightly concave transversely, are directed downward and medially and articulate with the anterior articular surfaces of the epistropheus. The articular surfaces of the atlas, like the anterior articular surfaces of the epistropheus, differ from those of other vertebræ in being situated in front of the places of exit of the spinal nerves.

Between the upper and lower articular surfaces on the inside of the ring are two smooth rounded **tubercles**, one on each side, to which the transverse ligament of the atlas is attached. This ligament divides the interior of the ring into a smaller anterior part for the dens of the epistropheus, and a larger posterior part, corresponding to the vertebral foramen of other vertebræ, for the spinal cord and its membranes.

The **transverse processes** are large and extend farther laterally than those of the vertebræ immediately below. They are flattened from above downward and each is perforated by a large **transverse foramen**; the extremity is commonly not bifid, but is broad and rough for the attachment of numerous muscles. The **posterior arch** [arcus posterior] unites the lateral

masses behind and forms about two-fifths of the entire circumference. It presents in the middle line a rough elevation the **posterior tubercle** [tuberculum posterius] representing a rudimentary spinous process. The posterior arch, at its junction with the lateral mass presents on its superior surface a deep **groove for the vertebral artery,** [sulcus arteriæ vertebralis], which lodges also the suboccipital (first spinal) nerve. The groove is occasionally converted into a foramen

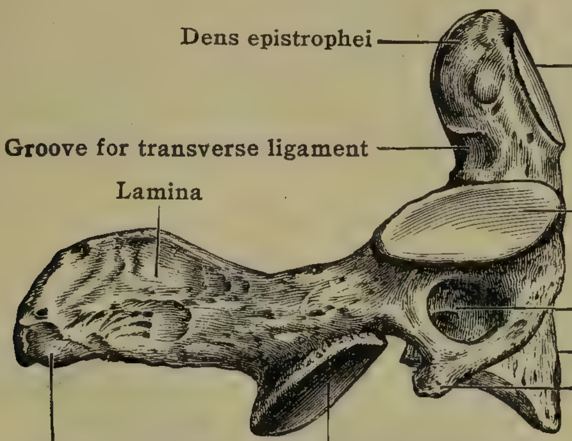


FIG. 99.—THE EPISTROPHEUS OR AXIS. (Right side.)

by a bony arch—the ossified oblique ligament of the atlas. A shallow notch is present on the inferior surface of the posterior arch, and, with a corresponding notch on the epistropheus, forms an intervertebral foramen for the exit of the second spinal nerve. The upper and lower surfaces of the posterior arch afford attachment to ligaments uniting the atlas to the occipital bone and to the epistropheus.

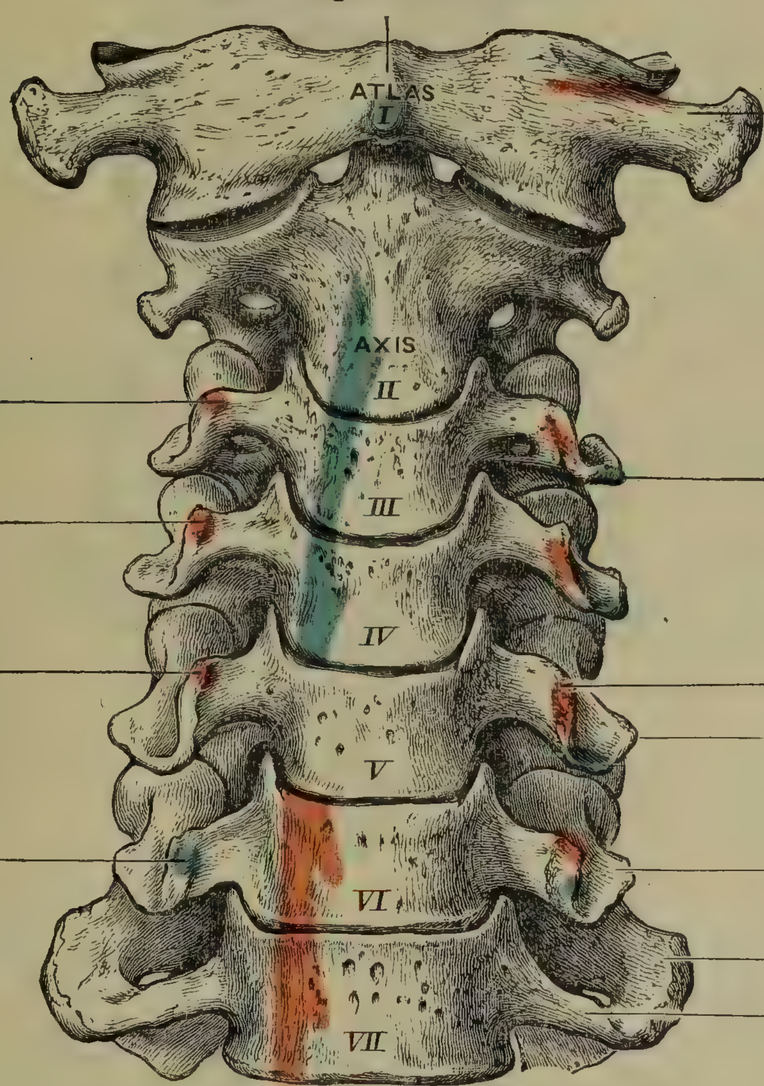


FIG. 100.—THE CERVICAL VERTEBRÆ. (Anterior view.) Showing attachments of muscles.

THE EPISTROPHEUS (AXIS)

The **epistropheus** (axis) (fig. 99), the second vertebra, is the thickest and strongest of the cervical vertebræ, and is so named from forming a pivot on

which the atlas rotates, carrying upon it the head. It is easily recognized by the projecting **odontoid process** [dens] which surmounts the upper surface of the body. The **anterior articular surfaces** [facies articulares anteriores] are remarkable in occupying positions partly on the roots and partly on the body. They articulate with the inferior articular surfaces of the atlas. The **posterior articular surfaces** [facies articulares posteriores] meeting the superior articular surfaces of the third vertebra, conform to the cervical type.

The odontoid process, which represents the displaced body of the atlas, is large and blunt, and bears on its anterior surface an oval saddle-form facet for articulation with the facet on the

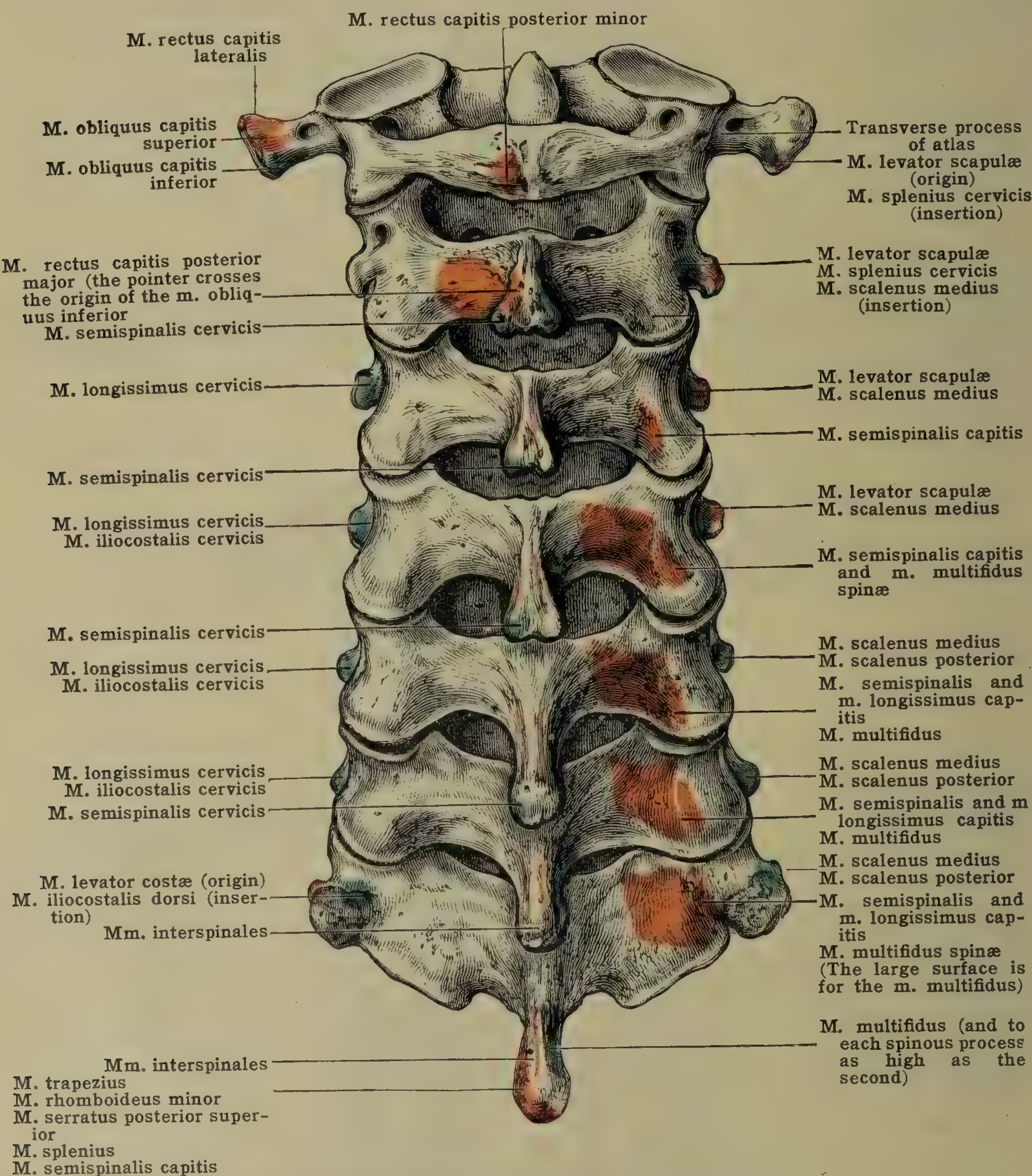


FIG. 101.—THE CERVICAL VERTEBRÆ. (Posterior view.)

posterior surface of the anterior arch of the atlas; posteriorly it presents a smooth groove which receives the transverse ligament of the atlas. To the apex is attached the apical dental ligament, and to the rough surface on the side of the apex are fastened the alar ligaments which connect it with the occipital bone. The inferior surface of the body resembles that of the succeeding vertebræ. Its anterior surface is marked by a median ridge separating two lateral depressions for the insertion of the longus colli muscle.

The roots (pedicles), are stout and broad; the **laminæ** are thick and prismatic: the **spinous process** is large and strong, deeply concave on its under surface, and markedly bifid; the **transverse processes** are small, not bifurcated and not grooved. The **transverse foramen** is directed very obliquely upward and laterally and the costal is larger than the lateral process.

The **anterior articular surfaces** are oval, convex in the sagittal direction, and directed upward and laterally for articulation with the atlas and are like the latter in being situated in

front of the superior vertebral notches. The **posterior articular surfaces** are similar in form and position to those of the succeeding vertebræ.

The Vertebra Prominens

Situated at the junction of the cervical and thoracic regions of the vertebral column, the seventh cervical vertebra (figs. 100, 101) may be described as a transitional vertebra—i. e., possessing certain features characteristic of both regions.

The **spinous process** is longer than that of any of the other cervical vertebræ. It is not bifurcated, but ends in a broad tubercle projecting beneath the skin, whence the name **vertebra prominens** has been applied to this bone. The **transverse process** is massive.

The costal process is very small, but, on the other hand, the posterior or lateral part of the process is large and so more like the transverse process of a thoracic vertebra. The **transverse foramen** is the smallest of the series and may be absent. It does not, as a rule, transmit the vertebral artery, but frequently gives passage to a vein.

Musculature.—The **muscular attachments** of the cervical vertebræ are shown in figs. 100 and 101, and described in Section V.

Variations.—The cervical vertebræ exhibit great variation in regard to the extremities of their spinous processes. As a rule among Europeans, the second, third, fourth, and fifth vertebræ possess bifid spines. The sixth and seventh exhibit a tendency to bifurcate, their tips presenting two small lateral tubercles; sometimes the sixth has a bifid spine, and more rarely the seventh presents the same condition. Occasionally all the cervical spines, with the exception of the second, are non-bifid, and even in the axis the bifurcation is not extensive. In the colored races of men the cervical spines are relatively shorter and more stunted than in Europeans generally and, as a rule, are simple. The only cervical vertebra which presents a bifid spine in all races is the epistropheus; even this may be non-bifid in the Negro, and occasionally in the European. The laminæ of the lower cervical vertebræ frequently present posteriorly distinct tubercles from which fasciculi of the multifidus muscle arise. They are usually confined to the sixth and seventh vertebræ, but are fairly frequent on the fifth, and are occasionally seen on the fourth.

In the atlas, ossification of the anterior or posterior arch may be incomplete. The groove for the vertebral artery is not rarely converted into a foramen (typical for mammals). Paired ossicles have been noted in the posterior atlantooccipital membrane, and have been interpreted as vestiges of a proatlas. Fusion, partial or complete, of the atlas with the occipital bone (atlas assimilation) sometimes occurs. The posterior tubercle of the atlas rarely is bifid; the transverse process occasionally presents two tubercles. The dens may form a separate *os odontoideum.* An ossicle sometimes occurs in the apical ligament. Fusion of the axis with the third vertebra is not rare. The spinous process of the seventh cervical is very often less prominent than that of the first thoracic vertebra. The transverse process of the seventh may be bifid. Occasionally the costal process is replaced by a cervical rib. It will be recalled that cervical ribs are normally present in reptiles and birds. The body sometimes bears on each side near the lower border a costal pit for the head of the first rib. When this is present, there is usually a well-developed cervical rib.

THE THORACIC VERTEBRÆ

These vertebræ support the ribs and indirectly the sternum and so enter into the constitution of the skeleton of the thorax. The general characters of the thoracic (or dorsal) vertebræ have already been considered (p. 90). The distinguishing features of the bones of this series are the **costal pits of the transverse processes** and sides of the **bodies** articulating with the **tubercles** and **heads of the ribs** respectively.

Peculiar thoracic vertebræ.—Several vertebræ in this series differ from the typical example. The exceptional ones are—the **first, ninth, tenth, eleventh,** and **twelfth** (fig. 102).

The **first** thoracic vertebra is a transitional vertebra. The **body** in its general conformation approaches very closely the seventh cervical, in that the greatest diameter is transverse, and its upper surface is concave from side to side. On each side is an entire costal pit, close to the upper border, for the head of the first rib, and a very small pit below for the head of the second rib. The **spinous process** is thick, strong, almost horizontal and frequently more prominent than that of the seventh cervical, an important point to remember when counting the spines in the living subject.

The **ninth** has superior costal pits, and usually no inferior.

The **tenth** usually has an entire costal pit at its upper margin, on each side, but occasionally only a superior (half) costal pit. It has no lower pits and the pits on the transverse processes are usually small.

It should be noted that the costal pits of the transverse processes are located at a higher level in the eighth, ninth and tenth, than in the vertebræ above them in the series.

The **eleventh** presents a large body resembling that of a lumbar vertebra. The costal pits, located on the roots, are complete and of large size. The transverse processes are short, show evidence of subdivision into three parts, and have no costal pits.

The **twelfth thoracic** resembles in general characters the eleventh, but may be distinguished from it by the articular surfaces on the inferior articular processes being convex and turned laterally as in the lumbar vertebræ. The transverse process is rudimentary and tripartite, presenting for examination three tubercles, *superior*, *inferior*, and *lateral*, which correspond respectively to the mammillary, accessory, and transverse processes of a lumbar vertebra. There is one complete pit on the root for the head of the twelfth rib.

Variations.—The body of the first thoracic may present on one or both sides two costal pits like those of the type; in such cases the articulation of the head of the first rib is completed by a costal pit on the body of the seventh cervical. The twelfth thoracic, in the absence of the twelfth pair of ribs, commonly conforms to the type of a lumbar vertebra. The transverse process of the tenth occasionally lacks the facet for costal articulation. The lumbar form of

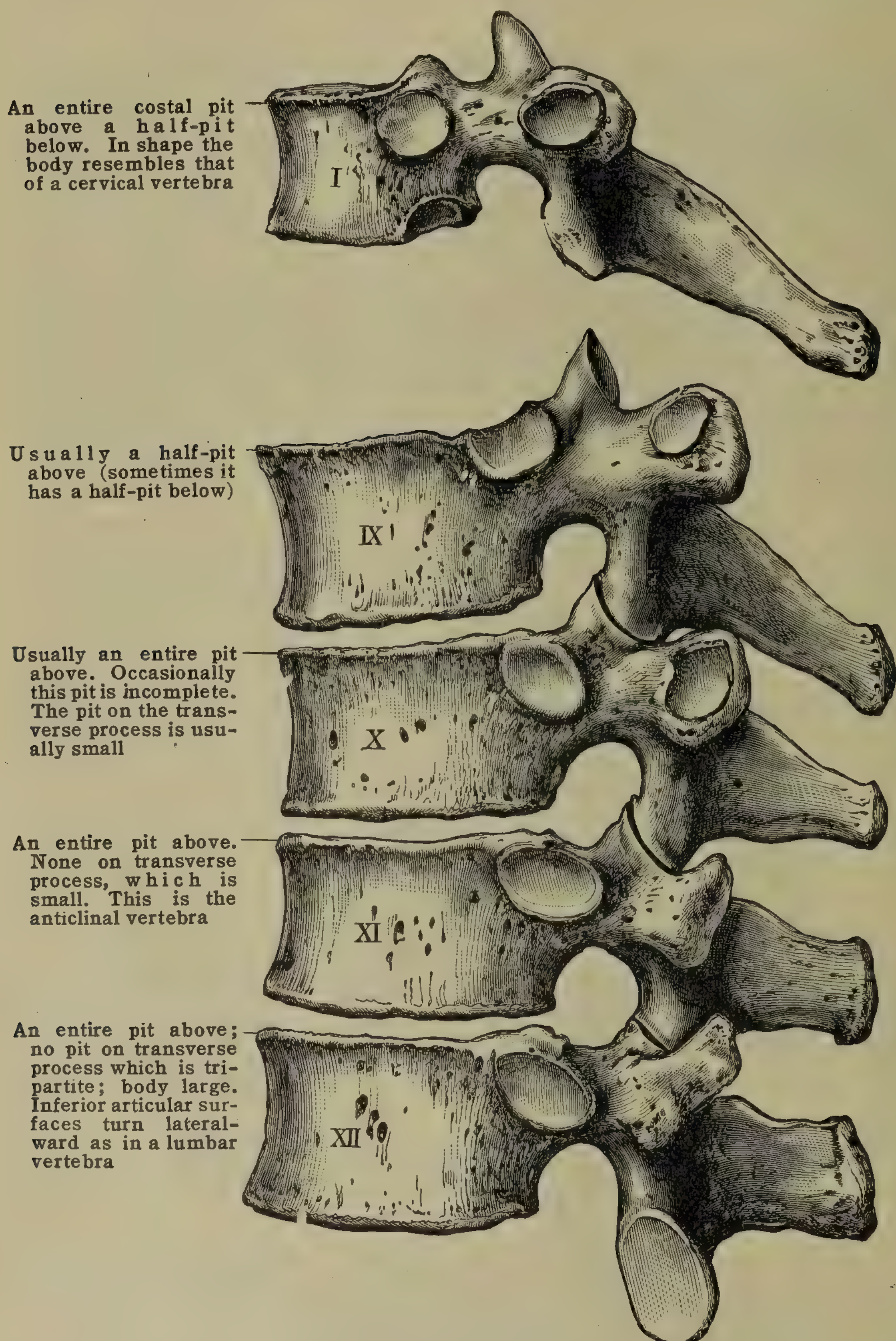


Fig. 102.—Peculiar Thoracic Vertebræ. (Left side.)

transverse process may be present in the eleventh thoracic vertebra. The transition from the thoracic to the lumbar type of articular processes may occur in the eleventh thoracic or in the first lumbar instead of in the twelfth thoracic. The articular process may be of the lumbar type on one side and thoracic on the opposite, resulting in asymmetry in the articulation (cf. Whitney, Am. Jour. Phys. Anthrop., 9, 1926). A peculiarity, more frequent in the thoracic and lumbar than in the cervical and sacral regions of the column, is the existence of a half-vertebra (fig. 113). Such specimens have a wedge-shaped half-centrum, to which are attached a lamina, a transverse process, superior, and inferior articular processes, and half a spinous process. As a rule, a half-vertebra is ankylosed to the vertebræ above and below.

THE LUMBAR VERTEBRÆ

The lumbar segment of the vertebral column is massive to support the weight of the head, thorax and upper limbs, yet sufficiently flexible to permit of a considerable range of movement. The **lumbar vertebræ** (figs. 103, 104) are distinguished from the cervical and thoracic vertebræ by their large size and by the absence of costal pits and transverse foramina.

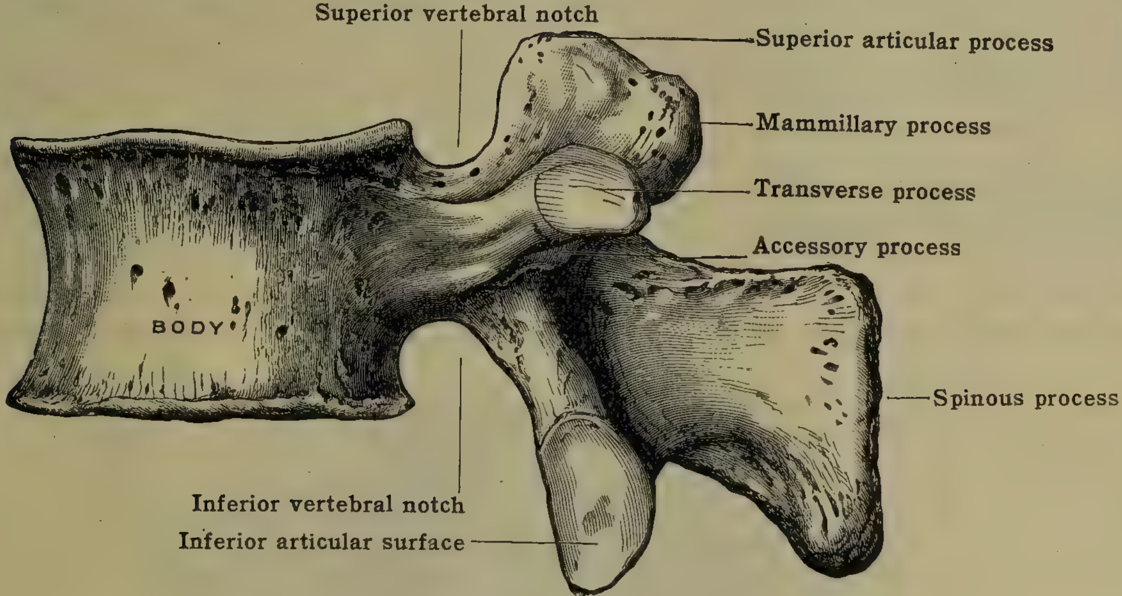


FIG. 103.—A LUMBAR VERTEBRA. (Side view.)

The **body** is somewhat reniform, with the greatest diameter transverse, flat above and below, and generally slightly deeper in front than behind. The **roots** are strong and directed straight backward, and the inferior vertebral notches are deep and large. The **laminæ** are shorter and thicker than those of the thoracic or cervical vertebræ, and the **vertebral foramen** is triangular, wider than in the

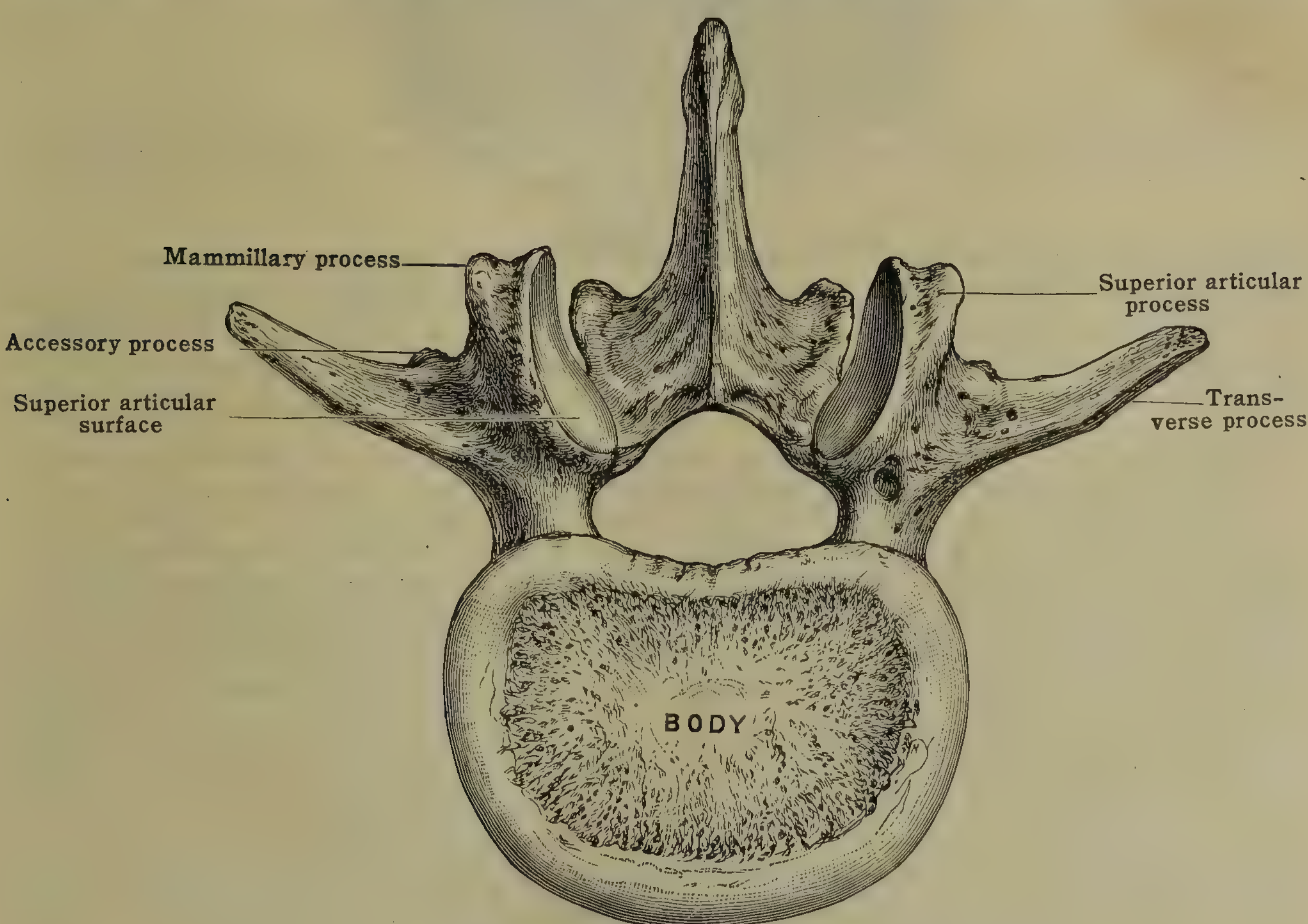


FIG. 104.—A LUMBAR VERTEBRA. (Viewed from above.)

thoracic, but smaller than in the cervical region. The vertebral canal of the lumbar region contains the termination of the spinal cord and its membranes and bloodvessels, and the cauda equina. The **spinous process**, thick, broad, and somewhat quadrilateral, projects horizontally backward. The **articular processes** are thick and strong. The superior articular surface is concave and directed

backward and medially; the inferior is convex and looks forward and laterally. The superior processes are more widely separated than the inferior pair and embrace the inferior articular processes of the vertebra above.

The posterior margin of each superior articular process is surmounted by the **mammillary process** [processus mammillaris] which corresponds to the superior tubercle of the transverse process of the last thoracic vertebra. The **transverse processes** are long, slender, somewhat spatula-shaped, compressed from before backward, and directed laterally and a little backward. They are longest in the third vertebra and diminish in the fourth, second, and fifth, in this order, to the first, in which they are shortest of all. Their extremities are in series with the lateral tubercles of the transverse processes of the twelfth thoracic vertebra. Behind the base of each transverse process is a small eminence, directed downward, named the **accessory process** [processus accessorius]. It is best developed in the vertebræ in the middle of the lumbar region.

The **fifth lumbar vertebra** deviates in some of its features widely from the other members of the series. It is massive, and the **body** is much thicker in front than behind; it articulates below with the base of the sacrum forming with it the *sacrovertebral angle.* The **transverse processes** are short, thick, conical, and spring from the body as well as from the roots of the arch. They afford attachment to

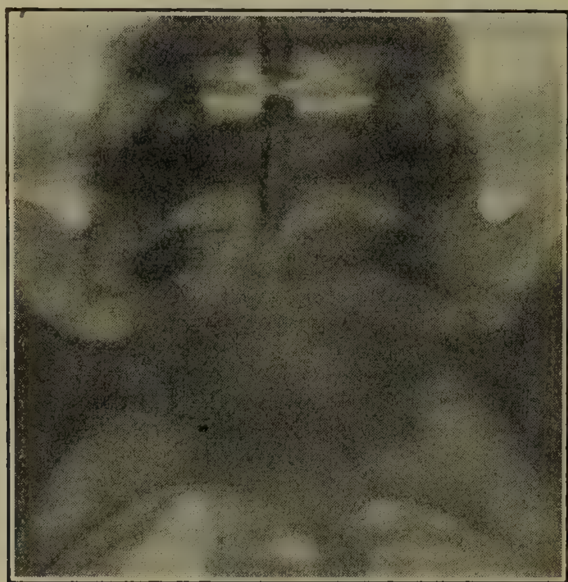


Fig. 105.—Radiogram Showing Defective Arch of the Fifth Lumbar Vertebra in a Case of Spina Bifida.

the iliolumbar ligaments. The **spinous process** is smaller than that of any of the other lumbar vertebræ; the **laminæ** project into the vertebral foramen on each side; and the **roots** are stout and flattened from above downward. The **inferior articular processes** are separated to such a degree as to be wider apart than the superior, and they articulate with the superior articular processes of the sacrum.

Variations.—The first lumbar may present the transitional form of articular processes as already mentioned (p. 96). A lumbar rib may be present united (a) with the anterior surface of the transverse process, or (b) with the tip of a short transverse process. The accessory process may be elongated, rudimentary or absent. It is specially concerned in sacralization of the fifth lumbar vertebra. The fifth lumbar vertebra is subject to variations of several sorts of which the two following are of special interest. (a) The **roots** of the arch in this vertebra are liable to a remarkable deviation from the conditions found in other parts of the spine. The peculiarity consists of a complete solution in the continuity of the arch immediately behind the superior articular processes. In such specimens the anterior part consists of the body carrying the roots, transverse and superior articular processes; while the posterior segment is composed of the laminæ, spine, and inferior articular processes. The posterior segment of this vertebra may even consist of two pieces. A similar condition is occasionally met with either unilaterally or bilaterally in the thoracic vertebræ. (b) The fifth lumbar may show a tendency to conform to the type of upper sacral vertebræ, with which it may become fused (p. 103). Fusion of the spinous processes of the fifth lumbar and first sacral vertebra is one of the commonest anomalies of the region. Failure in the union of the halves of the vertebral arch, and defective laminae in this and other regions of the column are found in *spina bifida* (fig. 105).

THE SACRUM

The five sacral vertebræ (figs. 106, 107) are united in the adult to form the **os sacrum,** a large, curved, wedge-shaped bone, forming the base of the vertebral column and lying between and firmly connected with the hip bones. Together with the coccyx, it completes the posterior boundary of the minor pelvis. Of

the five vertebræ which compose the sacrum the uppermost is the largest, the succeeding ones become rapidly smaller, and the fifth is quite rudimentary. In the erect posture the sacrum lies obliquely, being directed from above downward and backward, and the most projecting part of the pelvic surface at the base, known as the **promontory** [promontorium] forms with the last lumbar vertebra an anterior projection known as the sacrovertebral angle.

Surfaces.—The **pelvic surface,** [facies pelvina] directed downward and forward, is smooth, concave from above downward and slightly from side to side. It is crossed in the middle by four transverse ridges [lineæ transversæ] which mark the positions of the intervertebral disks and separate the bodies of the five sacral vertebræ. Of the bodies, the first and second are nearly equal in size and are larger than the third, fourth, and fifth, which, in vertical depth, are also nearly equal to each other. At the extremities of the transverse ridges on each side are four openings, called the **anterior sacral foramina** [foramina sacralia anteriora]

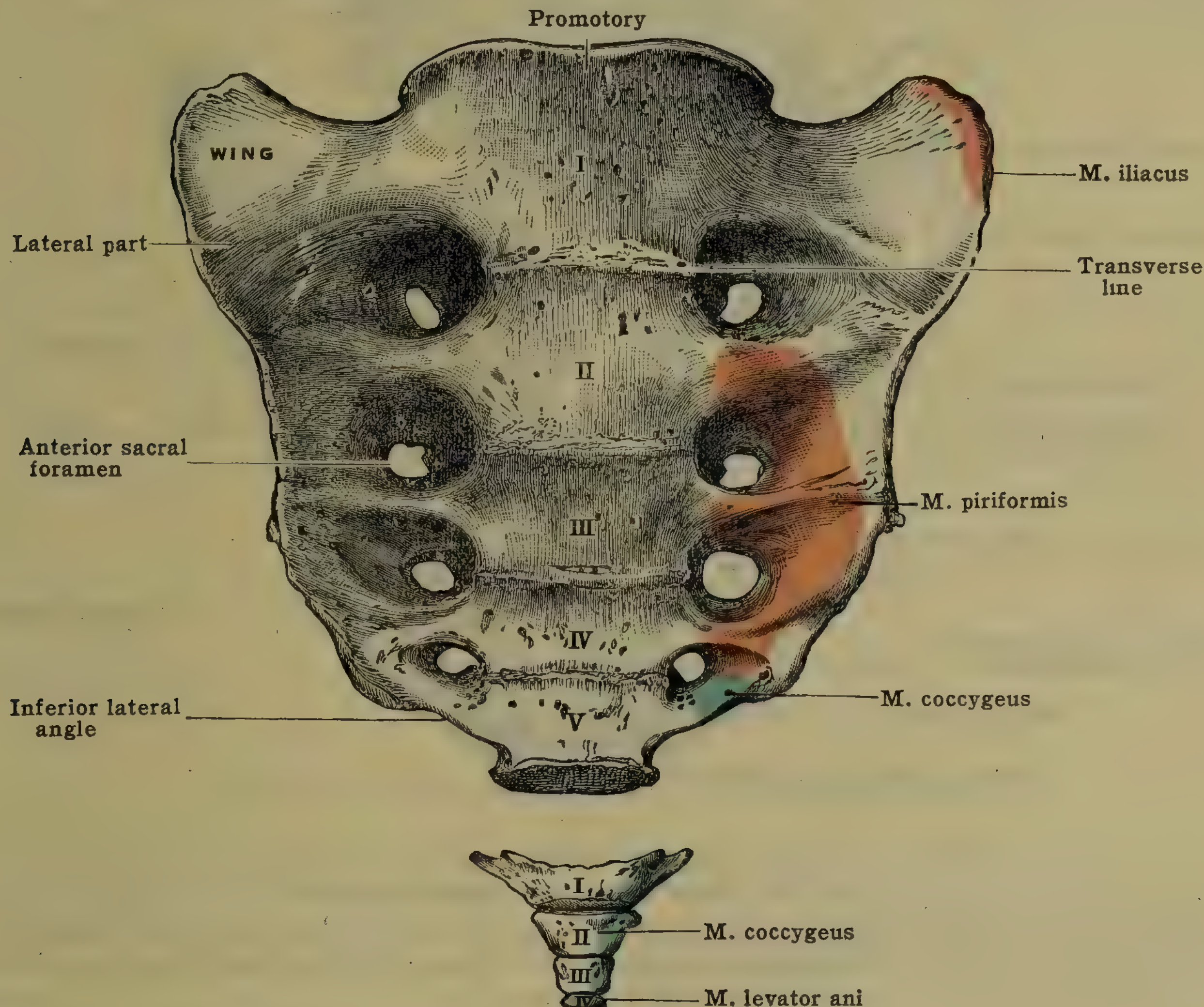


FIG. 106.—THE SACRUM AND COCCYX. (Pelvic surface.)

which transmit the anterior divisions of the first four sacral nerves, and branches of the lateral sacral arteries. The foramina are separated by wide processes, which laterally enter into the formation of the **lateral portion** (or mass) [pars lateralis]. Between these processes and extending laterally from the anterior sacral foramina are broad grooves occupied by the sacral nerves. The pelvic surface is rough opposite the second, third, and fourth sacral vertebræ, where the piriformis muscle takes origin. The lateral part of the fifth sacral vertebra gives insertion to the coccygeus muscle.

The **dorsal surface** [facies dorsalis] is strongly convex and rough giving origin to the powerful sacrospinalis muscle. The midline is occupied by the **median sacral crest** [crista sacralis media] representing the somewhat suppressed upper four **spinous processes.** Of these the first is the largest, the second and third may be confluent, and the fourth is rudimentary. The bone on each side of the median sacral crest is slightly hollowed and is formed by the united **laminæ.** In the fourth sometimes, but always in the fifth, the laminæ fail to meet in the middle line, leaving the **sacral hiatus** [hiatus sacralis], at the termination of the spinal canal.

Lateral to the median sacral crest are the paired **articular sacral crests** [cristæ sacrales articulares] representing the **articular processes** of the vertebræ above. In series with them superiorly are the large pair of articular processes meeting the inferior articular processes of the fifth lumbar vertebra, and inferiorly the **sacral cornua** [cornua sacralia] which bound laterally the sacral hiatus and articulate with the coccygeal cornua.

Immediately lateral to the articular processes are the **posterior sacral foramina** [foramina sacralia posteriora], four on each side; they are smaller than the anterior, and give exit to the posterior primary divisions of the first four sacral nerves and branches of the lateral sacral arteries. Lateral to the foramina on each side are five elevations representing the **transverse processes.** The first pair, situated at the junction of the posterior surface with the base, are large and conspicuous; all serve for the attachment of ligaments and muscles.

Together they form on each side of the sacrum the irregular **lateral sacral crest** [crista sacralis lateralis]. The space between the spinous and transverse processes presents a shallow concavity known as the **sacral groove,** continuous above with the vertebral groove of the upper part of the column, and, like it, lodging the multifidus muscle. Bridging across the groove and

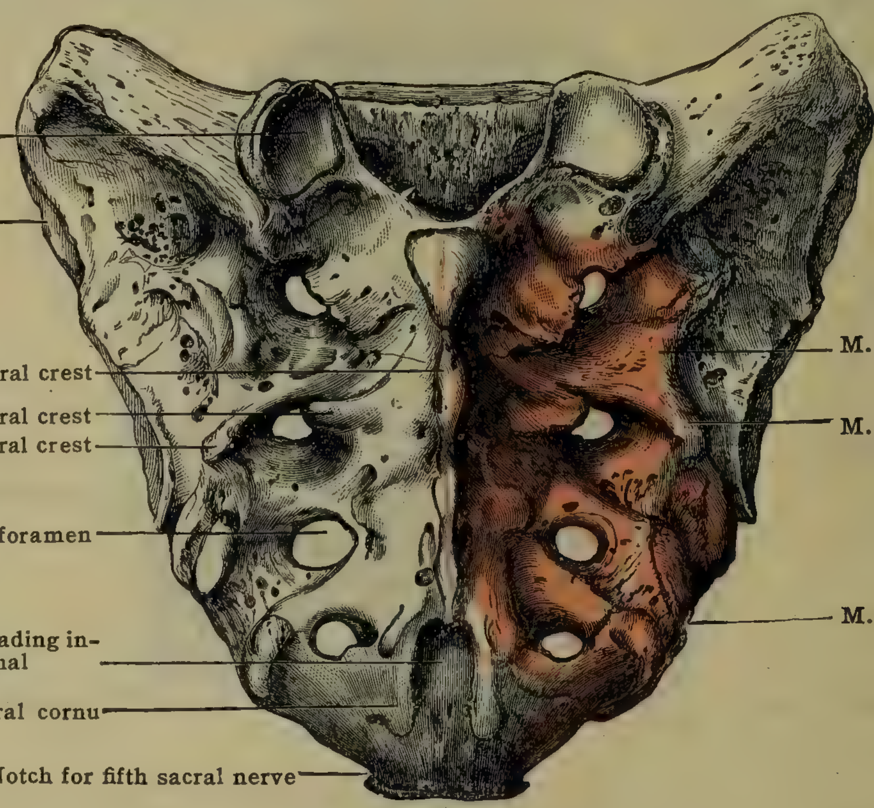


FIG. 107.—THE SACRUM. (Dorsal surface.)

attached to the median sacral crest, and to the lower and back part of the sacrum laterally, is the flat tendon of origin of the sacrospinalis muscle. The gluteus maximus muscle takes origin from the back of the lower two pieces of the sacrum.

The **base of the sacrum** [basis ossis sacri] or upper surface (fig. 109) bears considerable resemblance to the upper surface of the fifth lumbar vertebra. It presents in the middle the body, of a reniform shape, posterior to which is the upper end of the **sacral canal** bounded by two laminæ. On each side of the canal are two **superior articular processes** [processus articularis superior] bearing well-marked mammillary tubercles. On each side is a broad surface, the wing or **ala** of the sacrum, continuous with the iliac fossa of the hip-bone, and giving attachment to fibers of the iliacus muscle.

The lateral portions (fig. 108).—It has already been noted that the lateral portion of the sacrum is the name given to the part lateral to the foramina. It is broad and thick above, narrow below. The lateral aspect of the upper part presents in front a broad irregular surface, covered in the recent state with fibrocartilage, which articulates with the ilium and is known as the **auricular surface** [facies auricularis]. The position is somewhat variable, but in most instances corresponds to the sides of the first, second and third sacral bones. The general direction of the auricular surface approaches an anteroposterior plane. It is bounded posteriorly by an area marked by some rough depressions for the attachment of the posterior sacroiliac ligaments and designated the **sacral tuberosity** [tuberositas sacralis].

Below the auricular surface, the lateral margin of the sacrum is rough for the sacrotuberous and sacrospinous (greater and lesser sacrosciatic) ligaments, and terminates in the projection known as the **inferior lateral angle.** Immediately below the angle is a notch, converted into a foramen by the transverse process of the first coccygeal vertebra, and the lateral sacrococcygeal ligament. Through this foramen passes the anterior branch of the fifth sacral nerve.

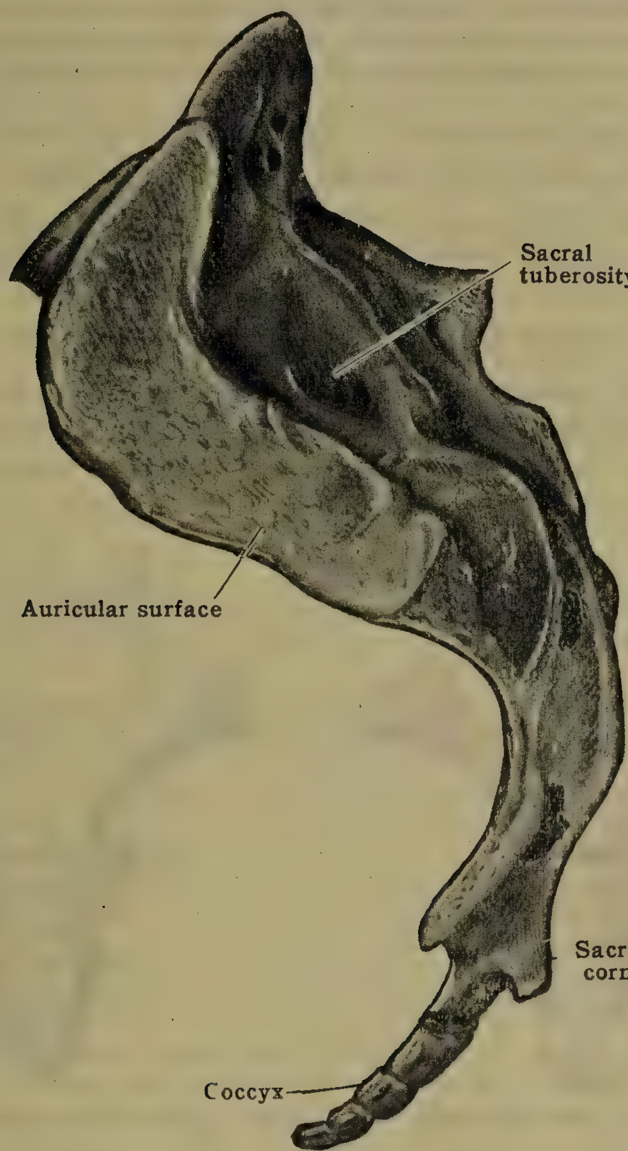


FIG. 108.—LEFT LATERAL VIEW OF SACRUM AND COCCYX.

The **apex of the sacrum** [apex ossis sacri] is directed downward and forward and is formed by the inferior aspect of the body of the fifth sacral vertebra. It is transversely oval and articulates by means of an intervertebral disk with the coccyx. In advanced life the apex of the sacrum becomes united to the coccyx by bone.

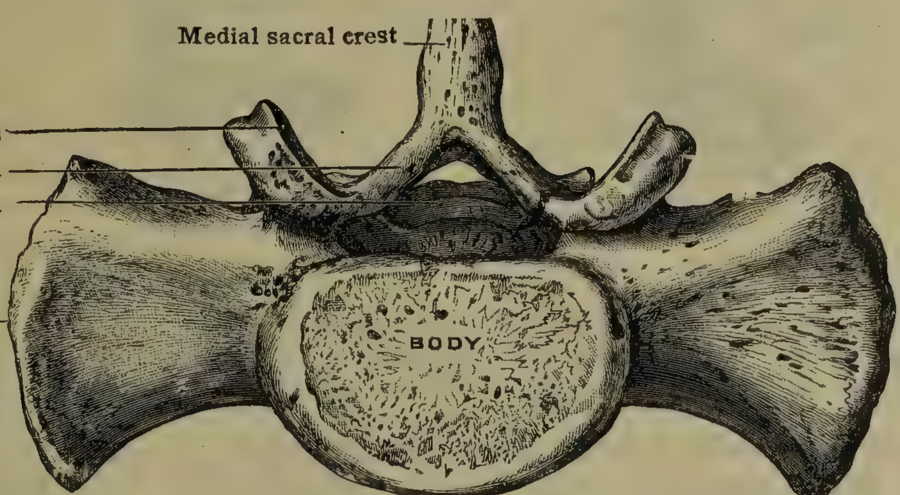


FIG. 109.—BASE OF SACRUM.

The **sacral canal** [canalis sacralis] is the continuation of the spinal canal through the sacrum. Like the bone it is curved, triangular in section at the base and flattened toward the apex. It terminates at the hiatus sacralis between the sacral cornua, where the laminæ of the fourth and fifth sacral vertebræ are incomplete. The canal communicates by four short tunnels [foramina

intervertebralia] with the anterior and posterior sacral foramina and lodges the lower branches of the cauda equina, the filum terminale, and the lower portion of the dura and arachnoid. The subdural and subarachnoid spaces extend downward within the canal as far as the body (or spine) of the second sacral vertebra.

Differences in the two sexes.—The sacrum of the female is usually broader in proportion to its length, much less curved, and directed more obliquely backward than that of the male. The curvature of the female sacrum belongs chiefly to the lower part of the bone, whereas in the male it is equally distributed over its whole length; but the curvature, as well as the other sex characters named, is subject to considerable variation in different skeletons (Trotter, Am. Jour. Phys. Anthrop., vol. 9, p. 445).

Racial differences.—The human sacrum is characterized by its great breadth in comparison with its length. The proportion is expressed by the *sacral index* $= \frac{\text{breadth} \times 100}{\text{length}}$. The average sacral index in the British male is 112, in the female 116. Sacra in which the index is above 100 are *platyhieric*, as in Europeans; those under 100 are *dolichohieric*, as in most of the black races (Sir W. Turner).

THE COCCYGEAL VERTEBRÆ

The four coccygeal vertebræ, originally separate, are united in the adult to form the **coccyx** [os coccygis] (fig. 110). Whereas four is the usual number of these rudimentary vertebræ, occasionally there are five, and rarely three. In middle

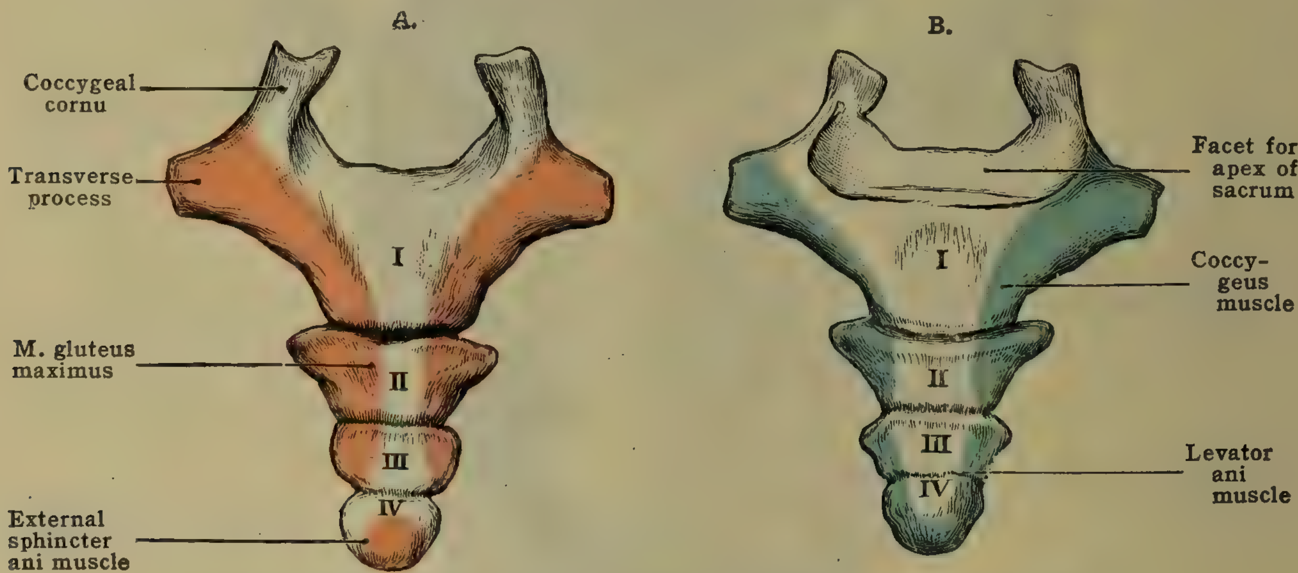


FIG. 110.—THE COCCYX. A. Posterior view; B. Anterior view.

life the first piece is usually separate, and the original division of the remaining portion of the coccyx into three parts is indicated by transverse grooves. In advanced life the pieces of the coccyx, having previously united to form one bone, may also become joined to the sacrum.

FIG. 111.—IRREGULAR LUMBOSACRAL VERTEBRÆ.
a, Sacrum with first vertebra ununited; *b*, sacrum with lumbosacral transitional vertebra. Both seen from the front (Rauber-Kopsch, Lehrbuch der Anatomie).

The first piece of the coccyx is much broader than the others. It consists of a body, transverse processes, and rudiments of a vertebral arch. The body presents on its upper surface an oval facet for articulation with the apex of the sacrum. On each side of the body a **transverse process** projects laterally and is joined either by ligament or bone to the inferior lateral angle of the sacrum, forming a foramen for the anterior division of the fifth sacral nerve. From the posterior surface of the body two long **coccygeal cornua** [cornua coccygea] project upward and are connected to the sacral cornua by the posterior sacrococcygeal ligaments, enclosing on each side an aperture—the last intervertebral foramen—for the exit of the fifth sacral nerve. The coccygeal cornua represent the roots and superior articular processes of the first coccygeal

vertebra. The **second** piece of the coccyx is much smaller than the first, and consists of a body, traces of transverse processes, and of a vertebral arch, in the form of slight tubercles at the sides and on the posterior aspect of the body. The **third** and **fourth** pieces of the coccyx, smaller than the second piece, are mere nodules of bone, corresponding solely to vertebral bodies.

The **anterior surface** of the coccyx gives attachment to the anterior sacrococcygeal ligament and near the tip to the levator ani muscle; it is in relation with the posterior surface of the rectum. The **posterior surface** of the coccyx is convex, and the upper three pieces afford attachment to the gluteus maximus muscle on each side, and the last piece to the coccygeal portion of the sphincter ani externus muscle. The **laetral margins** are thin, and receive parts of the sacrosciatic ligaments, of the coccygeal, and of the levatores ani muscles.

Variations of the sacrum and coccyx.—The number of sacral vertebræ may be increased to six, resulting from the fusion of the first coccygeal or, less often, of the last lumbar (sacralization). The number may be reduced to four, apparently by the lumbarization of the first sacral. The junction between the lumbar and sacral parts of the column is occasionally made by an element presenting the characteristics of a lumbar vertebra on one side and of a sacral on the opposite (hemi-sacralization, hemi-lumbarization) (fig. 111). The auricular surface may extend beyond the general level of the base of the sacrum or be displaced downward to the fourth sacral vertebra. The sacral canal may be open posteriorly to a greater degree than is normally the case and the sacral hiatus is variable in extent and form. Coalescence of the coccyx and sacrum takes place less often and later in life in the female than in the male. Rudiments of an arch on the anterior surface of the first coccygeal vertebra have been noted and interpreted as vestiges of the hemal arch.

THE VERTEBRAL COLUMN AS A WHOLE

The vertebral column (fig. 112) is the central axis of the skeleton and is situated in the median plane at the posterior aspect of the trunk. Superiorly it supports the skull; laterally it gives attachment to the ribs, through which (in part) it receives the weight of the upper limbs, and inferiorly it is supported by the hip-bones, by which the weight of the trunk is transmitted to the lower limbs.

Length.—Following the curves of the anterior surface and including the intervertebral fibrocartilages the vertebral column in Europeans measures between 720 and 750 mm. The length of the presacral division is 619 mm. in the male and 574 mm. in the female; of this division in males the cervical part constitutes 21.5 per cent., the thoracic 46.3 and the lumbar 32.2. The lumbar part is relatively longer in the female. About one-fourth of the length of the presacral spine is made up of intervertebral disks.

Curvatures.—The vertebral column presents a series of curvatures, four when viewed in profile and one when viewed from the front or back. The former are directed alternately forward and backward, and are named, from the regions of the column in which they occur, **cervical, thoracic, lumbar,** and **sacral.** The fifth curve is **lateral,** being in most cases directed toward the right side. The cervical, thoracic and lumbar curvatures pass imperceptibly into one another, but at the junction of the last lumbar vertebra with the sacrum a well-marked angle occurs, known as the **sacrovertebral** angle, which overhangs the cavity of the minor pelvis and forms a portion of the boundary of its superior aperture.

The thoracic and sacral curves have their concavities directed forward and are developed during intrauterine life (fig. 112) They are in obvious relation to two great cavities of the trunk, thoracic and pelvic, and may be regarded as **primary** or **accommodation** curves, for the thoracic and pelvic viscera. The thoracic curve extends from the second to the twelfth thoracic vertebra and the sacral curve coincides with the sacrum and coccyx.

The cervical and lumbar curves have their convexities directed forward, and are developed during the first year after birth (see p. 30). They are essentially curves of **compensation,** necessary for the maintenance of the upright posture, and are brought about mainly by modifications in the shape of the intervertebral disks. The cervical curve is formed about the third month, or at the time when the infant can sit upright. The great peculiarity of the curve is that it is never consolidated, being present when the body is placed in the erect position and obliterated by bending the head down upon the chest. The lumbar curve is developed about the end of the first year or when the child begins to walk, but is not consolidated until adult life. (Symington.) The cervical curve extends from the atlas to the second thoracic vertebra, and the lumbar curve from the twelfth thoracic to the promontory of the sacrum.

The lateral curve is situated in the upper thoracic region, usually presenting the convexity to the right; it is probably associated with the greater use made of the right hand. This curve, however, is particularly liable to modification in different occupations and in different races. The *aortic impression* normally present consists of a variable flattening of the left side of the thoracic vertebræ in the middle of the series.

Viewed from the front, the vertebral column presents a series of **pyramids** due to the successive increase and decrease in size of the bodies. These become broader from the axis to the first thoracic vertebra and then decrease to the fourth thoracic. The first pyramid therefore includes all the cervical vertebræ except the atlas, and has the apex directed upward and its base downward, whilst the second is inverted and formed by the first four thoracic vertebræ. The third pyramid, much the longest, is the result of the increase in size from the fourth thoracic to the fifth lumbar vertebra, and the fourth, which is inverted, is produced by the rapid contraction of the sacral and coccygeal vertebræ.

Viewed from behind, the spinous processes project in the midline, and the transverse processes as two lateral rows. Of the spines, those of the epistropheus, seventh cervical, first thoracic, and the lumbar vertebræ appear most prominent. On each side is the **vertebral groove,** the floor of which is formed in the cervical and lumbar regions by the laminæ and articular processes, and in the thoracic region, by the laminæ and transverse processes. The transverse processes project laterally for a considerable distance in the atlas, first thoracic, and in the middle of the lumbar series; they are shortest in the third cervical and the twelfth thoracic.

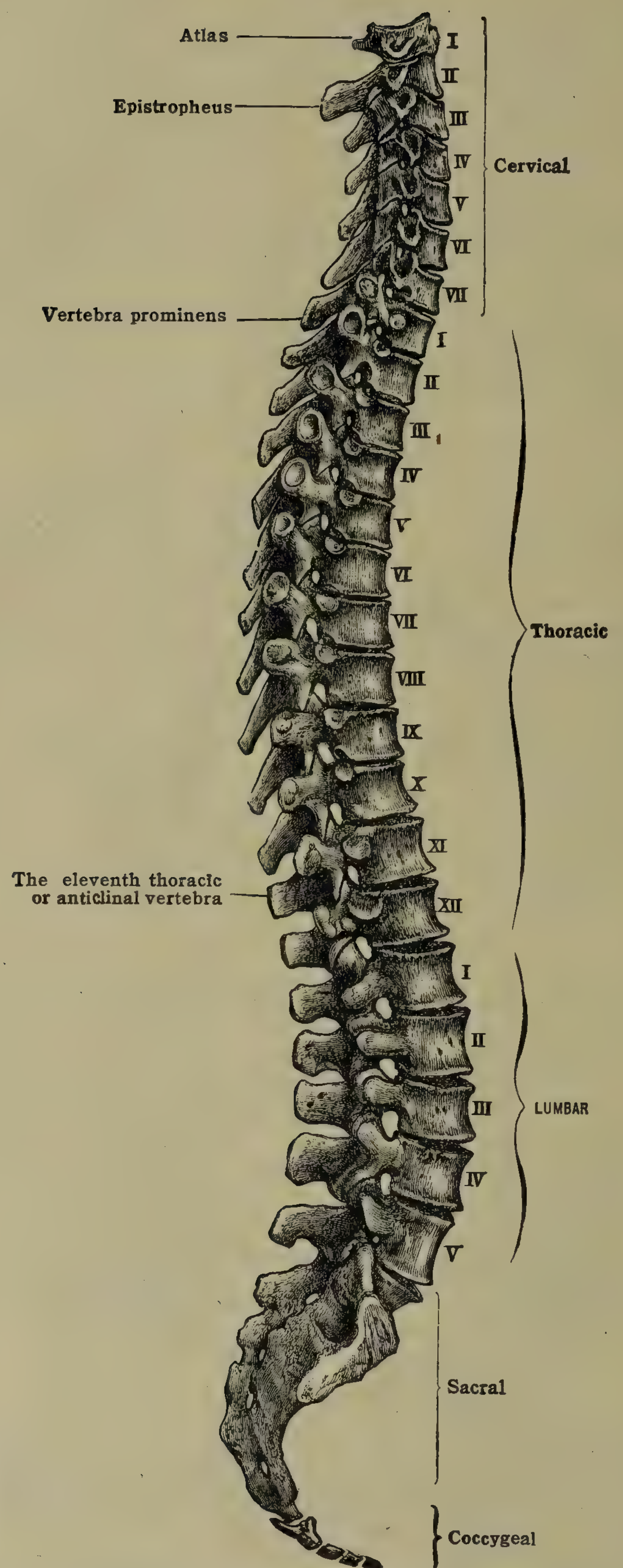


FIG. 112.—VERTEBRAL COLUMN. (Lateral view.)

In the lateral view, the intervertebral foramina appear oval in shape, and are small in the cervical, larger in the thoracic, and largest in the lumbar region.

Numerical variation.—Addition to the total number of vertebræ by intercalation of an element probably does not occur. Addition to a group is rather frequently observed and has been accounted for by reduction in number of the elements in an adjacent group, the total number of vertebræ in the column remaining unaltered. In this fluctuation, the vertebra added is intermediate in form between the types of the two groups concerned.

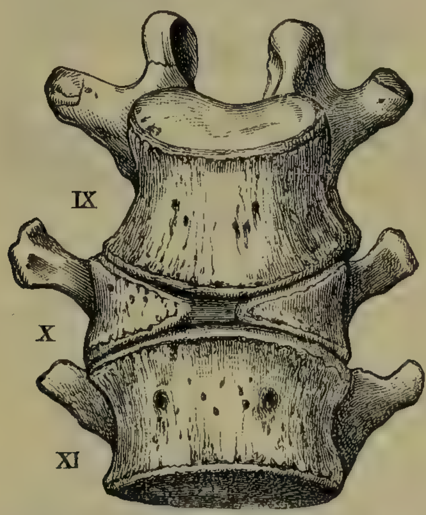


FIG. 113.—A DIVIDED THORACIC VERTEBRA. (After Turner.)

Structure of a vertebra.—The bodies of the vertebræ are largely composed of spongy substance, with a thin outer covering of compact bone. In a vertical section through the body the plates of the spongy substance are seen to be arranged vertically and horizontally, the vertical plates being curved with their concavities directed toward the center of the bone (fig. 114). The horizontal plates are slightly curved parallel with the upper and lower surfaces, and have their convexities toward the center of the bone. They are not so well defined as the vertical set.

Blood supply: see Section VI on the Blood-Vascular System.

Ossification.—The vertebræ in general.—The ossification of each vertebra (see p. 30) takes place in cartilage from three primary and five secondary centers. The three primary

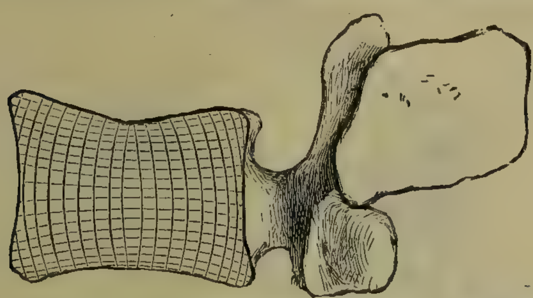


FIG. 114.—A VERTEBRAL BODY IN SECTION TO SHOW THE BONY STRUCTURE. (Schematic.)

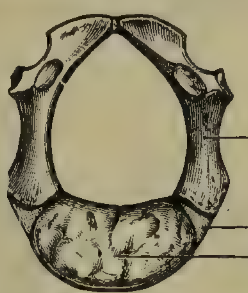


FIG. 115.—A VERTEBRA AT BIRTH.

centers appear, one in the body and two in the arch, about the seventh week of intrauterine life. In the thoracic region the nucleus for the body appears first, but in the cervical region it is preceded by the centers for the arch. The nucleus for the body soon becomes bilobed, and this condition is sometimes so pronounced as to give rise to the appearance of two distinct nuclei. Indeed, the nucleus is, very rarely, double and the two parts of the body may remain separate throughout life (fig. 113). The bilateral character of the nucleus is further emphasized by the occasional formation of half-vertebræ. Lateral centers are deposited near the bases of the

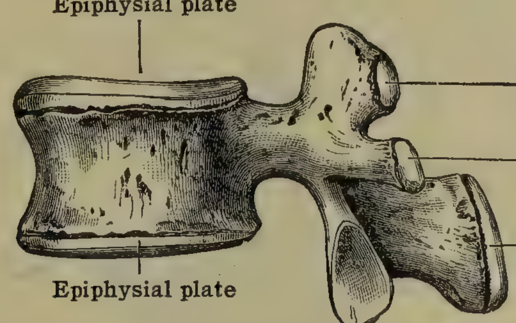


FIG. 116.—LUMBAR VERTEBRA AT THE EIGHTEENTH YEAR WITH SECONDARY CENTERS.

superior articular processes and give rise to the roots, laminæ, articular, and the greater parts of the transverse and spinous processes.

At birth a typical vertebra (fig. 115) consists of three osseous pieces—a body and two lateral masses, which constitute the arch, the parts being joined together by hyaline cartilage. The line of union of the lateral portion with the body is known as the *neurocentral* synchondrosis, and is not actually obliterated for several years after birth. In the thoracic region the central ossification does not pass beyond the point with which the head of the rib articulates, and leaves a

portion of the body on each side formed from the lateral ossification. A thoracic vertebra at the fifth year shows that the pits for the heads of the ribs are situated behind the neurocentral joint, which is directed obliquely backward and medially. The laminæ unite during the first year after birth; and by the gradual extension of ossification into the various processes, the vertebræ have attained almost their full size by the time of puberty. Subsequently the secondary centers appear in the cartilaginous extremities of the spinous and transverse proc-

Fig. 117.—Upper Thoracic Vertebra with an Epiphysial Plate Removed and Drawn at the Side.
The plate shows the characteristic deficiency in the center. ×1.

esses (fig. 116), and in the cartilage on the upper and lower surfaces of the bodies, forming in each vertebra two annular plates, thickest at the circumference and gradually thinning toward the central deficiency (figs. 116, 117). The epiphyses appear from the fifteenth to the twentieth year and join with the vertebra by the twenty-fifth year.

In several vertebræ the mode of ossification differs from the account given above—in some cases considerably—and necessitates special consideration.

Fig. 118.—Immature Atlas. (Third year.)

Atlas (fig. 118).—The lateral masses and posterior arch are formed from two centers of ossification, which correspond to the lateral centers of other vertebræ and appear about the seventh week. The anterior arch is ossified from one center, which, however, does not appear until a few months after birth. Union of the lateral parts occurs posteriorly in the third year, being sometimes preceded by the appearance of a secondary center of ossification in the intervening cartilage, and the union of the lateral parts with the anterior arch occurs about the sixth year.

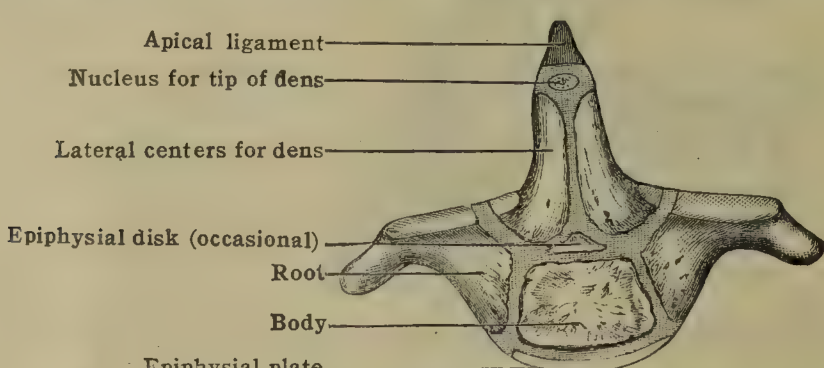


Fig. 119.—Development of the Epistropheus (Axis).

Epistropheus (figs. 119–120).—The arch, and the processes associated with it, are formed from two lateral centers which appear, like those in the other vertebræ, about the seventh week. The common piece of cartilage which precedes the body and dens is ossified from four (or five) centers, one (or two) for the body of the epistropheus, in the fourth month, two, laterally disposed, for the dens, a few weeks later, and one, for the apex of the dens, in the second

year. The two collateral centers for the main part of the dens soon coalesce, so that at birth the epistropheus consists of four osseous pieces—two lateral portions which constitute the

FIG. 120.—THE EPISTROPHEUS AT FOUR YEARS OF AGE, SHOWING THE SIZE AND EXTENT OF THE DENS. (Natural size.)

arch, the body, and the dens, surmounted by a piece of cartilage. During the third or fourth year the dens joins with the body, the line of union being indicated even in advanced life

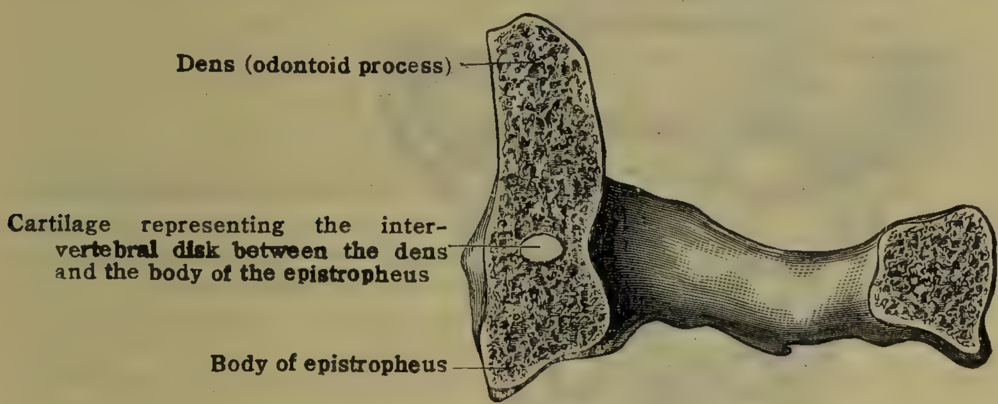


FIG. 121.—THE EPISTROPHEUS (FROM AN ADULT) IN SAGITTAL SECTION.

by a small disk of cartilage, and the arch unites in front and behind about the same time or a little later. The apical nucleus of the dens, which represents an epiphysis, joins the main part

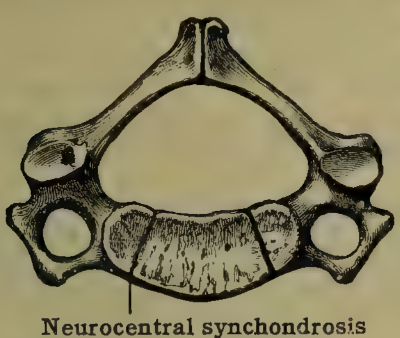


FIG. 122.—AN IMMATURE CERVICAL VERTEBRA.

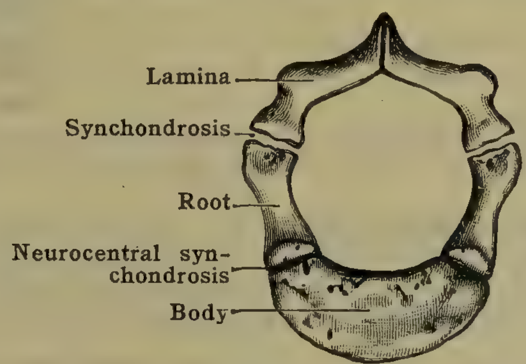


FIG. 123.—OSSIFICATION OF THE FIFTH LUMBAR VERTEBRA.

about the twelfth year and in the seventeenth year an epiphysial plate appears for the lower surface of the body. There are also rudiments, adjoining the cartilaginous disk, of the upper plate of the body.

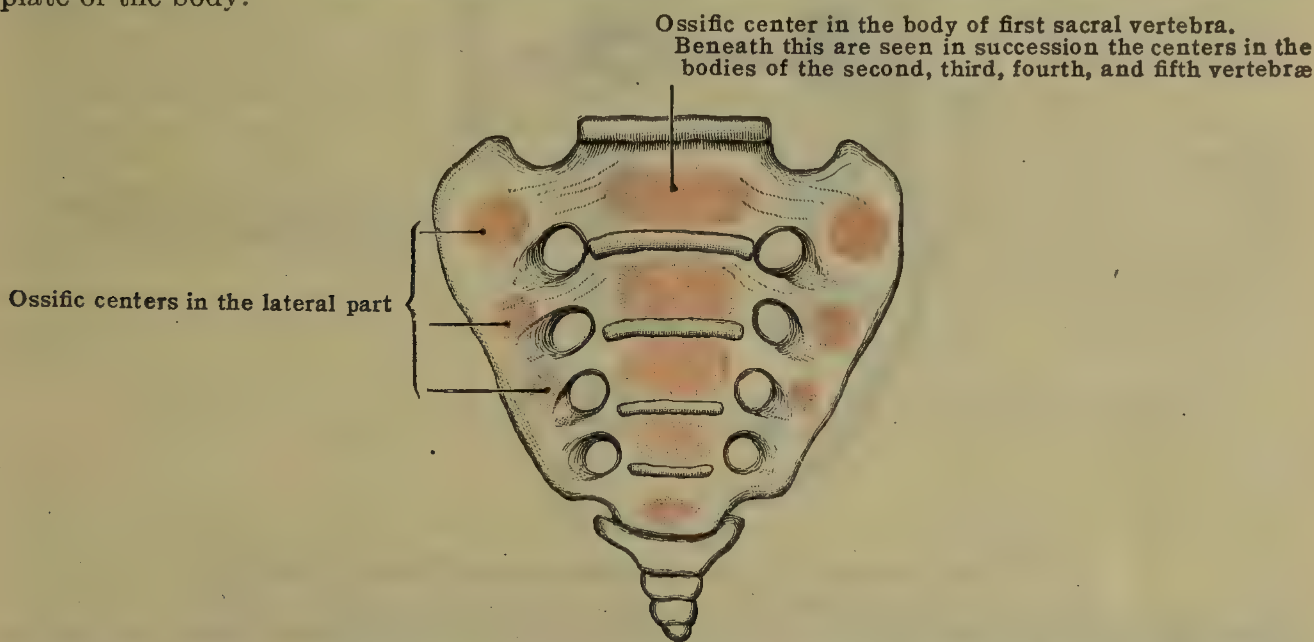


FIG. 124.—SACRUM AT BIRTH TO SHOW CENTERS OF OSSIFICATION. (Enlarged one-third.)

Cervical vertebræ (fig. 122).—In the cervical vertebræ the lateral centers form a larger share of the body than in the vertebræ of other regions, and the neurocentral synchondrosis runs

almost in a sagittal direction. The sixth, seventh, and even the fifth have additional centers which appear before birth for the anterior or costal divisions of the transverse processes. In the other cervical vertebræ the costal processes are ossified by extension of the lateral nuclei. The costal processes of the seventh cervical sometimes remain separate, constituting cervical ribs.

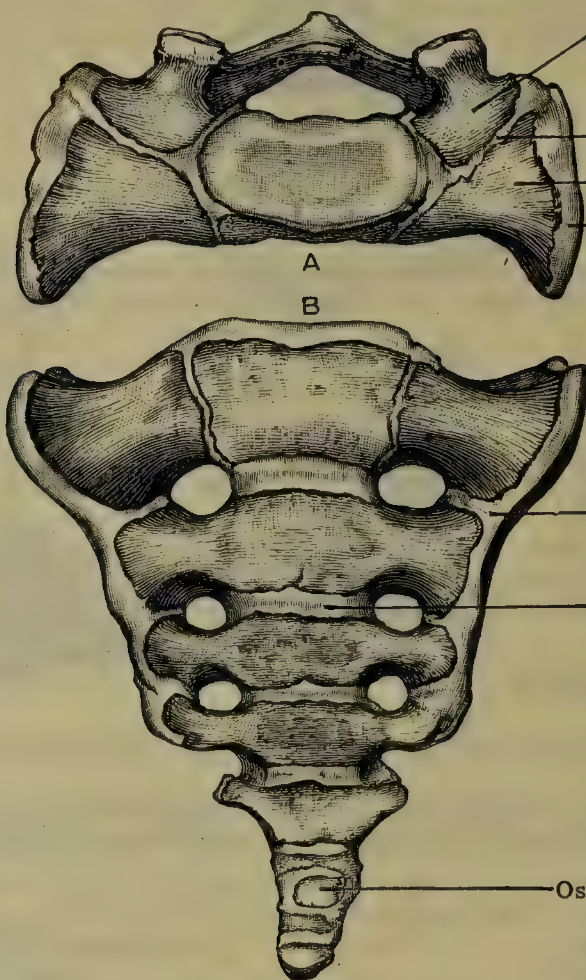


FIG 125.—THE SACRUM AND COCCYX AT FOUR YEARS OF AGE. (A) BASE DRAWN FROM ABOVE. (B) PELVIC SURFACE. (×¾.)

Lumbar vertebræ (fig. 116).—In the lumbar vertebræ the neurocentral suture is almost transverse, and to the usual number of centers of ossification, two other epiphyses for the mammillary tubercles are added, the centers appearing about puberty. In the stage of chondrification the costal elements ordinarily fuse with the transverse processes and body, but occasionally

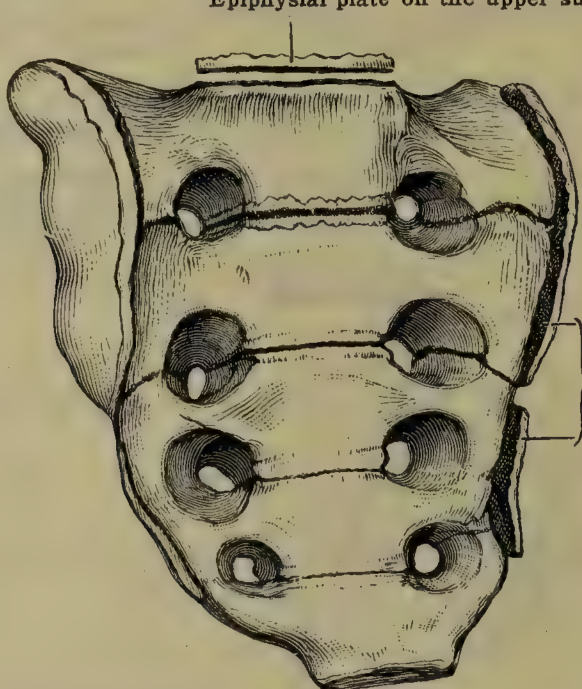


FIG. 126.—SACRUM AT ABOUT TWENTY-TWO YEARS. (×⅗.)

remain separate and, ossifying, constitute a lumbar rib. The transverse process of the first lumbar vertebra is occasionally developed from an independent center.

The fifth lumbar exhibits in some cases a special mode of ossification in the arch. Instead of two centers, there are four—one on each side for the root, transverse process, and superior articular process, and another on each side for the lamina, inferior articular process, and the

lateral half of the spinous process (fig. 123). There may be failure of union of roots with the laminæ or of the laminæ with one another constituting the well known anomaly of the adult.

Sacral vertebræ (figs. 124–126).—The sacrum ossifies from thirty-five centers, which may be classified as follows:—In each of the five vertebræ there are three primary nuclei—one for the body and two for the arch; in each of the first three the so-called costal element of the lateral part on each side is formed from a separate nucleus; associated with each body are two epiphysial plates; and on each lateral margin are two irregular epiphyses, one for the auricular surface and another for the rough edge below. The centers for the bodies appear about the eighth or ninth week and for the vertebral arches from the third to the fifth month. The arches join the bodies at different times in the different vertebræ, ranging from the second year below, to the fifth or sixth year above, and union of the laminæ takes place behind some years later, from about the ninth to the fifteenth year.

The centers for the costal elements appear lateral to the anterior sacral foramina, from the fifth to the seventh month, and these unite with the bodies somewhat later than the arches.

The centers for the epiphysial plates appear about the fifteenth year, and for the auricular epiphyses and the edges below, from the eighteenth to the twentieth year.

Consolidation begins soon after puberty by fusion of the costal elements, and this is followed by ossification from below upward in the intervertebral disks, resulting in the union of the adjacent bodies and the epiphysial plates, the ossific union of the first and second being completed by the twenty-fifth year or a little later. The marginal epiphyses are also united to the sacrum by the twenty-fifth year. Even in advanced life intervertebral disks persist in the more central parts of the bone and can be well seen in sections.

Coccygeal vertebræ.—The coccygeal vertebræ are cartilaginous at birth and each is usually ossified from a single center, though there may be two for the first piece. Ossification begins soon after birth in the first segment, and in the second from the fifth to the tenth year. The centers for the third and fourth segments appear just before, and after, puberty respectively: As age advances the various pieces become united with each other, the three lower uniting before middle life and the upper somewhat later. In advanced life the coccyx may join with the sacrum, the union occurring earlier and more frequently in the male than in the female.

THE SERIAL MORPHOLOGY OF THE VERTEBRÆ

Although at first sight many of the vertebræ exhibit peculiarities, nevertheless a study of the mode by which they develop, and their variations, indicates the serial homology of the constituent parts of the vertebræ in each region of the column (fig. 127).

The *body* of the vertebra is that part which immediately surrounds the notochord. This part is present in all the vertebræ of man, but the centrum of the atlas is dissociated from its arch, and ankylosed (as the dens) to the body of the epistropheus.

The *arches* and *spinous processes* are easily recognized throughout the various parts of the column in which complete vertebræ are present. The *articular processes* or *zygapophyses* are of slight morphological interest.

The *transverse processes* are somewhat less easily identified. They occur in the simplest form in the thoracic series. Here they articulate with the tubercles of the ribs, whence the term *tubercular processes* or *diapophyses* has been given them (the place of articulation of the head of the rib with the vertebra is the *capitular process* or *parapophysis*), and the transverse process and the neck of the rib enclose a space named the costotransverse foramen. In the cervical region the costal element (*pleurapophysis*) and the transverse process are fused together laterally by the costotransverse lamella, and the conjoint process thus formed is pierced by the costotransverse foramen. The compound nature of the cervical transverse process is indicated by the fact that the anterior or costal processes in the lower cervical vertebræ arise from additional centers and occasionally retain their independence as cervical ribs. In birds and reptiles these processes are represented by free ribs. In the lumbar region, the compound nature of the transverse process is further marked. The true transverse process is greatly suppressed, and its extremity is indicated by the accessory tubercle. Anterior to this in the adult vertebræ a group of holes represents the costotransverse foramen, and the portion in front of this is the costal element. Occasionally it persists as an independent ossicle, the lumbar rib.

In the sacral series the costal elements are coalesced in the first three vertebræ to form the greater part of the lateral portion for articulation with the ilium, the costotransverse foramina being completely obscured. In rare instances the first sacral vertebra will articulate with the ilium on one side, but remain free on the other, and under such conditions the free process exactly resembles the elongated transverse process of a lumbar vertebra. The first three sacral vertebræ which develop costal processes for articulation with the ilium are termed *true sacral* vertebræ, while the fourth and fifth are termed *pseudosacral*. A glance at fig. 127 will show the homology of the various parts of a vertebra from the cervical, thoracic, lumbar, and sacral regions.

STRUCTURES AT LEVELS OF THE VERTEBRAL BODIES

Cervical

First. Level of hard palate.

Second. Level of free edge of upper teeth.

Second and third. Superior cervical ganglion of sympathetic.

Fourth. Hyoid bone. Upper aperture of larynx.

Fifth. Thyroid cartilage and rima glottidis. Between this and the last would be the bifurcation of the common carotid.

Sixth. Cricoid cartilage. Ending of pharynx and larynx. Consisting of the fused fifth and sixth ganglia, the middle cervical ganglion is usually opposite this vertebra. Here the

omohyoid crosses the common carotid, and at this spot, the site of election, the center of the incision for tying this vessel is placed. At this level the inferior thyroid artery passes behind the carotid trunk.

Seventh. Inferior cervical ganglion. Apex of lung. Arch of thoracic duct over apex of lung, outward and downward to termination.

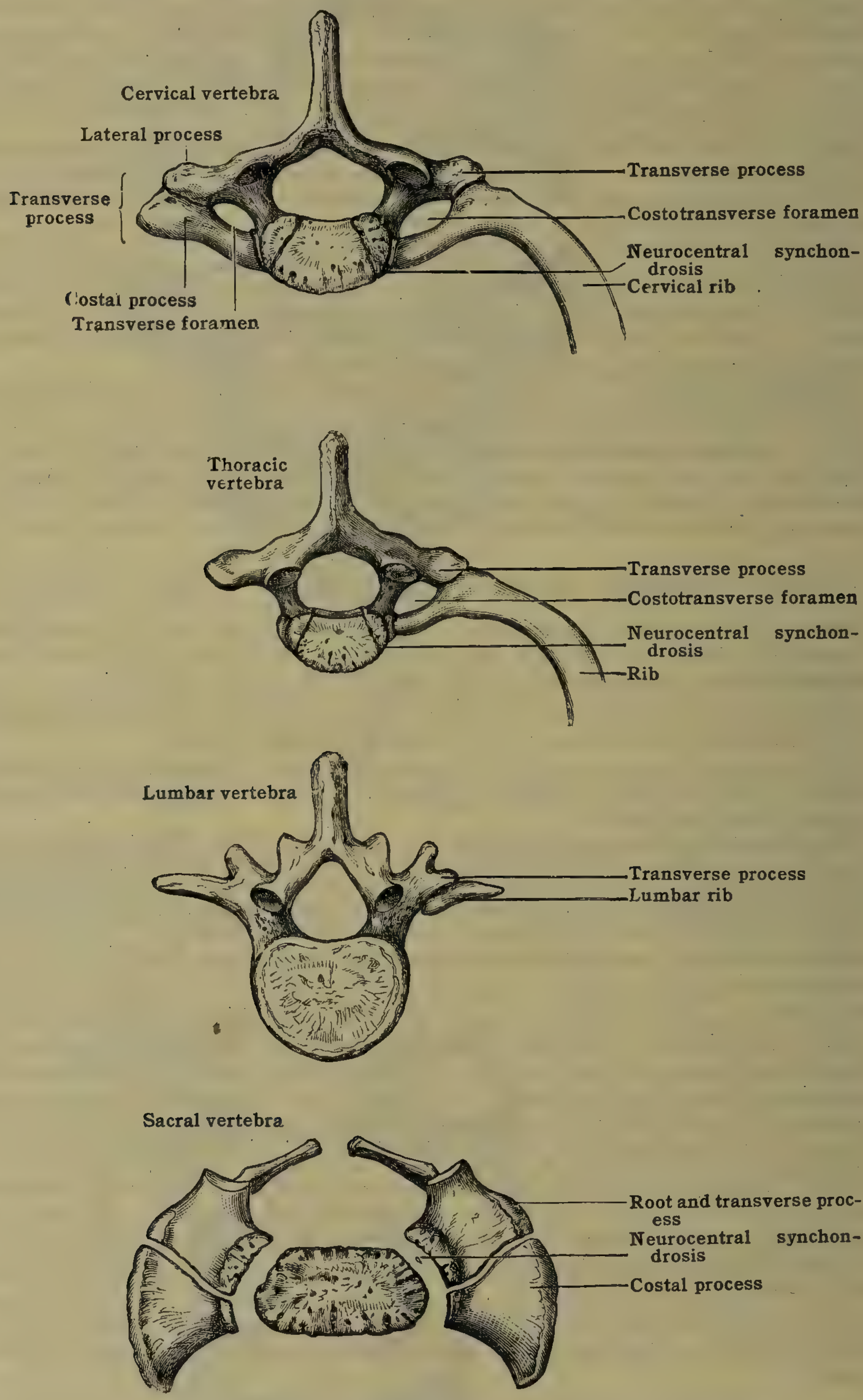


FIG. 127.—MORPHOLOGY OF THE TRANSVERSE AND ARTICULAR PROCESSES.

THORACIC

First. Summit of arch of subclavian. (Godlee.) The height of this varies. Usually it is from 1.2 to 2.5 cm. (½ to 1 in.) above the clavicle. It is always in close relation with the cervical pleura.

Second. Level of jugular notch. This is usually opposite the disk between the second and third. Bifurcation of innominate. (Godlee.)

Third. Beginning of superior cava, at junction of first right costal cartilage with sternum. Highest part of aortic arch, about 2.5 cm. (1 in.) below jugular notch.

Fourth. Bifurcation of trachea. Second part of aortic arch, extending from upper border of second right costal cartilage, reaches spine. Arch of vena azygos. The superior medias-

tinum is bounded behind by the upper four thoracic vertebræ. Louis' angle, junction of manubrium and body of sternum. Thoracic aorta begins.

Fifth to ninth. Base of heart.

Sixth. Pulmonary and aortic valves, opposite third left costal cartilage at its sternal junction, in front. Commencement of aorta and pulmonary artery. End of superior cava, third right chondrosternal junction in front.

Seventh. Mitral orifice.

Eighth. Tricuspid orifice.

Ninth. Lower level of body of sternum and inferior sternal synchondrosis (at lower border). Opening in diaphragm for inferior vena cava (lower border).

Tenth. Level of tip of xiphoid cartilage. Lower limit of lung posteriorly. Upper limit of liver comes to the surface posteriorly. Esophagus passes through diaphragm. Cardiac orifice of stomach (sometimes). Upper limit of spleen.

Eleventh. Lower border of spleen. Suprarenal gland. Cardia (sometimes).

Twelfth. Lowest part of pleura. Aorta passes through diaphragm (lower border). Celiac artery (lower border). Upper end of kidney.

LUMBAR

First. Origin of superior mesenteric artery. Pancreas. Pelvis of kidney. Renal arteries. Transpyloric line (Addison.)

Second. Spinal cord ends at junction of first and second. Duodenojejunal flexure. Cisterna (receptaculum) chyli. Lower end of left kidney.

Third. Umbilicus, opposite disk between third and fourth. Lower end of right kidney.

Fourth. Bifurcation of aorta. Highest part of iliac crest.

Fifth. Commencement of inferior vena cava.

SACRAL

Second. End of sigmoid colon and beginning of first part of rectum. Lower limit of dural sheath and subdural space.

Fifth. Reflection of rectovesical pouch of peritoneum 2.5 cm. (1 in.) above base of prostate.

Coccyx (tip). Termination of filum terminale. 2.5 cm. (1 in.) below this, commencement of anal canal.

B. THE SKULL OR CRANIUM

The bony framework of the head, termed the **skull** [cranium], presents the most complex structure of the skeleton. This condition is the result mainly of the presence and close association in the head of the brain and group of sense organs on the one hand and, on the other, the highly specialized entrances to the digestive and respiratory systems, namely the mouth and nasal cavities. In adaptation to the huge, rounded brain of man a bony capsule, the **cerebral cranium** [cranium cerebrale], has been formed, consisting mostly of flat bones rigidly united by special joints called sutures. The cerebral cranium is directly supported by the vertebral column, and where the two come together a certain degree of transition of form of adjacent parts can be distinguished. The cerebral cranium passes without sharp line of demarcation into the **visceral cranium** [cranium viscerale], or facial skeleton, which includes the jaws and the bony support of the tongue, the hyoid bone.

Both subdivisions of the cranium in this zone of contact are concerned in providing the skeletal support for the nose, the eyes and ears. Many individual bones, some singly, but most of them in pairs, go to make up the skull; and whereas some of those entering into the cerebral division are confined entirely to that division and some of the bones constituting the visceral skeleton are purely visceral in relation and function, other elements are both cerebral and visceral in position and use. It follows that a sharp distinction of cerebral and visceral limits can hardly be made and that attempts to range all cranial bones in one of two categories must lead in some instances to arbitrary choice. The term cranium is frequently restricted to the cerebral cranium, the visceral cranium being then designated as the facial skeleton.

THE SKULL AS A WHOLE

The skull, consisting of the cerebral and visceral crania, may first be considered as a whole. Taking a general view, it is spheroidal in shape, smooth above, compressed from side to side, flattened and uneven below, and divisible into six regions: a superior region or vertex, a posterior or occipital region, an anterior or frontal region, an inferior region or base, and two lateral regions.

(1) THE SUPERIOR REGION [VERTEX]

Viewed from above (*norma verticalis*) (fig. 128) the skull presents an oval outline with the broader end behind, and includes those portions of the **frontal bone** [os frontale], the two **parietal bones** [ossa parietalia], and the interparietal portion of the **occipital bone** [os occipitale] which comprise the **skull cap** [calvaria].

The lateral limits of the superior region may be set at the **temporal lines** [lineae temporales] which pass through the **parietal eminences** [tubera parietalia]. The surface is smooth and rounded and covered in the recent state by the **periosteum of the skull** [pericranium] and by the scalp. In a skull of average width the **zygomatic arches** are visible, but in very broad skulls they are obscured.

The **sutures of the cranium,** seen on the vertex are the following:

The **metopic,** which is, in most skulls, merely a median fissure in the frontal bone just above the **glabella**; occasionally it involves the whole length of the bone. It is due to the persistence of the fissure normally separating the two halves of the bone in the infant (fig. 150).

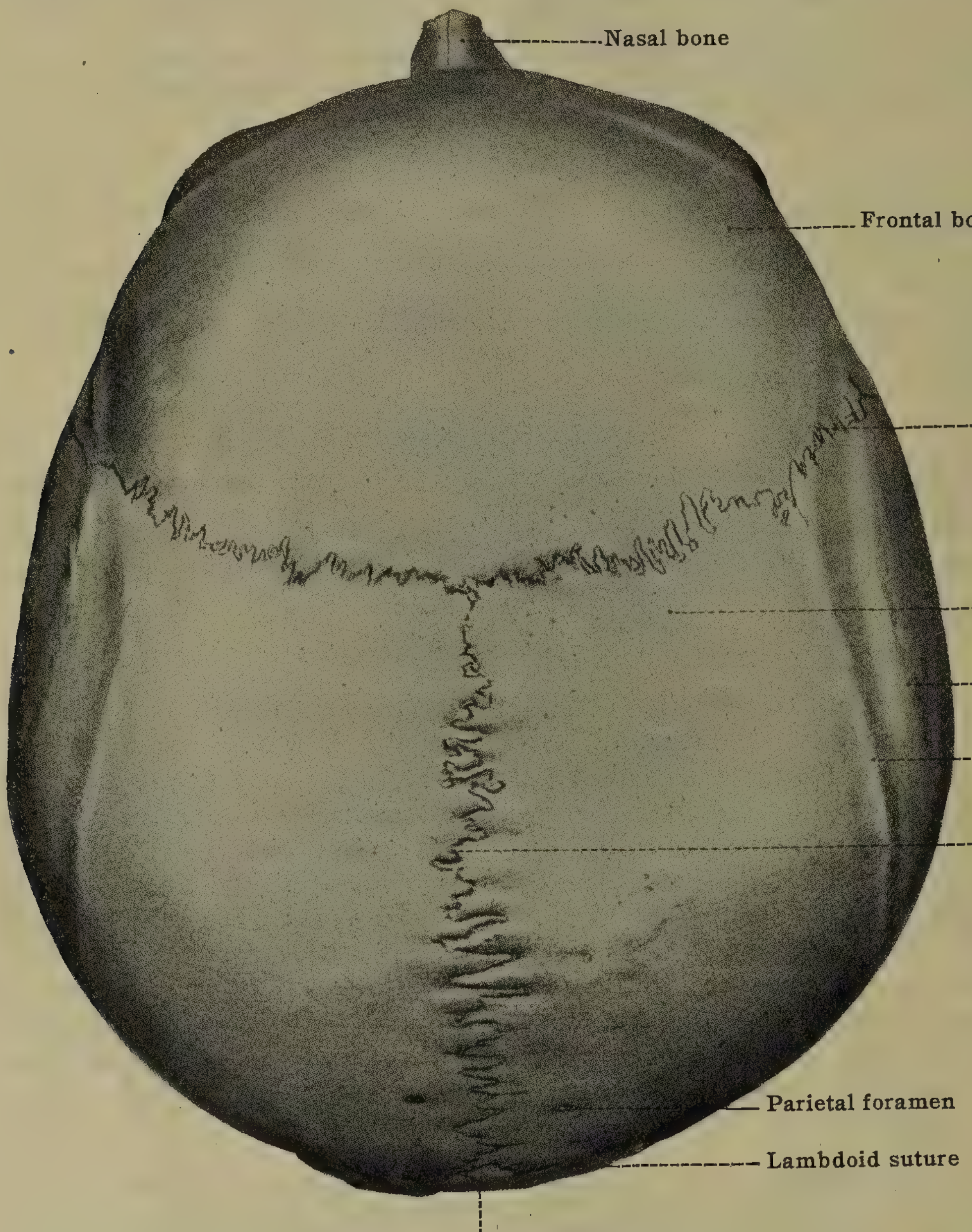


FIG. 128.—CRANIUM OF A MAN OF 45 YEARS. (Superior view.) (Rauber-Kopsch, Lehrbuch der Anatomie.)

The **sagittal suture** [sutura sagittalis] is situated between the two parietal bones. The single or paired **parietal foramen** [foramen parietale] lies close to the sagittal suture a short distance anterior to the spot (lambda) where it joins the lambdoid suture. The **coronal suture** [sutura coronalis] lies between the frontal bone anteriorly and the two parietal bones posteriorly. The **lambdoid suture** [sutura lambdoidea] is formed by the parietal bones in front and the occipital bone behind.

(2) THE ANTERIOR REGION

The **anterior region** (*norma facialis*) (fig. 129) comprises the anterior end of the cerebral cranium, or **forehead** [frons], and the **skeleton of the face** [facies (ossea)]. The configuration of this region is adapted to the frontal lobes of the brain and is largely determined by the presence of the eyes, nose and mouth, the **orbits, nasal skeleton** and **jaws** giving support to these organs.

The convex, smooth surface of the forehead presented by the **frontal bone** passes above into the vertex and laterally into the temporal fossæ, the limits of which are given by the temporal lines. The low bulging on either side of the mid-line is termed the **frontal eminence** [tuber frontale]. Between the latter and the **supraorbital border** [margo supraorbitalis] is

the horizontal **superciliary arch** [arcus superciliaris] subjacent to the eye-brow. The name **glabella** is applied to the flattened region between the superciliary arches, corresponding to the smooth space between the eyebrows. The **supraorbital foramen or notch** [foramen sive incisura supraorbitalis] transmits the supraorbital vessels and nerve, and the more medially placed **frontal notch** [incisura frontalis], less marked is occupied by the frontal artery and nerve.

The **entrances to the orbits** are located between the cerebral component of the norma facialis above, and the external facial component below. The latter includes the **nasal bones** [ossa nasalia], the maxillæ, the zygomatic bones and the mandible.

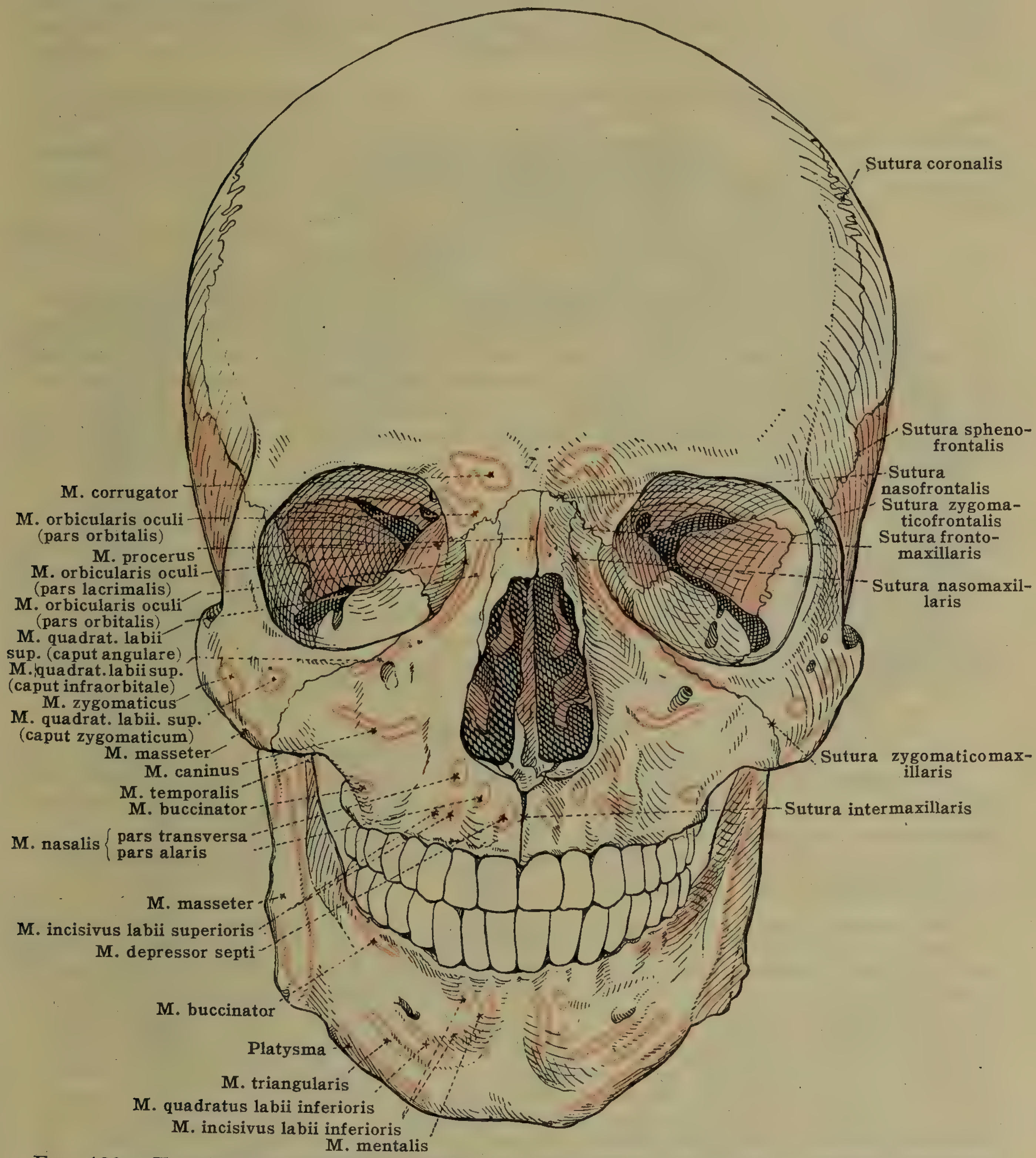


FIG. 129.—THE SKULL, ANTERIOR VIEW, WITH MUSCULAR ATTACHMENTS. (From Spalteholz, 'Handatlas of Anatomy,' J. B. Lippincott Co.)

In the mid-region is the **piriform aperture** [apertura piriformis] the anterior opening of the nasal cavity, bounded above by the inferior margins of the nasal bones, laterally by the borders of the **nasal notch** [incisura nasalis] of the maxillæ, which is continued into the inferior boundary and leads to the **anterior nasal spine** [spina nasalis anterior] projecting in the mid-plane. Through the piriform aperture a glimpse is obtained of skeletal parts within the nasal cavity; the vomer and perpendicular plate of the ethmoid bone in the mid-plane; the middle and inferior conchæ, laterally.

The nasal bones and **frontal processes** [processus frontales] of the maxillæ meet in the **frontomaxillary suture** [sutura frontomaxillaris] and unite above with the frontal bone in the semicircular **nasofrontal suture** [sutura nasofrontalis]. Laterally the frontal process enters into the margin of the entrance to the orbit, articulating there with the lacrimal bone. Both frontal processes and nasal bones afford attachment to mimetic muscles. The anterior surface of the maxilla helps to form the **infraorbital border** [margo infraorbitalis], extends laterally to the

zygomatic process and medially presents the nasal notch. The **infraorbital foramen** [foramen infraorbitale], the facial opening of the infraorbital canal, lies below the infraorbital border and transmits the infraorbital vessels and nerve. The **canine fossa** [fossa canina] when present is found below the infraorbital foramen. The anterior surface of the body of the maxilla gives origin to a number of the mimetic muscles.

Projecting downward from the maxillary body is the arch-formed **alveolar process** with the incisor, canine and premolar teeth conspicuous in the norma facialis. Corresponding to the roots of these teeth are rounded elevations of the surface [juga alveolaria], with intervening depressions. The alveolar processes and adjacent parts of the bodies of the maxillæ meet in the mid-plane in the **intermaxillary suture** [sutura intermaxillaris]. The roughness of surface of the zygomatic process is continued across the zygomaticomaxillary suture on to the malar surface of the zygomatic bone, whose free curved infraorbital border enters into the lower boundary of the entrance to the orbit.

Seen from in front, the **body of the mandible** shows the characteristically human mark in the **mental protuberance** [protuberantia mentalis] the bony prominence of the chin, which extending laterally reaches the more or less projecting **mental tubercle** [tuberculum mentale]. The inferior margin of the jaw is thick and rounded; the upper part is adapted to the roots of teeth in the form of the **alveolar process.** The incisors and canine teeth are seen best in the anterior view; corresponding to their roots are **juga alveolaria.**

(3) The Posterior Region [Occiput]

Viewed from behind (*norma occipitalis*) the skull appears somewhat pentagonal in general form. Of the five angles, the superior or median is situated in the line of the sagittal suture; the two upper lateral angles coincide with the parietal eminences and the two lower with the **mastoid processes** [processus mastoidei] of the **temporal bones** [ossa temporalia]. Of the sides, four are somewhat rounded, and one, forming the basal line, running between the mastoid processes, is flattened.

The center is occupied by the **lambda,** and radiating from this point are three sutures, the **sagittal,** and the two parts of the **lambdoid suture.** Each half of the lambdoid suture bifurcates at the mastoid portion of the temporal bone, the two divisions constituting the **parietomastoid suture** [sutura parietomastoidea] and **occipitomastoid suture** [sutura occipitomastoidea].

In the lower part of the view is seen the **external occipital protuberance** [protuberantia occipitalis externa], the **external occipital crest** [crista occipitalis externa], and the three pairs of **nuchal lines** [lineæ nuchæ], which give the surface a rough and uneven appearance and correspond to the attachment of powerful muscles of the back of the neck.

(4) The Lateral Region

The **lateral region** (*normal lateralis*) (fig. 130) may be divided into a cerebral and a visceral (facial) portion by a line extended between the root of the nose and the tip of the mastoid process.

The *cerebral portion* presents two regions: that of the **temporal fossa** and that of the **external auditory meatus.**

The **temporal fossa** [fossa temporalis] is occupied in the recent state by the body of the temporal muscle to which it is adapted. It is somewhat semilunar in shape, is bounded *above* and *behind* by the **temporal lines,** in *front* by the frontal and zygomatic bones, and by the great wing of sphenoid, and *laterally* by the **zygomatic arch** [arcus zygomaticus], by which it is separated superficially from the infratemporal fossa; more deeply the **infratemporal crest** [crista infratemporalis] of the sphenoid bone separates the two fossæ. The temporal fossa is formed by parts of five bones, the zygomatic, temporal, parietal, frontal, and by the great wing of the sphenoid, and is traversed by six sutures, coronal, sphenozygomatic [sutura sphenozygomatica], sphenosquamosal [sutura sphenosquamosa], sphenoparietal [sutura sphenoparietalis], squamosal [sutura squamosa], and sphenofrontal [sutura sphenofrontalis]. The temporal lines, two in number, run a somewhat parallel course, separated by a narrow smooth tract of bone. The lower line begins at the temporal crest of the frontal bone, passes on to the parietal bone and terminates by joining the **supramastoid crest** of the temporal bone; it marks the limit of the temporal muscle above and behind.

The osseous **external acoustic meatus** [meatus acusticus externus] is a short canal in the lateral region of the skull confined to the temporal bone and leading internally to the tympanic cavity. Its walls are formed for the most part by the **tympanic portion of the temporal bone** [pars tympanica oss. temporalis], above to some extent by the **squamous portion** of the temporal [squama temporalis]. The entrance to the canal, external acoustic pore, [porus acusticus externus] is bounded by the roughened, free margin of the tympanic portion, to which is fixed the cartilaginous auricle. At the bottom of the meatus, the slight **tympanic groove** [sulcus tympanicus] can be seen which receives the inferior part of the circumference of the tympanic membrane.

Behind the external auditory meatus is the **mastoid portion** [pars mastoidea] of the temporal bone, projecting downward in the conical **mastoid process.** Its surface is rough, affording attachment to muscles. A **mastoid foramen** [foramen mastoideum], at or near the posterior margin of this portion, gives passage to a vein from the transverse sinus. The mastoid portion

is demarcated from the temporal fossa by the supramastoid crest which continues forward over the entrance to the external auditory meatus and into the posterior root of the zygoma.

The *visceral (facial) portion of the lateral region* is concerned chiefly with mastication and includes the region of the origin of the masticatory muscles, namely the **infratemporal fossa**, the lateral aspects of the **zygomatic bone**, the **maxilla**, and the **mandible**.

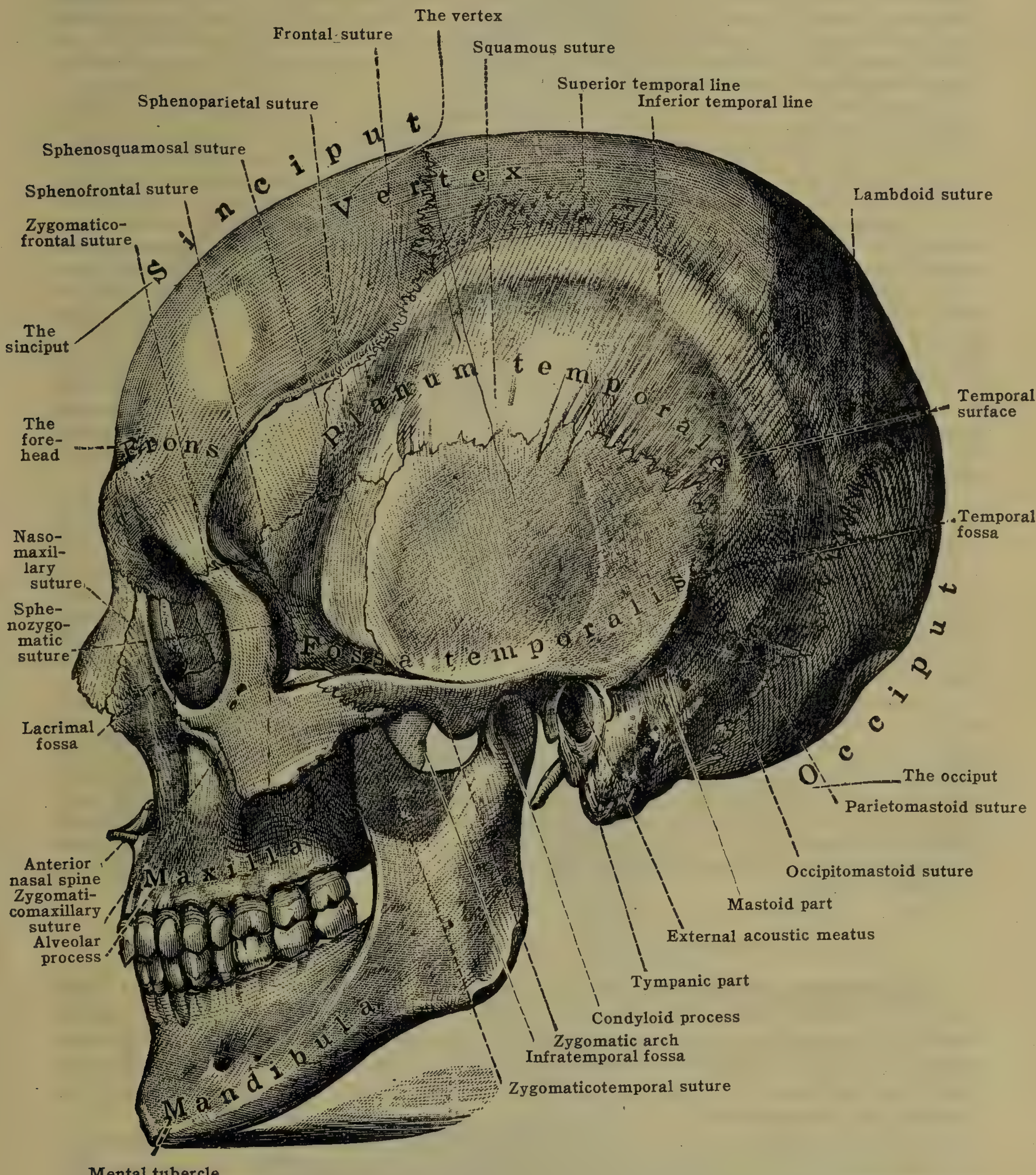


Fig. 130.—The Skull, Seen from the Left Side: Norma Lateralis. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

The **infratemporal fossa** [fossa infratemporalis] (zygomatic fossa), irregular in shape, is situated below and to the medial side of the zygomatic arch, covered in part by the ramus of the mandible. It is directly continuous above with the temporal fossa. It is bounded *in front* by the lower part of the medial surface of the zygomatic bone, and by the infratemporal surface of the maxilla, on which are seen the orifices of the **alveolar canals** [canales alveolares]; *behind* it reaches to the mandibular fossa; *above* is limited by the infratemporal crest, a small part of the squamous portion of the temporal, the great wing of the sphenoid perforated by the **foramen ovale** and **foramen spinosum**; *below* it is open; *laterally* it is bounded by the **ramus of the mandible** and by the zygomatic arch; *medially* it leads through the **sphenomaxillary fissure** to the

pterygopalatine fossa and on to the base of the skull to the level of the **lateral plate of the pterygoid process.** The infratemporal fossa contains the lower part of the temporal muscle and the coronoid process of the mandible, the external and internal pterygoid muscles, the internal maxillary vessels, and the mandibular division of the trigeminal nerve with their numerous branches.

Anterior to the external auditory meatus and separated from it by the tympanic part is a deep concavity, the anterior portion of which, the **mandibular fossa** [fossa mandibularis], is adapted to the articulation of the lower jaw; the posterior part, contributed by the tympanic, lodges an extension of the parotid gland. These two portions are separated by the **petrotympanic (Glaserian) fissure** [fissura petrotympanica (Glaseri)], a narrow gap separating the squamous from the tympanic. Regarding the latter, it is further to be observed that it is quite thin in its middle, sometimes perforated; and that it presents medially a free irregular margin, **sheath of the styloid process** [*vagina processus styloidei*] in relation to the base of the styloid process.

The **zygomatic arch** functions chiefly as the origin of the masseter muscle and in the articulation of the mandible. It is formed by the broad, **temporal process** [processus temporalis] of the zygomatic bone articulating with the slender **zygomatic process** [processus zygomaticus] of the temporal bone. Beneath the zygomatic arch, between it and the wall of the cranium, is a wide opening leading from the temporal into the infratemporal fossa which accommodates the lower portion of the temporal muscle and the coronoid process of the mandible into which it is inserted.

The **zygomatic bone** [os zygomaticum] gives the bony prominence of the cheek and yokes together the cerebral and facial parts of the skull. For, on the one hand, its **frontosphenoidal process** [processus frontosphenoidalis] unites with the sphenoid and with the frontal bone, and its **temporal process** is joined with the zygomatic process of the temporal, and on the other hand, it forms a broad articulation with the zygomatic process of the maxilla [processus zygomaticus corporis maxillæ]. The convex **malar surface** [facies malaris] presents the **zygomaticofacial foramen,** for the zygomaticofacial branch of the zygomatic nerve, gives origin to the zygomatic muscle and upon its free inferior margin to the masseter muscle. Below the zygomatic bone the **anterior surface** [facies anterior] of the **maxilla** appears in the lateral view of the skull, presenting the zygomatic process, in the form of an inverted buttress, and the **alveolar process** [processus alveolaris] with the upper range of teeth, of which the molars and premolars are best seen in the normal lateralis. The alveolar process affords partial origin to the buccinator muscle.

In the lateral aspect of the **mandible** [mandibula] are seen half the **body** [corpus mandibulæ] and the **ramus** [ramus mandibulæ]. The former presents a thickened **base** [basis mandibulæ] below, upon which and continuous with it is the **alveolar part** [pars alveolaris] containing the roots of the lower range of teeth. These are received in the **dental alveoli** [alveoli dentales], sockets between which are thin bony partitions [septa interalveolaria]. The name **limbus alveolaris** is given to the upper free edge of the alveolar process. The conspicuous **mental foramen** [foramen mentale], transmitting mental vessels and nerve, lies about half way between the upper and lower free margins of the body of the jaw, at the level of the premolar teeth. The **oblique line** [linea obliqua] extends upward and backward to the front of the ramus of the jaw.

The **ramus of the mandible** is adapted in form for articulation with the base of the cranium and for the insertion of the masticatory muscles. This stout, flat plate stands up from the body of the mandible, and ends above in two processes separated by the broad **mandibular notch** [incisura mandibulæ]. The posterior, **condyloid process** [processus condyloideus], is articular, its oval **head** [capitulum mandibulæ] fitting into the mandibular fossa, the fibrocartilaginous articular disk intervening; the anterior, **coronoid process** [processus coronoideus], slender and pointed, receives the tendon of insertion of the temporal muscle. The flat, lateral surface of the ramus receives the insertion of the masseter muscle and is extended downward and backward on to the **angle of the jaw** [angulus mandibulæ]. For detailed description of the mandible see p. 172.

(5) Inferior Region or External Base of Skull

The **external base of the skull** [basis cranii externa] (*norma basilaris*) (figs. 131, 132) extends from the incisor teeth to the occipital protuberance, and is bounded on each side by the alveolar arch, zygomatic bone, zygomatic arch, temporal bone, and the superior nuchal line of the occipital bone. It may be divided into three portions: (a) anterior or visceral, (b) middle or subcerebral, and (c) posterior or suboccipital.

(a) The **anterior portion** includes portions of the maxilla and the palate bone. For convenience the mandible may be examined from below in connection with the anterior region of the base. (For description of the hyoid bone, see p. 176.)

Mandible.—The inferior margin and medial surface of the body of the mandible can be seen in an examination of the inferior aspect of the cranium. The two halves of the body extending from the ramus forward in a parabolic curve meet at the **symphysis of the chin** [symphysis menti]. Their rounded, thick, inferior edges can be readily palpated. At the back of the symphysis, the **mental spine** [spina mentalis] gives attachment to muscles of the tongue and hyoid bone. Lateral to the midplane, a shallow depression, **digastric fossa** [fossa digastrica], marks the origin of the anterior belly of the digastric muscle. The oblique **mylohyoid line** [linea mylohyoidea] indicates the origin of the mylohyoid muscle, which enters into the formation of the floor of the mouth. The region of the medial surface of the jaw above this line is related to the mouth cavity; the sublingual salivary gland lies in this region, its place near the symphysis being marked by a shallow **sublingual pit** [fovea sublingualis]. The region

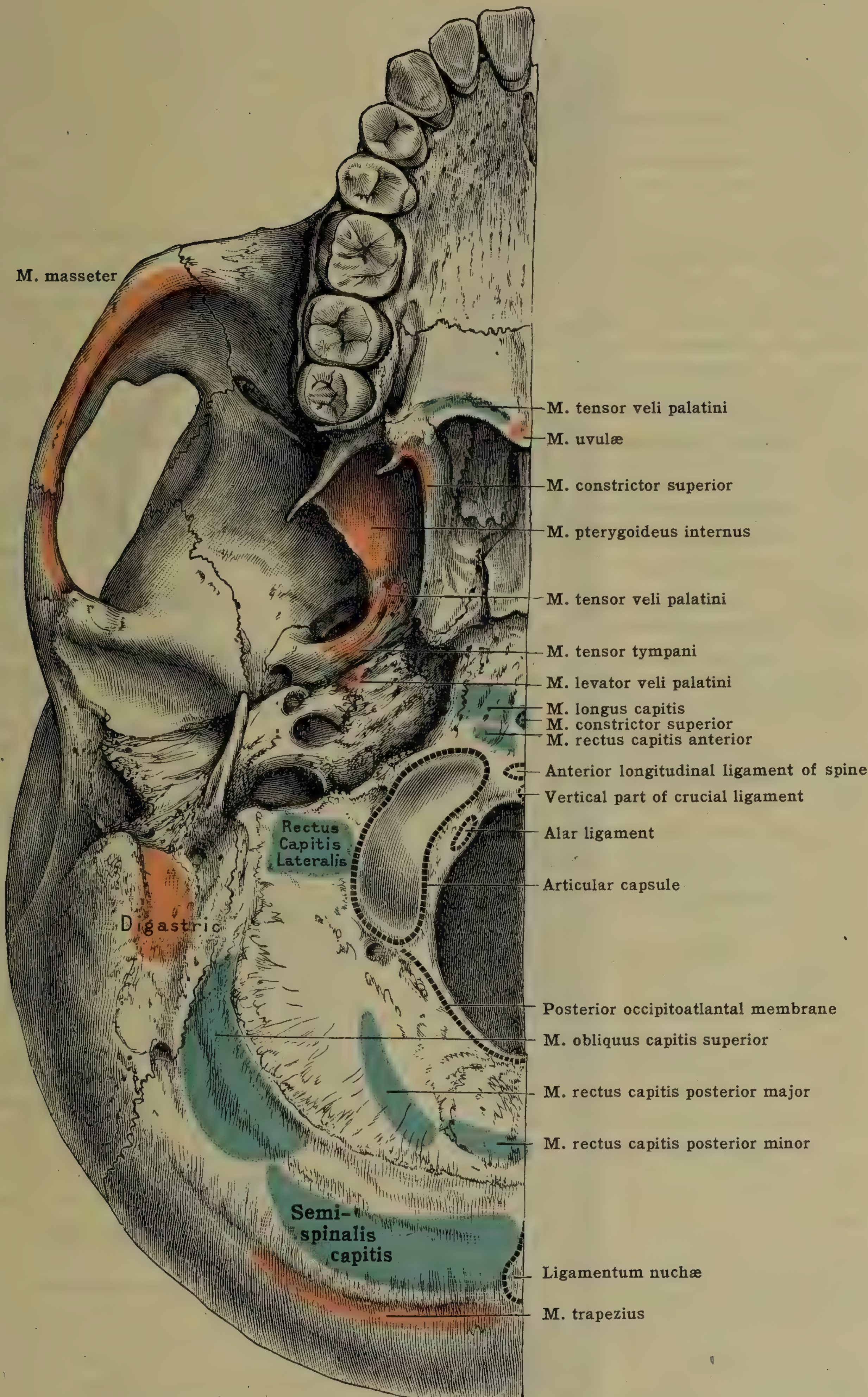


FIG. 131.—THE SKULL. EXTERNAL BASE. (To show muscular attachments.)

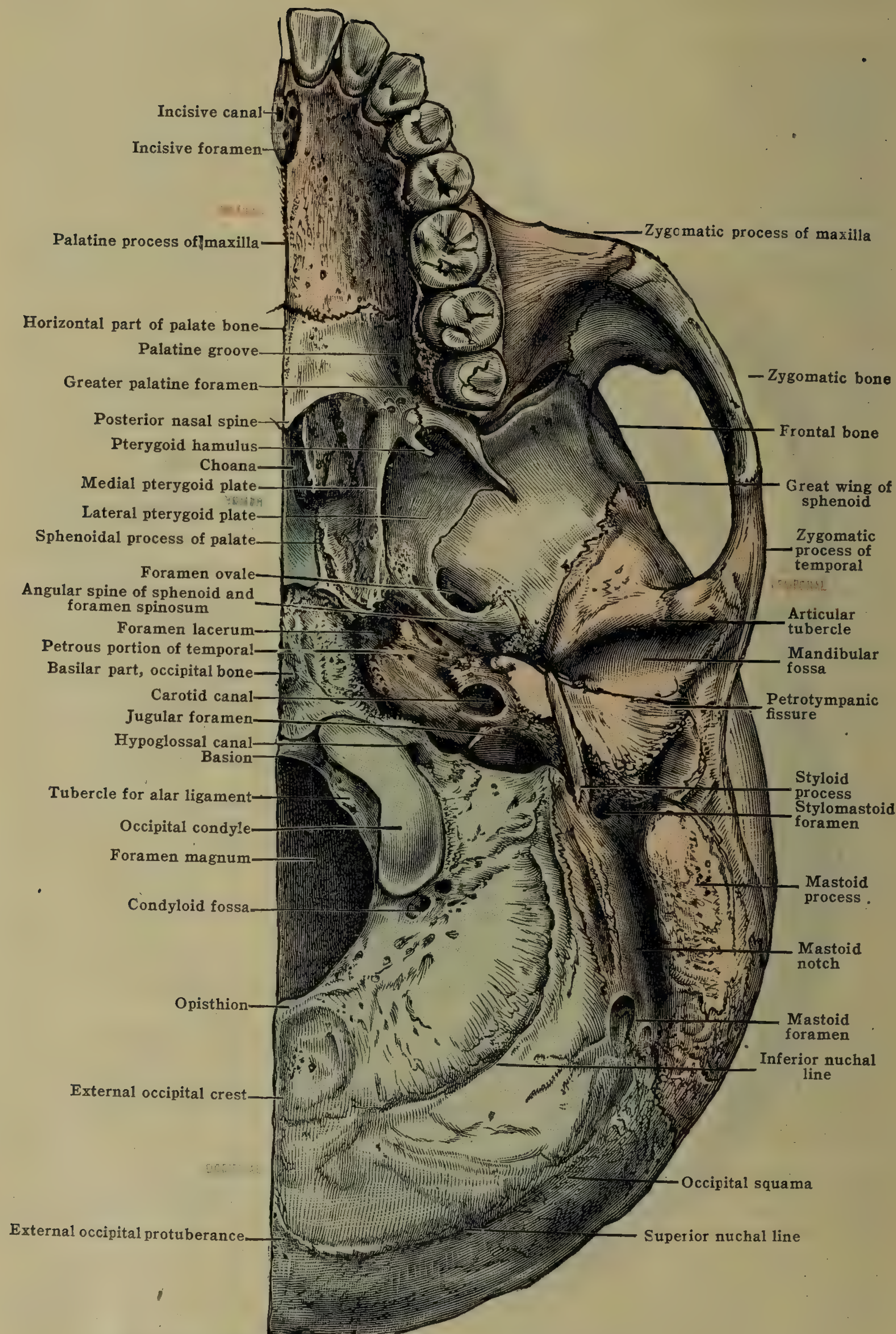


FIG. 132.—THE SKULL. External Base. Bones colored.

below the mylohyoid line is in relation to structures of the neck: a depression [fossa submaxillaris] posteriorly indicates the position of the submaxillary salivary gland and opposite it the inferior margin of the body of the bone is often slightly grooved where the external maxillary artery passes from the neck onto the face. The posterior portion of the mylohyoid line stands at the level of the transition between the mouth and pharynx, giving attachment to the superior constrictor muscle of the pharynx and the pterygomandibular ligament. Below and behind this spot is the **mylohyoid groove** [sulcus mylohyoideus] which lodges the mylohyoid branch of the inferior alveolar artery and the mylohyoid nerve. The mylohyoid groove leads upon the medial surface of the ramus to the nearly centrally placed **mandibular foramen** [foramen mandibulare]. This is the opening into the **mandibular canal** [canalis mandibulæ] within the jaw, transmitting the inferior alveolar vessels and nerve. A scale of bone [lingula mandibulæ] overhangs the mandibular foramen from in front and gives partial attachment to the sphenomandibular ligament. The surface below and behind the mylohyoid groove, extending to the angle of the jaw receives the insertion of the internal pterygoid muscle.

The alveolar process of the mandible has been described from the anterior and lateral aspects of the skull. The alveolar processes of the maxillæ together form an elliptic curve. They present the dental alveoli adapted to the form of the roots of the eight pairs of permanent teeth of the adult. Between the processes of the two sides extends the **hard palate** [palatum durum] which separates the mouth and nasal cavity. It is composed of the **palatine process of the maxilla** [processus palatinus] and the **horizontal part of the palate bone** [pars horizontalis] meeting their fellows in the **median palatine suture** [sutura palatina mediana]. The **transverse palatine suture** [sutura palatina transversa] connects the palate process of the maxilla with the horizontal part of the palate bone behind it. The roughened surface of the hard palate is adapted to the presence of many glands in the mucosa which covers it, and the grooves and foramina are occupied by the palatine vessels and nerves. A large median **incisive foramen** [foramen incisivum] anteriorly communicates with the nasal fossa on each side by the **incisive canals** [canales incisivi]. The large opening of the pterygopalatine canal between the palate and maxilla and the lower openings of the canals in the palate bone itself, the **greater** and **lesser palatine foramina** [foramen palatinum majus,—minora] give passage to nerves and vessels. The soft palate is fixed to the posterior sharp margin of the hard palate, which is extended backward in the midline to form the **posterior nasal spine** [spina nasalis posterior].

(b) The **middle** or **subcerebral portion** of the external base of the skull presents a central region, adapted largely to the nasopharynx, and lateral areas.

The *central region* presents the stout **basilar part** [pars basilaris] of the occipital bone, continuous anteriorly with the body of the sphenoid, the **pterygoid processes** [processus pterygoidei] of the latter, and the apices of the **petrosal parts** [pars petrosa] of the temporal bones. This region communicates with the nasal fossæ by the paired openings, **choanæ,** limited by the **horizontal parts** of the palate bones below, by the **vaginal processes** [processus vaginales] of the pterygoids and **alæ of the vomer** [alae vomeris] above, laterally by the **medial pterygoid laminæ** [laminæ mediales proc. pteryg.] and medially by the **vomer** (see fig. 132). With the exception of the vomer, these also give support to the upper part of the pharynx. A **notch** in the upper part of the free margin of the medial pterygoid plate is adapted to the cartilaginous portion of the auditory tube which opens nearby in the lateral wall of the nasopharynx and leads to the adjacent **groove for the auditory tube** [sulcus tubæ auditivæ] on the **angular spine** [spina angularis] of the great wing of the sphenoid. The pharyngeal aponeurosis (see p. 1218) is attached to the external cranial base in this region. The **pharyngeal tubercle** [tuberculum pharyngeum] of the pars basilaris of the occipital bone, the free edge of the medial pterygoid plate and its **hamulus** give origin to the superior constrictor muscle of the pharynx. Whereas the lateral plate of the pterygoid process is adapted to the origin of masticatory muscles, the medial lamina is related chiefly to pharyngeal structures. From its base in the **scaphoid fossa** [fossa scaphoidea] arises the tensor veli palatini muscle whose tendon is deflected by the hamulus. Branches of the sphenopalatine artery and sphenopalatine ganglion reach the roof of the nasopharynx by the **pharyngeal canal** [canalis pharyngeus] running above the vaginal process of the medial pterygoid plate. **Foramen lacerum** is the name given to the space (occupied by the basal fibrocartilage) with jagged margins between the pars basilaris of the occipital and the great wing of the sphenoid on the one hand and the extremity of the pars petrosa of the temporal bone on the other.

The central region of the subcerebral division, close to the occipital foramen, gives insertion to muscles of the vertebral column and, under cover of the occipital condyles, passage by way of the **hypoglossal canals** [canales hypoglossorum] to the hypoglossal nerves.

The *paired lateral areas* of the subcerebral region include parts of the infratemporal fossæ, the mandibular fossæ and the inferior surface of the petrous portion of the temporal bones. The part of the external base entering into the infratemporal fossa is formed by the inferior portion of the temporal squama and the adjoining inferior aspect of the great wing of the sphenoid. This surface and the lateral face of the lateral pterygoid plate afford origin to the external pterygoid muscle. Near the root of the lateral plate, perforating the great wing, are the **foramen ovale,** transmitting the mandibular nerve, and the **foramen spinosum** for the entrance of the middle meningeal artery. The mandibular fossa, oval, concave anteroposteriorly, is covered with fibrocartilage for articulation with the mandible. The articular surface extends forward upon the **articular tubercle** [tuberculum articulare], the rounded prominence which is continuous laterally with the anterior root of the zygoma. The external orifice of the **carotid canal** [canalis caroticus], occupied by the internal carotid artery appears on the inferior surface of the pars petrosa of the temporal bone. Behind this orifice is the large **jugular foramen** [foramen jugulare] in which the internal jugular vein is formed and through which pass the glossopharyngeal, vagus and accessory nerves. At the side of the jugular foramen and behind the base of the styloid process is the **stylomastoid foramen** [foramen stylo-

mastoideum] the inferior opening of the facial canal, the passageway through the cranial wall for the facial nerve. The slender **styloid process** [processus styloideus], ensheathed at its base by the vaginal process, springs from the temporal bone, beneath the tympanic cavity.

(c) The **posterior** portion of the external cranial base presents the joint surface for articulation with the vertebral column and the great areas for the attachment of the muscles which move the head and neck. The foramen magnum lies within this region.

The paired **occipital condyles,** [condyli occipitales], oval in form and projected below the general level lie upon either side of the foramen magnum chiefly in the *lateral parts* of the occipital bone. They articulate with the atlas; a tubercle on the margin gives attachment to the alar ligament. Lateral to the condyle, the rough surface of the **jugular process** [processus jugularis] gives insertion to the rectus capitis lateralis muscle. This process articulates laterally with the pars mastoidea of the temporal; in front it enters into the boundary of the jugular foramen. Behind the jugular process and condyle is the **condylar fossa** [fossa condyloidea], in the bottom of which a foramen is sometimes present giving passage to an emissary vein.

Regarding the areas for the attachment of muscles: the posterior belly of the digastric arises from the **mastoid notch** [incisura mastoidea] of the mastoid portion medial to the mastoid process. The **squamous part** (squama occipitalis), behind the foramen magnum and lateral parts, convex and rough, is marked by ridges indicating the limits of muscular insertion and sites of ligamentous attachment. The **external occipital crest,** in the midline from the external occipital protuberance to the foramen magnum, gives attachment to the ligamentum nuchæ. From the external **occipital protuberance,** the **superior nuchal line** [linea nuchæ superior] reaches to the lateral angle of the occipital bone; from the middle of the crest, the **inferior nuchal line** [linea nuchæ inferior] arches toward the jugular process. The names of the muscles inserted here will be found in the description of the occipital bone (p. 132).

Within this region of the external base, openings for the passage of so-called emissary veins are present: the **mastoid foramen** near the posterior margin of the pars mastoidea, communicating with the transverse groove (lodging the transverse sinus); a **condylar canal** [canalis condyloideus] often found in the bottom of the condylar fossa opening into the terminal part of the same groove. The occipital artery occupies the **occipital groove** [sulcus a. occipitalis] of the pars mastoidea medial to the mastoid notch.

For description of the **foramen occipitale magnum,** see p. 135.

(6) Bony Landmarks and Clinical Relations

The bony landmarks of the skull will now be reviewed with special reference to certain points of clinical interest.

Bony landmarks.—These should be studied with the aid of a skull, as well as on the living subject. Beginning in front, a depression at the root of the nose approximates the **nasion,** and immediately above it, the smooth area between the eyebrows indicates the **glabella,** a slight prominence joining the two **superciliary arches.** These points mark the remains of the frontal suture, and the junction of the frontal, nasal, and maxillary bones and is one of the sites of a meningocele. In the middle line, behind, is the external occipital protuberance (**inion**), the thickest part of the vault, and corresponding internally with the confluence of five sinuses. A midline joining the inion and glabella corresponds to the sagittal, and occasionally the metopic suture, the falx cerebri, the superior sagittal sinus, and the longitudinal fissure of the brain. From the inion the **superior nuchal lines** pass laterally toward the upper and back part of the base of the **mastoid processes,** and indicate the first or so-called horizontal part of the transverse (lateral) sinus.

About 6.2 cm. (2½ in.) above the external occipital protuberance is the **lambda,** or meeting of the sagittal and lambdoidal sutures (posterior fontanelle, small and triradiate in shape). It is useful to remember, as guides on the scalp to the above two important points, that the lambda is on a level with the superciliary ridges, and the external occipital protuberance on one with the zygomatic arches. Below the external occipital protuberance, between it and the foramen magnum, an **occipital,** the commonest form of cranial **meningoceles,** makes its appearance. It comes through the median fissure in the cartilaginous part of the squamous portion of the bone.

The point of junction of the occipital, parietal, and mastoid bones, the **asterion,** is placed about 3.7 cm. (1½ in.) behind and 1.2 cm. (½ in.) above the center of the external acoustic meatus (fig. 130). It indicates the site of the mastoid fontanelle and just below it the superior nuchal line terminates. The **bregma,** or junction of the coronal, sagittal, and, in early life, the frontal suture (anterior fontanelle, large and lozenge-shaped), lies just in front of the center of a line drawn transversely over the cranial vault from one preauricular point to the other. The bregmatic fontanelle normally closes before the end of the second year. The lambdoid fontanelle is closed at birth. The **pterion,** or region of the junction of the frontal and sphenoid in front, parietal and squamous bones behind, lies in the temporal fossa, 3.7 to 5 cm. (1½ to 2 in.) behind the zygomatic process of the frontal, and about the same distance above the zygoma (fig. 130). This spot also gives the position of the trunk and the anterior division of the middle meningeal artery, the Sylvian point and divergence of the limbs of the lateral (Sylvian) fissure, the insula (island of Reil), and middle cerebral artery. It further,

corresponds to the sphenoidal fontanelle. On the side of the skull the **zygomatic arch,** the **temporal ridge,** and **external auditory meatus** need attention. That important landmark, the **zygomatic arch,** wide in front where it is formed by the zygomatic (malar), narrowing behind where it joins the temporal, gives off here three roots, the most anterior marked by the tuberculum articulare, in front of the mandibular (glenoid) fossa, the middle behind this point, while the posterior curves upward and backward to be continuous with the temporal ridge. Within the zygomatic arch lie **two fossæ** separated by the infratemporal (pterygoid) ridge: above is the **temporal,** with the muscle and deep temporal vessels and nerves; below is the **infratemporal** or **zygomatic** fossa, with the lower part of the temporal muscle, the two pterygoids, the internal maxillary vessels, and the mandibular division of the fifth nerve. To the upper border of the zygomatic arch is attached the temporal fascia, to its lower, the masseter. Its upper border

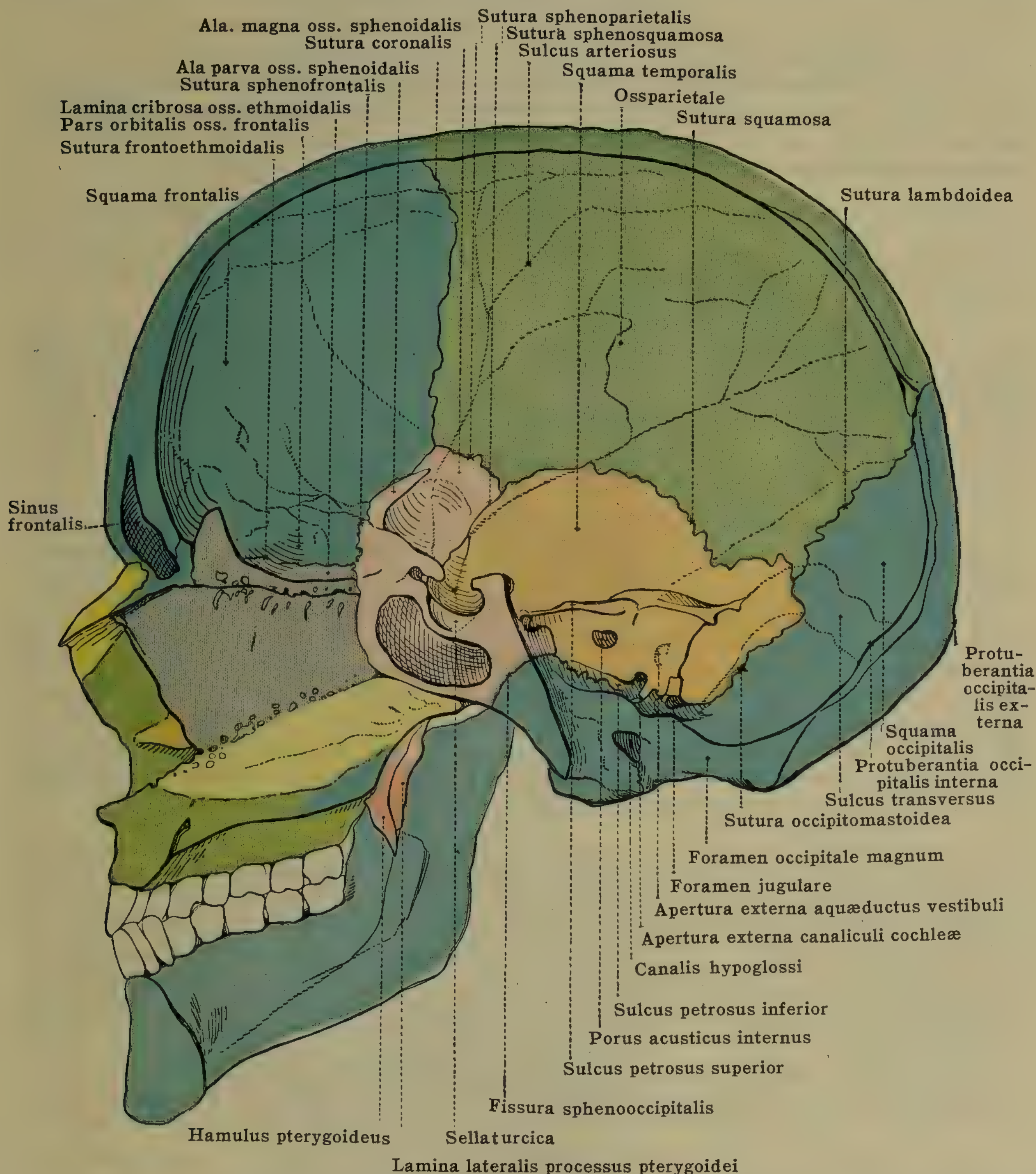


FIG. 133.—MEDIAN SECTION OF THE SKULL. Viewed from the left. (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

marks the level of the lower lateral margin of the cerebral hemisphere. A point corresponding to the middle root of the zygoma, immediately in front of the tragus, and on a level with the upper border of the bony meatus, is called the **preauricular point.** Here the superficial temporal vessels and the auriculotemporal nerve cross the zygoma, and a patient's pulse may be taken by the anesthetist. The lower end of the central (Rolandic) fissure lies 5 cm. (2 in.) vertically above this point. The **temporal line,** giving origin to the temporal fascia, starts from the zygomatic process of the frontal, and becoming less distinct, curves upward and backward over the lower part of that bone, crosses the coronal suture, traverses the parietal bone, curving downward and backward to its posterior inferior angle. Here it passes on to the temporal, and passing forward over the external auditory meatus, is continuous with the posterior root of the zygoma. Below the root of the zygoma will be felt the mandibular joint, and when the mouth

is opened, the condyle will be felt to glide forward on the articular tubercle, leaving a well-marked depression behind.

The **anterior inferior angle of the parietal bone**, and its great importance as a landmark, have already been noted. The **posterior inferior angle** of this bone (grooved by the transverse (lateral) sinus) lies a little above and behind the base of the mastoid process, on a level with the roots of the zygoma. Just below and in front of the tip of the mastoid the **transverse process of the atlas** can be palpated in a spare subject.

THE INTERIOR OF THE CRANIUM

The **size** of the cranial cavity is in relation to that of the contained brain and its envelopes. The cavity conforms rather closely to the shape of the brain, the larger divisions of which all leave their marks upon the base and walls.

Median section (fig. 133).—In this section conditions are presented for an advantageous review of the structure of the cranial wall, and of the size and form of the cranial cavity. The walls of the brain-case are built up mainly from the parietal, frontal and occipital bones; to a lesser extent by the temporals, the sphenoid and ethmoid.

The structure of the bony capsule in the midplane shows considerable variation. It is thinnest at the cribriform plate of the ethmoid, and thickest through the basilar portion of the occipital and body of the sphenoid. In the cranial walls may be seen the **diploë**, between the **outer** and **inner tables** [lamina externa; interna]; also the frontal and sphenoidal air sinuses. For structure of the cranial wall, see also p. 126.

The inner surface of the cranium presents slight depressions [impressiones digitatæ] corresponding to the convolutions [gyri] of the cerebrum. A series of branching **arterial and venous grooves** [sulci arteriosi; venosi] are occupied by meningeal vessels; the largest, for the **middle meningeal vessels**, may be traced to the foramen spinosum in the base. The shallow **groove for the superior sagittal sinus** [sulcus sagittalis] occupies the midline of the roof; and on each side are small **pits** [foveolæ granulares] for the Pacchionian bodies of the arachnoid. Posteroinferiorly on each side the **groove for the transverse sinus** [sulcus transversus] crosses the occipital, angle of the parietal, and mastoid portion of the temporal bones.

The **floor or internal cranial base** [basis cranii interna] of the cranial cavity presents three irregular subdivisions termed the anterior, middle, and posterior fossæ (figs. 134 and 135) in adaptation to the contour of the base of the brain.

The Anterior Cranial Fossa [fossa cranii anterior].—The floor of this fossa is on a higher level than the rest of the cranial floor. It is formed by the orbital part of the frontal bone, the cribriform plate of the ethmoid, the lesser wings of the sphenoid and the fore part of the body of the sphenoid. It supports the frontal lobes of the cerebrum. The **sutures** traversing the floor of the fossa are the frontoethmoidal, forming three sides of a rectangle, that portion of the transverse facial suture which traverses the roof of the orbit, namely, the sphenoorbital suture, and the sphenoethmoidal suture.

In the midline of the floor is the **crista galli**, its alæ articulating with the frontal and so completing the boundaries of the **foramen cecum** (lodging an emissary vein); beyond, is the **frontal crest** to which as well as to the crista galli the falx cerebri is attached. On either side of the crista galli, the **cribriform plate** [lamina cribrosa] presents numerous foramina for filaments of the olfactory nerve. The lateral parts of the floor are constituted by the **orbital parts** of the frontal bone, which at the same time form the **roofs of the orbits**. This region is convex here and shows marked grooves and ridges for the cerebral gyri and sulci. In the **frontoethmoidal suture** [sutura frontoethmoidalis] are the cerebral openings of the **anterior** and **posterior ethmoidal canals** transmitting ethmoidal arteries, the anterior carrying besides, the anterior ethmoidal nerve.

The posterior margin of the lesser wing of the sphenoid corresponds to the anterior part of the lateral fissure of the cerebrum, separating the frontal lobe occupying the anterior cranial fossa, from the temporal lobe which projects downward and forward into the middle fossa.

The Middle Cranial Fossa [fossa cranii media] situated on a lower level than the anterior, consists of a central and two lateral portions. In front it is limited by the posterior borders of the lesser wings of the sphenoid and the anterior margin of the groove of the chiasma, behind by the dorsum sellæ and the upper margins of the petrous portions of the temporal bones. Laterally it is bounded on each side by the temporal squama, great wing of the sphenoid, and the parietal bone, whilst the floor is formed by the body and great wings of the sphenoid and the anterior surfaces of the **petrous portions** of the temporals. It includes the following sutures:—**sphenoparietal, sphenosquamosal, squamous,** and the **sphenopetrosal fissure** [fissura sphenopetrosa].

In general the form of the lateral portion corresponds to that of the temporal lobe of the brain. A conspicuous groove lodges the middle meningeal vessels in their course from the **foramen spinosum**. The semilunar (Gasserian) ganglion of the trigeminal nerve occupies the slight

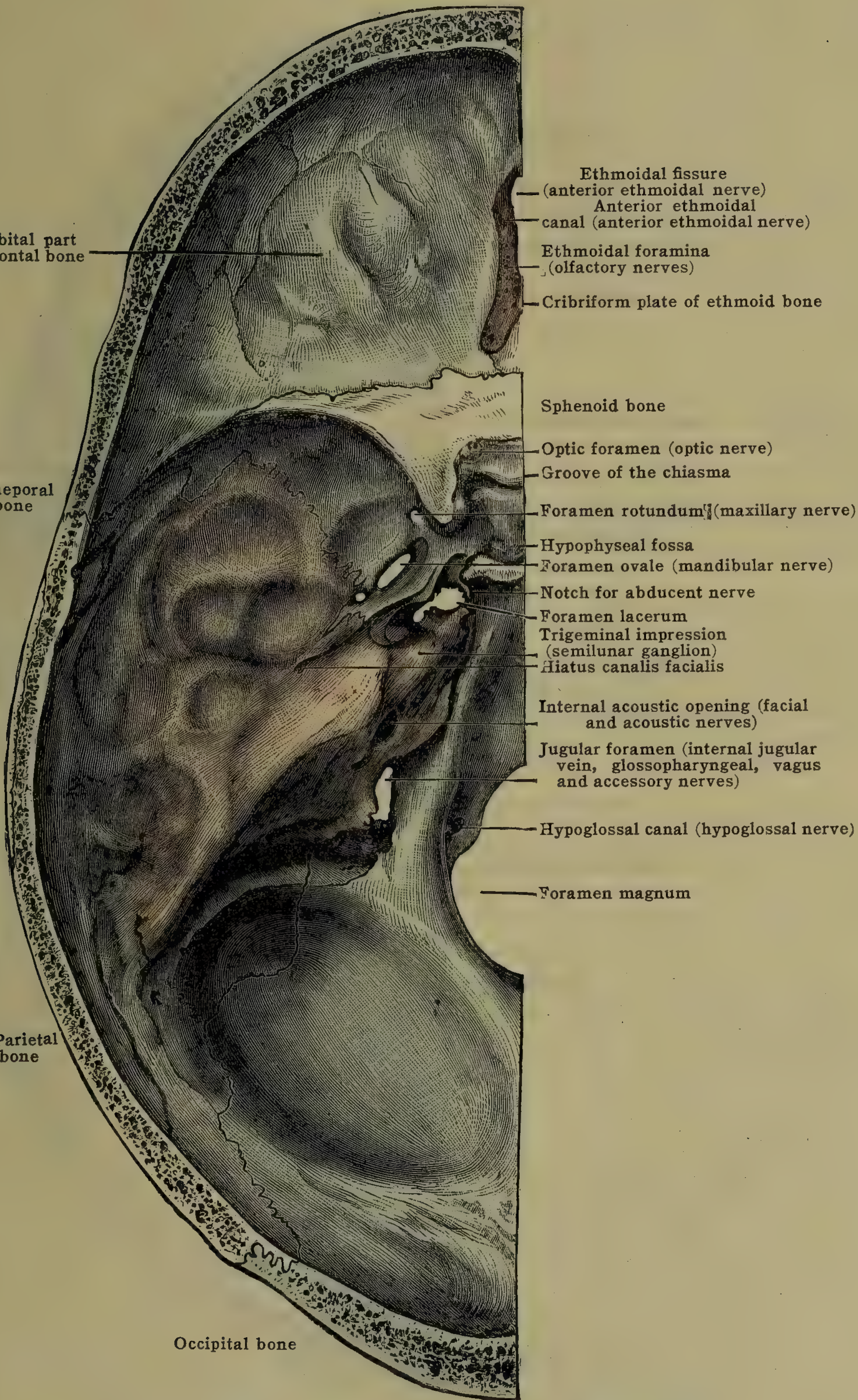


Fig. 134.—Internal Base of the Skull. (Bones colored.)

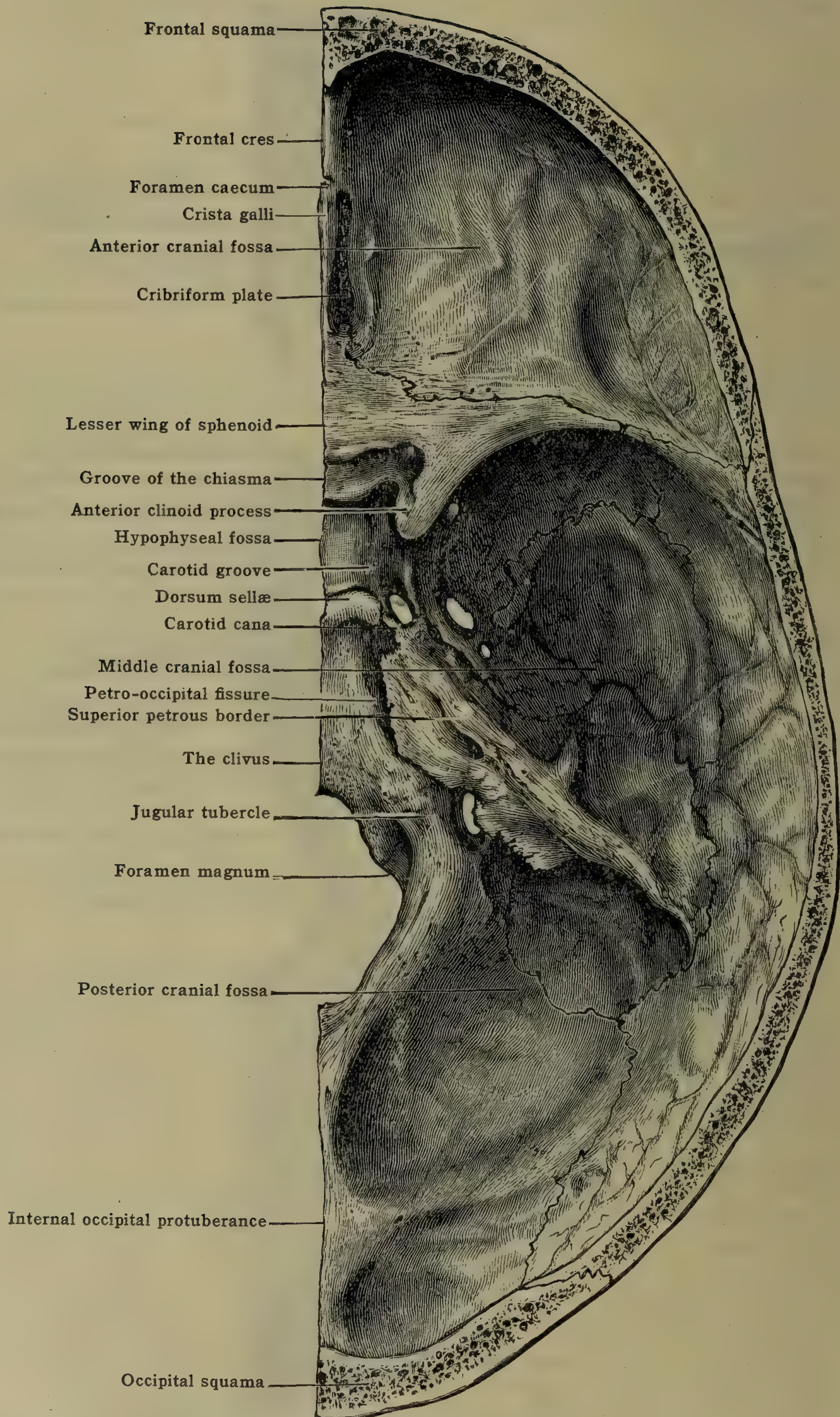


Fig. 135.—Internal Base of the Skull.

trigeminal impression [impressio trigemini] on the front of the apex of the petrous part; its mandibular branch passes to the infratemporal fossa by the **foramen ovale**; its maxillary branch passes into the pterygopalatine fossa via the **foramen rotundum**; its ophthalmic branch goes through the **superior orbital fissure** into the orbit.

Upon the anterior face of the petrous portion is a small opening, **hiatus canalis facialis,** which gives passage to the great superficial petrosal nerve; this runs in a groove to the irregular **lacerated foramen** in the base of the cranium. The internal carotid artery enters the cranial cavity from the **carotid canal** at the apex of the petrous part, and runs in the **carotid groove** [sulcus caroticus] upon the side of the body of the sphenoid, together with the cavernous sinus. Lateral to the carotid aperture is a slender bony process, the **lingula sphenoidalis.** Lateral to the hiatus canalis facialis is the **tegmen tympani,** the thin roof of the tympanic cavity, behind which is the **eminentia arcuata,** made by the superior semicircular canal.

The middle portion of the middle cranial fossa is occupied mainly by the **sella turcica** which includes the following: the **hypophyseal fossa** [fossa hypophyseos] lodging the hypophysis or pituitary gland, limited in front by a rounded eminence, the **tuberculum sellæ,** and posteriorly by a quadrilateral plate, the **dorsum sellæ.** The lateral angles of the dorsum sellæ form the **posterior clinoid processes** [processus clinoideus posterior]. The **anterior clinoid processes** [processus clinoideus anterior] project backward from the lesser wings of the sphenoid. The carotid groove terminates opposite the last-named process. Here the ophthalmic artery is given off which accompanies the optic nerve through the **optic foramen** [foramen opticum] between the two roots of the lesser wing, into the orbit. The transverse groove of the chiasma [sulcus chiasmatis] joins the optic foramina.

The Posterior Cranial Fossa [fossa cranii posterior] is the deepest and largest of the three. It is bounded in front by the dorsum sellæ of the sphenoid and on each side by the superior border of the petrosal, and the mastoid portion of the temporal bone, the posterior inferior angle of the parietal, and posteriorly and above by the **transverse groove** on the occipital bone for the transverse sinus. These bones take part in the formation of the fossa, and there are included the occipitomastoid and parietomastoid sutures and the **petro-occipital fissure** [fissura petrooccipitalis].

In the recent state the fossa lodges the cerebellum, pons, and medulla, and is roofed in by the tentorium cerebelli, a tent-like process of the dura mater attached to the superior boundaries of the fossa. It communicates with the general cranial cavity by means of the tentorial notch (foramen ovale of Pacchionius), a large opening bounded anteriorly by the **clivus** and posterolaterally by the free edge of the tentorium; inferiorly the posterior cranial fossa communicates with the vertebral canal by the **foramen magnum** [foramen occipitale magnum].

Between the posterior cranial fossa and the middle cranial fossa on each side is the **pyramid,** or petrous portion of the temporal bone, enclosing the inner ear. The features of its anterior surface were mentioned above. On the posterior surface, the most conspicuous mark is the **internal acoustic opening** [porus acusticus internus], which transmits the acoustic, facial and glossopalatine nerves. Posterolateral to this are the **fossa subarcuata** and the **aquaeductus vestibuli.** The superior margin of the pyramid is grooved for the superior petrosal sinus; the posterior margin for the inferior petrosal sinus.

Through the **foramen magnum** the spinal cord passes into the brain-stem which rests upon the **basilar portion** [pars basilaris] of the occipital between the two paired eminences, the **jugular tubercles** [tubercula jugularia]; this surface leads forward to the **clivus** and continues upon the dorsum sellæ. The cerebellum occupies the greater part of the remaining space of the posterior fossa. A low ridge in the midline of the occipital squama extends from the **internal occipital protuberance** [protuberantia occipitalis interna] to the foramen magnum and gives attachment to the falx cerebelli. On either side of the foramen magnum is the internal orifice of the **hypoglossal canal,** transmitting the hypoglossal nerve. Still more laterally is the **jugular foramen,** a large opening between the occipital and petrous bones, which transmits the vagus, glossopharyngeal and accessory nerves and the transverse sinus. The groove for this sinus is shallow at its beginning (near the internal occipital protuberance) but deeper in its terminal portion [**sulcus sigmoideus**], where it presents the small mastoid foramen for the passage of the mastoid emissary vein and the mastoid branch of the occipital artery.

Clinical relations.—Some of the chief points in the surgical anatomy of the interior, especially of the **base** will be mentioned. **The three fossæ** are of paramount importance in fractures. In the **anterior fossa** the delicacy of parts of the floor, the connection of this with the nose and orbit, and the exact adaptation of its irregular surface to that of the frontal lobes, no 'water-bed' intervening, are the chief points. Thus the slightness of a fatal fissure, the frequent presence of bruising after a blow perhaps on the occiput, which has been considered to have caused only concussion, the characteristic palpebral hemorrhage, and the infection of a fracture here are all explained, together with the possibility and gravity of a fracture here from a severe blow on the nose. In the **middle fossa** the frequency of fractures is explained by the facts that while here, as in the other fossæ, a fracture often radiates down from the vertex, the overlying vault being a region often struck, the base is weakened by numerous foramina and fissures. Further, the resisting power of the petrous bone must be lessened by the cavities for the internal ear, the carotid canal, and, to a less degree, by the jugular fossa. For fluids to escape through the external meatus there must be injury to the dura, to the prolongation of the arachnoid into the internal meatus, the membrani tympani, and probably the internal ear. The presence of the middle meningeal artery as well as the cavernous sinus in this fossa must also be

remembered, especially in such operations as that on the Gasserian ganglion. **Posterior fossa:** It is not sufficiently recognized that fractures here are, owing to the anatomy of the parts, in some respects the most important of all. It is here that a small fissure-fracture, ultimately fatal, with severe occipital and frontal bruising and some intradural hemorrhage, has been so often overlooked, especially in the drunken. This is explained by the supposed strength of the bone, which is really very thin in places, by the thickness of the soft parts, and the abundance of hair. Further, there is no very apparent escape of cerebral contents as in the anterior and middle fossæ. Blood, etc., may trickle into the pharynx far back, or a deep-seated ecchymosis coming up after some days, under the muscles about the mastoid process, may call attention to the damage within. Fracture of the base involving the hypoglossal canal may be manifested by paralysis of one side of the tongue.

Dura mater.—The outer layer of this membrane acts as a periosteum, by bringing blood-vessels to the bone, while the inner layer supports the brain. The influence of its partitions and its damping effect on vibrations is great in blows on the head. Its varying adhesions, according to site and age, must be remembered. Thus while it is intimately connected over the base with its adhesions to the different foramina, it is more loosely connected with the vault, as is shown in middle meningeal hemorrhage. In early and later life the closeness of its connection with the bones is also more marked. It is united to the inter-sutural membranes.

The **pericranium** differs from the periosteum elsewhere in that it gives little nourishment to the bone beneath, which is supplied chiefly by the meningeal vessels from the dura mater. After necrosis of the skull, there is no tendency to the formation of an involucrum of new periosteal bone as in the long bones. The pericranium is firmly adherent to the sutures of the skull bones, so that any subpericrania effusion of blood or pus is limited by the sutures. The *emissary veins* are described on p. 725.

Finally the existence of **the cerebrospinal fluid** with its power of lessening the evil of vibrations and its aid in regulating intracranial pressure, must be borne in mind. The chief collections, in which the subarachnoid meshwork is almost absent, are met with in front and behind the medulla. That in front, also lying under the pons, Hilton's 'water-bed,' sends a prolongation forward to the optic chiasma, but does not extend under the frontal or temporal lobes. The collection behind lies between the medulla and under surface of the cerebellum. Here, by the foramen of Magendie, the intraventricular cavities communicate with the subarachnoid space of the brain and spinal cord.

Structure of cranium.—Two layers and intervening spongy diploë. Each layer has special properties. The **outer** gives thickness, smoothness, and uniformity, and, above all, elasticity. The **inner** is whiter, thinner, less regular—e.g., the depressions for vessels, Pacchionian bodies, dura mater, and brain. The **diploë**, formed by absorption after the cranium has attained a certain thickness, reduces the weight of the skull without proportionately reducing its strength, and provides a material which will prevent the transmission of vibrations.

A blow on the head may fracture the internal layer only, the external one and diploë escaping. This is difficult to diagnose, and thus it is impossible to judge of the severity of a fracture from the state of the external layer. This may be whole, or merely cracked, while the internal shows many fragments. It is usual to find more extensive splintering of the inner than of the outer layer (table).

The average **thickness** of the adult skull-cap is about 5 mm. (Holden). The thickest part is at the external occipital protuberance, where the bone is often 1.8 cm. (¾ in.) in thickness. The thinnest part of the skull vault is over the squamous part of the temporal. The extreme fragility of the skull here is partly compensated for by the thickness of the soft parts; these two facts are always to be remembered in the diagnosis of a fracture of the skull here, after a slight injury. Other weak spots are the medial wall of the orbit, the cerebellar fossæ, the cribrous plate of the ethmoid and that part of the middle fossa corresponding to the glenoid fossa.

Anatomical conditions tending to minimise the effects of violence inflicted upon the skull.—(1) The **density** and **mobility of the scalp.** (2) The **dome-like shape of the skull.** This is calculated to bear relatively hard blows and also to allow them to glide off. (3) The **number of bones** tends to break up the force of a blow. (4) The **sutures** interrupt the transmission of violence. (5) The **intersutural membrane** (remains of fetal periosteum) acts, in early life, as a linear buffer. (6) The **elasticity of the outer layer** (table). The **overlapping of some bones,** e. g., the parietal by the squamous; and the alternate bevelling of adjacent bones, e. g., at the coronal suture. (8) The **presence of ribs,** or **groins,** e. g., (*a*) from the crista galli to the internal occipital protuberance; (*b*) from the root of the nose to the zygoma; (*c*) the temporal ridge from orbit to mastoid; (*d*) from mastoid to mastoid; (*e*) from external occipital protuberance to the foramen magnum. (9) **Buttresses,** e. g. zygomatic processes and the greater wing of the sphenoid. (10) The **mobility** of the head upon the spine.

The Pterygopalatine Fossa

The **pterygopalatine** (sphenomaxillary) **fossa** [fossa pterygopalatina] (fig. 136) is a small space, of the form of an inverted pyramid, interposed between the maxilla, pterygoid process of the sphenoid and palate bones, and opening laterally into the infratemporal fossa. It contains the sphenopalatine ganglion, the maxillary nerve, and the terminal part of the internal maxillary artery, and numerous branches of these vessels and nerves.

It is bounded *in front* by the infratemporal surface of the maxilla; *behind*, by the base of the pterygoid process and the lower part of the anterior surface of the great wing of the sphenoid; *medially* by the **perpendicular part of the palate** [pars perpendicularis] with its **orbital** and **sphenoidal processes**; *above* by the lower surface of the body of the sphenoid. Through the **superior orbital fissure** [fissura orbitalis superior] it communicates with the cranial cavity, through the

inferior orbital fissure [fissura orbitalis inferior] with the orbit, and through the **sphenopalatine foramen** [foramen sphenopalatinum] on the medial wall it communicates with the upper and back part of the nasal fossa. Three foramina open in the posterior wall, *viz.*, the **foramen rotundum,** the **pterygoid (Vidian) canal** and the **pharyngeal canal.** The apex of the fossa leads below into the **pterygopalatine canal** [canalis pterygopalatinus] and the **accessory palatine canals** which branch from it; and anteriorly is the beginning of the **infraorbital canal** [canalis infraorbitalis].

THE ORBITS

Below the forehead are the openings of the **orbits** [orbitæ] (figs. 129, 130, 136), two cavities of pyramidal shape, with their bases directed forward and laterally and their apices backward and medially. Each cavity forms primarily a socket for the eyeball and the muscles, nerves, and vessels associated with it, but also contains vessels and nerves not directly related to the eye, which pass through the orbit to other regions.

Seven bones enter into formation of its walls, viz., the frontal, zygomatic, sphenoid, ethmoid, lacrimal, palate, and maxilla; but as three of these—the frontal, sphenoid, and ethmoid—are single median bones which form parts of each cavity, there are only eleven bones represented in the two orbits. Each orbit presents four walls, a circumference or base, and an apex.

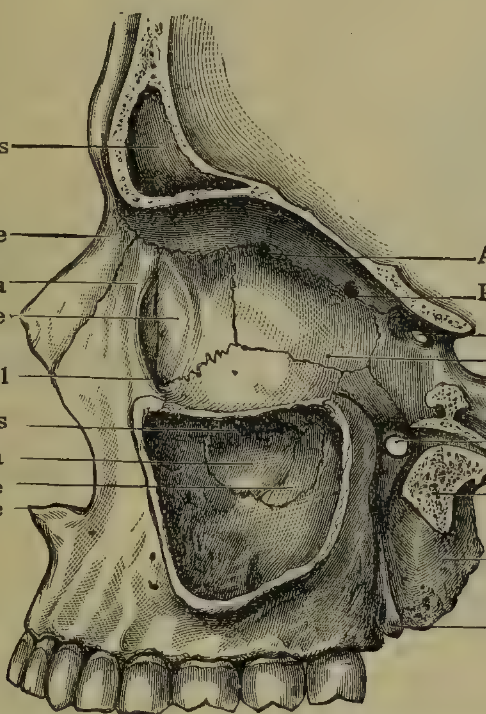


FIG. 136.—A SAGITTAL SECTION OF THE SKULL SHOWING THE MEDIAL WALL OF THE ORBIT, THE MEDIAL WALL OF THE MAXILLARY SINUS, AND THE PTERYGOPALATINE FOSSA.

The **apex** of each orbit corresponds to the **optic foramen,** a circular orifice between the two roots of the small wing of the sphenoid bone, which transmits the optic nerve and ophthalmic artery. From the circumference of the optic foramen the straight muscles (recti) of the eyeball arise.

The **superior wall** [paries superior] or **roof,** vaulted and smooth, is formed mainly by the orbital plate of the frontal and is completed posteriorly by the small wing of the sphenoid between which is the sphenofrontal suture. At the lateral angle it presents the **fossa of the lacrimal gland,** and at the medial angle a depression, **trochlear pit,** [fovea trochlearis] or a spine for the pulley of the superior oblique muscle of the eye.

The **inferior wall** [paries inferior] or **floor** is directed upward and laterally and is not so large as the roof. It is formed by the orbital surface of the maxilla, the orbital surface of the zygomatic, and the orbital process of the palate bone participating in the formation of the **lacrimomaxillary suture** [sutura lacrimomaxillaris], the **ethmoideomaxillary suture** [sutura ethmoideomaxillaris], the **palatoethmoidal suture** [sutura palatoethmoidalis], the **sphenoorbital suture** [sutura sphenoorbitalis], the **palatomaxillary suture** [sutura palatomaxillaris], and the **zygomaticomaxillary suture** [sutura zygomaticomaxillaris]. It is marked near the middle by the **infraorbital groove** [sulcus infraorbitalis] for the infraorbital artery and the maxillary nerve, terminating anteriorly in the **infraorbital canal,** through which the nerve and artery emerge on the face. Near the commencement of the canal narrow passages, the **alveolar canals** run forward and downward in the anterior wall of the maxillary sinus, transmitting nerves and vessels to the incisor and canine teeth.

The **lateral wall,** directed forward and laterally, is formed by the orbital surface of the great wing of the sphenoid, and of the zygomatic process of the frontal bone. The sutures presented are as follows: the **zygomaticofrontal suture** [sutura zygomaticofrontalis], the **spheno-zygomatic suture** and the **sphenofrontal suture.** Between it and the roof, near the apex, is the

superior orbital fissure, a narrow gap intervening between the great and small wings of the sphenoid, and connecting the orbit and cranial cavity. It transmits several structures, including the ophthalmic, oculomotor, trochlear and abducent nerves and the ophthalmic vein or veins; it also transmits some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery and recurrent branches of the lacrimal artery. The lower margin of the fissure presents near the middle a small tubercle, from which the inferior head of the lateral rectus muscle arises. Between the lateral wall and the floor, near the apex, is the **inferior orbital fissure** [fissura orbitalis inferior] through which pass the maxillary nerve and its zygomatic branch, and the infraorbital vessels from the pterygopalatine fossa. A connection is established through the fissure between the orbital veins and the pterygoid plexus in the infratemporal fossa. The great wing of the sphenoid forms the posterior margin of the fissure, the body of the maxilla its anterior edge, and the zygomatic bone its lateral boundary. On the latter bone are seen the **zygomatico-orbital orifices** [foramina zygomaticoorbitalia] of the zygomaticotemporal and zygomaticofacial canals, which traverse the zygomatic bone, transmitting the nerves of the same name to the temporal fossa and cheek. The commencement of the zygomaticotemporal canal is sometimes seen in the sphenozygomatic suture.

The **medial wall,** narrow and nearly vertical, is formed from before backward by the frontal process of the maxilla, the lacrimal, the lamina papyracea of the ethmoid, and the body of the sphenoid. It is traversed by three vertical sutures:—one between the frontal process of the maxilla and the lacrimal, **lacrimomaxillary suture,** a second between lacrimal and lamina papyracea, **lacrimoethmoidal suture,** and a third, the **sphenoethmoidal suture** [sutura sphenoethmoidalis], between the lamina papyracea and the sphenoid. Between the lacrimal and frontal bones is the **frontolacrimal suture** [sutura frontolacrimalis]. Occasionally the sphenoidal concha appears in the orbit between the ethmoid and the body of the sphenoid. Anteriorly is the **fossa of the lacrimal sac** [fossa sacci lacrimalis], hollowed out of the lacrimal bone and frontal process of the maxilla; behind this the **posterior lacrimal crest** [crista lacrimalis posterior], from which the lacrimal part of the orbicularis oculi muscle arises. At the junction of the medial wall with the roof, and in the suture between the ethmoid and frontal, are seen the orifices of the **anterior** and **posterior ethmoidal foramina** [foramen ethmoidale anterius; posterius], the anterior, transmitting the anterior ethmoidal vessels and nerve; and the posterior, the posterior vessels and nerve.

The **base** or circumference is quadrilateral in form and corresponds to the anterior **entrance of the orbit** [**aditus orbitæ**]. It is bounded by the frontal bone above, presenting the **zygomatic process** and the sharp **supraorbital margin,** broken by the **supraorbital notch** (sometimes a foramen) giving passage to the supraorbital branch of the ophthalmic nerve and the supraorbital artery. The frontal process of the maxilla is on the medial side, the zygomatic bone on the lateral side of the aditus orbitæ. The zygomatic and the body of the maxilla form the inferior boundary which is in the shape of a sharp raised edge, **infraorbital margin,** between the orbital and facial surfaces of these bones. The infraorbital margin is continued medially into the **anterior lacrimal crest** [crista lacrimalis anterior], in front of the fossa of the lacrimal sac, which gives origin to the orbicularis oculi, pars orbitalis. Below the infraorbital margin is to be seen the facial opening of the infraorbital canal, the **infraorbital foramen** for the nerve and artery of the same name.

The orbit communicates with the cranial cavity by the optic foramen and superior orbital fissure; with the nasal fossa, by means of the nasolacrimal canal; with the infratemporal and pterygopalatine fossæ, by the inferior orbital fissure. In addition to these large communications, the orbit has four other openings—the infraorbital, zygomatico-orbital, and the anterior and posterior ethmoidal canals—leading into it or from it.

Clinical relations.—In front, the circumference of the **bony orbit** can be traced in its whole extent. The *supraorbital notch* lies at the junction of the medial and intermediate thirds of the supraorbital arch. When this notch is a complete foramen, its detection is much less easy. To its medial side the *supratrochlear nerve* and *frontal artery* cross the supraorbital margin; like the supraorbital, this nerve and vessel lie, at first, in close relation with the periosteum. The frontal artery is one of the chief blood-supplies to flaps taken from the forehead. Owing to the paper-like thinness of the bones on the **medial wall** of the orbit, e. g., lacrimal, ethmoid, and body of sphenoid, injuries which are possibly penetrating ones, as from a lead-pencil, etc., are always to be looked upon with suspicion. After a period of latency of symptoms, infection of the membranes and frontal abscess have often followed. Injuries of the medial wall such as may be associated with fractures of the nose bring the ethmoidal air cells into communication with the cellular tissue of the orbit. The latter may thus be distended with air on attempting to blow the nose. This wall is readily destroyed by malignant growths of the nose. The thin **floor** which is formed mainly by the maxilla and corresponds to the roof of the maxillary sinus, is readily destroyed by growths extending up from the sinus and in the process pressure on the infraorbital nerve is apt to cause pain referred to the cheek. The **roof** formed by the orbital plate of the frontal bone is also thin, and foreign bodies thrust into the orbit may perforate it and enter the frontal lobe of the cerebrum. The **lateral wall** is formed in its anterior third by the zygomatic bone, which separates the orbit from the infratemporal fossa. The posterior two-thirds formed by the sphenoid bone separate the orbit from the temporal lobe of the brain in the middle cranial fossa. The orbit communicates with the cranium by the optic foramen, which transmits the optic nerve and ophthalmic artery and by the superior orbital fissure through which pass most of the other vessels and nerves of the orbit.

In cases of fracture of the base of the skull involving the anterior clinoid process, a traumatic communication (arteriovenous aneurysm) may be formed between the internal carotid artery and cavernous sinus, behind the apex of the orbit, giving rise to pulsating exophthalmos.

NASAL SKELETON

The **nasal skeleton** includes the bony and cartilaginous support of the external nose, the walls of the nasal cavity and the paranasal sinuses.

Skeleton of the external nose.—The cartilaginous framework is described in the section on the Respiratory System, p. 1296. The bony skeleton forms the bridge of the nose which is composed medially of the **nasal bones** articulating with each other in the **internasal suture** [sutura internasalis], and laterally of the **frontal processes** of the maxillæ articulating with the nasal bones [sutura nasomaxillaris]. These elements unite above with the frontal bone in the **nasofrontal** and **frontomaxillary sutures.**

Below the bridge of the nose the cartilaginous portion projects from the margins of the **piriform aperture.** This large opening leads into the bony-walled nasal fossæ, is higher than wide and is bounded by the nasal bones above and the **nasal notches** of the maxillæ laterally and below. In the midline below is the **anterior nasal spine** which supports the extremity of the cartilaginous nasal septum. For muscular attachments in this region, see fig. 129.

The **nasal cavity** [cavum nasi] (figs. 129, 137, 138, 139) cmoprises two irregular spaces, the **nasal fossæ**, separated by a median vertical septum. They open in front by the piriform aperture and communicate behind with the pharynx by the choanæ. They are somewhat oblong in transverse section, and extend vertically from the anterior part of the base of the cranium above to the superior surface of the hard palate below. Their transverse extent is very limited, especially in the

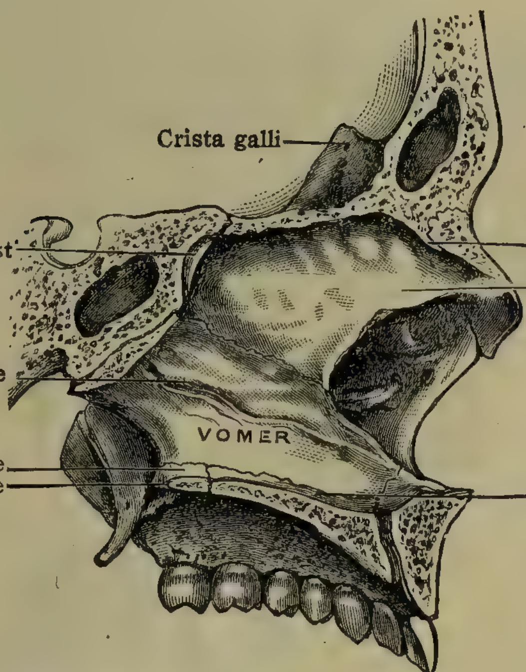


FIG. 137.—SAGITTAL SECTION THROUGH THE NASAL CAVITY TO SHOW THE SEPTUM NASI.

upper part. Each fossa presents a roof, floor, medial and lateral walls, and communicates with the paranasal sinuses of the frontal, sphenoid, maxilla, and ethmoid bones.

The **roof** is horizontal in the middle, but sloped downward in front and behind. The anterior slope is formed by the posterior surface of the nasal bone and the nasal process of the frontal; the horizontal portion corresponds to the **cribriform plate of the ethmoid** and the **sphenoidal concha**; the posterior slope is formed by the inferior surface of the body of the sphenoid, the ala of the vomer, and a small portion of the **sphenoidal process of the palate.** The sphenoidal sinus opens at the upper and back part of the roof into the **sphenoethmoidal recess** [recessus sphenoethmoidalis], above the superior meatus.

The **floor** is concave from side to side, and in the transverse diameter wider than the roof. It is formed mainly by the palatine process of the maxilla and completed posteriorly by the horizontal part of the palate bone. Near its anterior extremity, close to the septum, is the incisive canal.

The **septum** or medial wall is formed by the perpendicular plate of the ethmoid, the vomer, the rostrum of the sphenoid, the crest of the nasal bones, the frontal spine, and the median crest formed by the apposition of the palatine processes of the maxillæ and the horizontal parts of the palate bones. The anterior border has an angular outline limited above by the perpendicular plate of the ethmoid and below by the vomer, and in the recent state the deficiency is filled up by the septal cartilage of the nose. The posterior border is formed by the pharyngeal edge of the vomer, which separates the two choanæ. The septum, which is usually deflected from the middle line to one side or the other, is occasionally perforated, and in some cases a strip of cartilage, continuous with the septal cartilage, extends backward between the vomer and perpendicular plate of the ethmoid (*posterior* or *sphenoidal process*).

The **lateral wall** is the most extensive and the most complicated on account of the presence of the meatuses of the nose. It is formed by the frontal process and the medial surface of the body of the maxilla, the lacrimal, the **superior** and **middle nasal conchæ** of the **ethmoid**, the

inferior nasal concha, the perpendicular part of the palate bone, and the medial pterygoid plate. The three conchæ (frequently four, see p. 162), which project medially, overhang the three recesses known as the **meatuses** of the nose. The **superior meatus** [meatus nasi superior], the shortest of the three, is situated between the superior and middle nasal conchæ, and into it open the **posterior ethmoidal cells.** The **middle meatus** lies between the middle and inferior conchæ. It presents a prominent groove, the **hiatus semilunaris,** bounded by the **ethmoidal bulla** [bulla ethmoidalis] above and the **uncinate process** [processus uncinatus] of the ethmoid below, and leading into a cleft-like space, the **ethmoidal infundibulum** [infundibulum ethmoidale]. Into the middle meatus open the **anterior ethmoidal cells** (including the middle or bullar group), the **frontal sinus** and the **maxillary sinus** (frequently by two apertures). The **inferior meatus,** longer than the others, is between the inferior nasal concha and the floor of the nasal fossa. Anteriorly and laterally it presents the lower orifice of the **nasolacrimal canal.**

The **common meatus of the nose** is the narrow space between the conchæ and the nasal septum; the name **nasopharyngeal meatus** is given to the region of the nasal fossa located on each side behind the level of the conchæ. The lateral wall is formed by the perpendicular

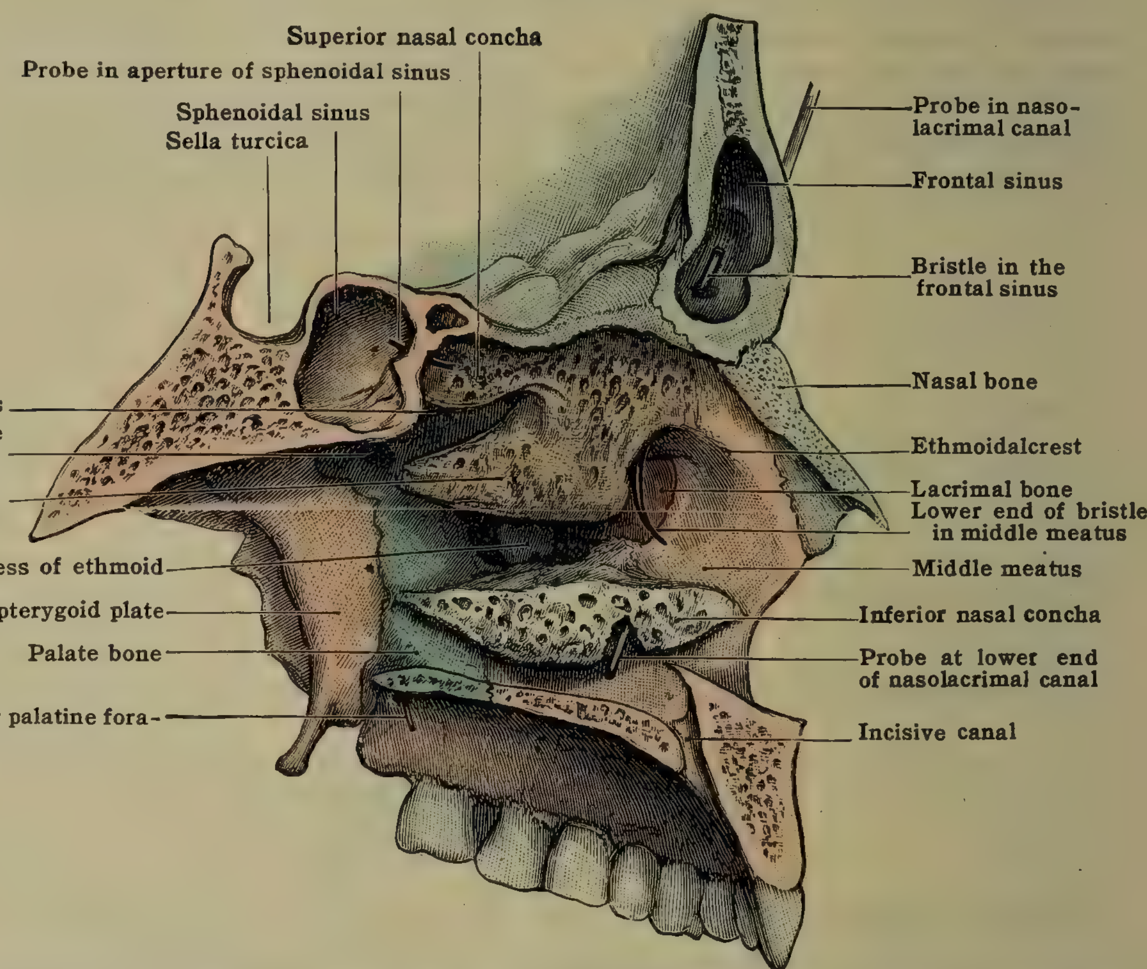


FIG 138.—SAGITTAL SECTION THROUGH THE NASAL FOSSA TO SHOW THE LATERAL WALL WITH THE MEATUSES.

plate of the palate; here the **sphenopalatine foramen,** standing just behind the posterior end of the middle concha, puts the nasal fossa into communication with the pterygopalatine fossa and gives passage to the sphenopalatine artery and nasal branches of the sphenopalatine ganglion.

The **nasal fossæ** open on the face by means of the **apertura piriformis** and posteriorly by the **choanæ.** The paired choanæ (fig. 139) are bounded superiorly by the alæ of the vomer, the sphenoidal processes of the palate, and the inferior surface of the body of the sphenoid; laterally by the medial pterygoid plates; and inferiorly by the posterior edge of the horizontal plates of the palate bones. They are separated from each other by the posterior border of the vomer.

PARANASAL SINUSES

Paranasal sinuses [sinus paranasales]. In the foregoing description of the nasal cavity references have been made to the several air-filled spaces in neighboring bones which are in communication with it. These pneumatic cavities, which in the recent state are lined with a mucosa continuous with that of the cavum nasi, are paired and are located in the frontal, maxillary, ethmoid and sphenoid bones and by extension may enter other bones. They are all subject to considerable variation in form and capacity and, in the case of the ethmoidal cells also in number. The **frontal sinuses** (figs. 136, 137, 151) are found at the junction of the squama and orbital parts of the frontal bone, may extend upward and laterally within the squama, backward through the roofs of the orbits or in both parts of the frontal bone. The two sinuses are separated by the **septum of the frontal sinuses,** often deviated or distorted, and communicate with the middle meatus by the **ethmoidal infundibulum** [infundibulum ethmoidale] which leads from a rounded orifice in the floor of each sinus. The **ethmoidal cells** [cellulæ

ethmoidales] (see p. 161), numerous, are small air spaces in the ethmoid labyrinth, enclosed by thin bony partitions, communicating with one another and with the nasal cavity. Some of these spaces are incompletely walled by the ethmoid itself and adjacent bones cover the gaps: the orbital part of the frontal above, the nasal part of the frontal and the frontal process of the maxilla anteriorly, the orbital process of the palate and body of the sphenoid behind, the body of the maxilla and the lacrimal bone laterally. The anterior cells open into the ethmoidal infundibulum, the middle and posterior cells into the superior meatus. The **sphenoidal sinuses** [sinus sphenoidales] variable in size and frequently unsymmetrical in position, occupy the body of the sphenoid bone, separated one from the other by the **septum of the sphenoidal sinuses.** The two **apertures of the sphenoidal sinuses,** by which communication with the sphenoethmoidal recesses is established, are located above the level of the floor of the sinuses and are partly closed by the apposition or synostosis of the sphenoidal conchæ with the front of the body of the sphenoid. The paired **maxillary sinuses** [sinus maxillares] are the most capacious of the series. Each is located within the body of the maxilla. Communication with the nasal cavity is given by the **hiatus maxillaris** opening into the ethmoidal infundibulum.

(For further details concerning the paranasal sinuses, see descriptions under the individual bones; also under **Respiratory System,** p. 1305.)

The nasal cavity has recently been studied anthropometically by Charles (Am. Jour. Phys. Anthrop., 14, 1930) and the comparisons shown between whites and American negroes.

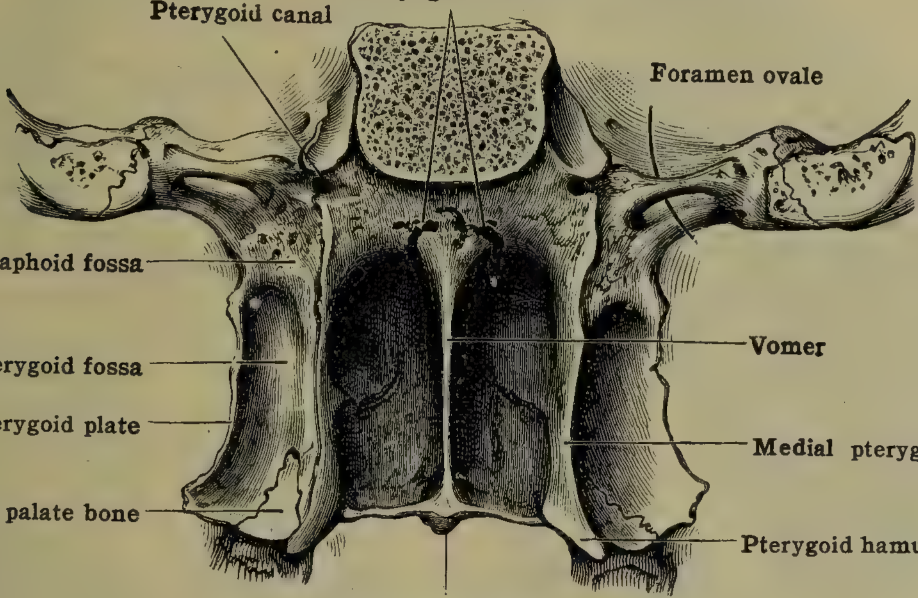


FIG. 139.—THE CHOANÆ. (Viewed from behind.)

BONES OF THE SKULL

The skull or cranium includes the cerebral cranium and the visceral cranium. The bones of the **cerebral cranium** are eight in number—viz., *occipital,* two *parietal, frontal,* two *temporal, sphenoid, ethmoid.* Those of the **visceral cranium** (facial bones), surrounding the mouth and nose, and forming with the cranium the orbital cavity for the reception of the eye, are fourteen in number—viz., two *maxillæ,* two *zygomatic* (*malar*), two *nasal,* two *lacrimal,* two *palate,* two *inferior conchæ* (*turbinates*), the *mandible,* and the *vomer.* A group of movable bones, comprising the *hyoid,* suspended from the external base of the cranium, and three small bones, the *incus, malleus,* and *stapes,* situated in the middle ear or tympanic cavity, are also included in the enumeration of the bones of the skull.

THE OCCIPITAL BONE

The **occipital bone** (fig. 140) is situated at the posterior and inferior part of the cranium. In general, it is flattened and trapezoid in shape, curved upon itself so that one surface is convex and directed backward and somewhat downward, while the other is concave and looks in the opposite direction. It is pierced in its lower and front part by a large aperture, the **foramen magnum,** by which the vertebral canal communicates with the cranial cavity.

The occipital bone is divisible into four parts, **basilar, squamous,** and two **lateral** (or condylar), so arranged around the foramen magnum that the basilar part lies in front, the lateral parts on either side, and the squamous part above and behind. In general, this division corresponds to the four separate parts of which the bone consists at the time of birth (fig. 144).

The **squamous part** [squama occipitalis] is continuous with the two lateral parts below and is elsewhere limited by four rough edges meeting in three angles, a superior and two lateral angles. Its external surface is convex and presents a varied contour. Midway between the superior angle and the posterior margin of the foramen magnum it presents a prominent tubercle known as the **external occipital protuberance,** from which a vertical ridge—the **external occipital crest**—runs downward and forward as far as the foramen magnum. The protuberance and crest give attachment to the ligamentum nuchæ.

Arching lateralward on each side from the external occipital protuberance toward the lateral angle of the bone is a semicircular ridge, the **superior nuchal**

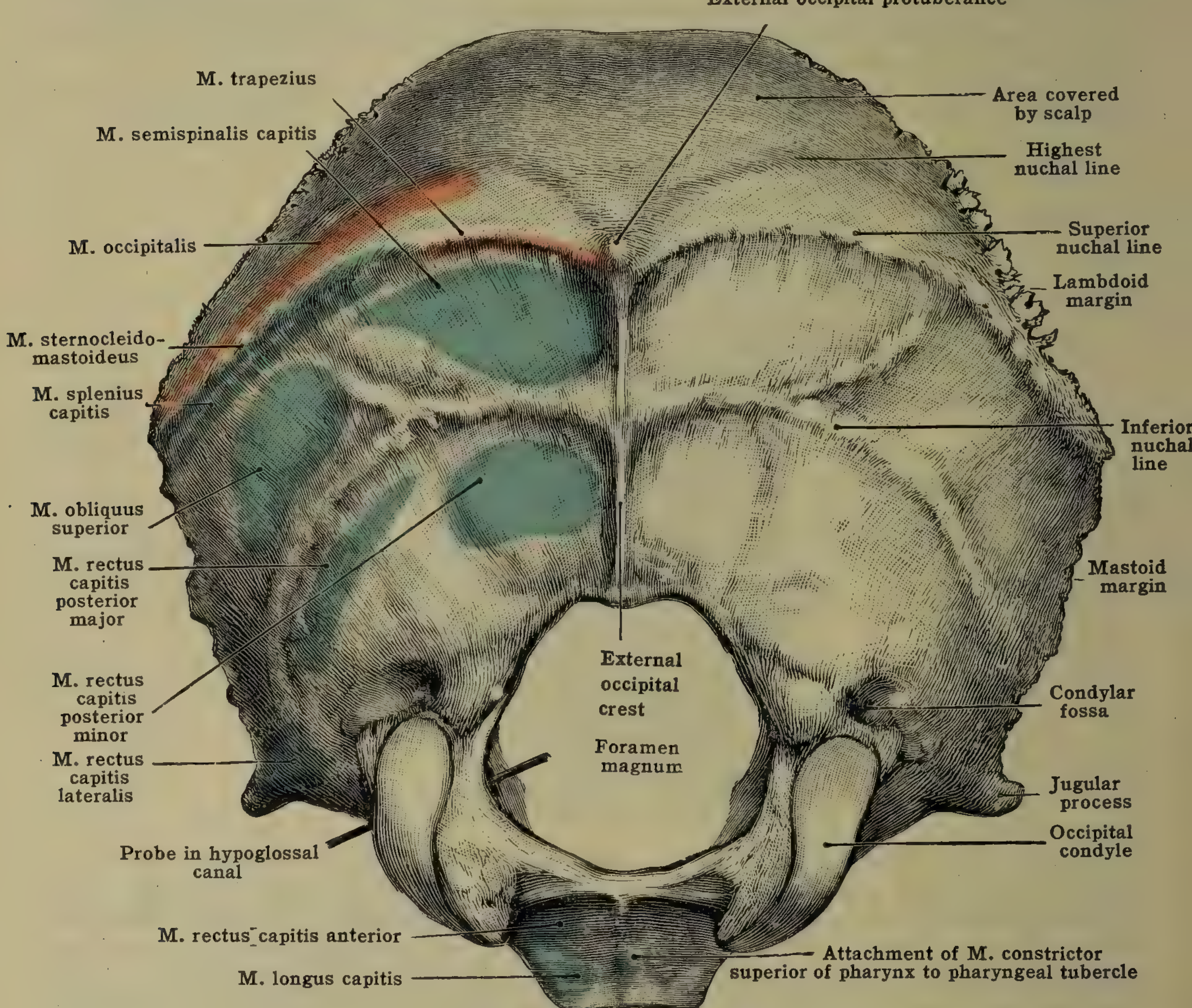


FIG. 140.—THE OCCIPITAL BONE. (External view.)

line [linea nuchæ superior], which divides the surface into two parts—an upper [planum occipitale] and a lower [planum nuchale]. Above this line is a second less distinctly marked ridge—the **highest nuchal line** [linea nuchæ suprema].

It is the most curved of the three lines on this surface and gives attachment to the epicranial aponeurosis and to part of the occipitalis muscle. Between the superior and highest curved lines is a narrow crescentic area in which the bone is smoother and denser than the rest of the surface, whereas the part of the bone above the linea suprema is convex and covered by the scalp.

The lower part of the surface is very uneven and subdivided into an upper and a lower area by the **inferior nuchal line,** which runs laterally from the middle of the crest to the jugular process.

The curved lines and the areas thus mapped out between and below them give attachment to several muscles. To the superior nuchal line are attached, medially the trapezius, and laterally the occipitalis and sternocleidomastoid; the area between the superior and inferior curved lines receives the semispinalis capitis muscle medially, and splenius capitis and obliquus capitis superior muscles laterally; the inferior nuchal line and the area below it afford insertion to the rectus capitis posterior minor and major muscles.

The **internal** or **cerebral surface** is deeply concave and marked by two grooved ridges which cross one another and divide the surface into four fossæ of which the two upper, triangular in form, lodge the occipital lobes of the cerebrum, and the two lower, more quadrilateral in outline, the lobes of the cerebellum. The sagittal ridge extends from the superior angle toward the foramen magnum and the transverse ridge from one lateral angle to the other. Their intersection forms the **eminentia cruciata**, the midpoint forming the **internal occipital protuberance.** The upper part of the sagittal ridge is grooved [sulcus sagittalis] for the superior sagittal (longitudinal) sinus and gives attachment, by its margins, to the falx cerebri; the lower part is sharp and known as the **internal occipital crest**, and affords attachment to the falx cerebelli.

Approaching the foramen magnum the ridge divides, and the two parts become lost upon its margin. The angle of divergence sometimes presents a shallow fossa for the extremity of the vermis of the cerebellum, and is called the **vermiform fossa.** The two parts of the transverse ridge are deeply grooved [sulcus transversus] for the transverse (lateral) sinuses, and the

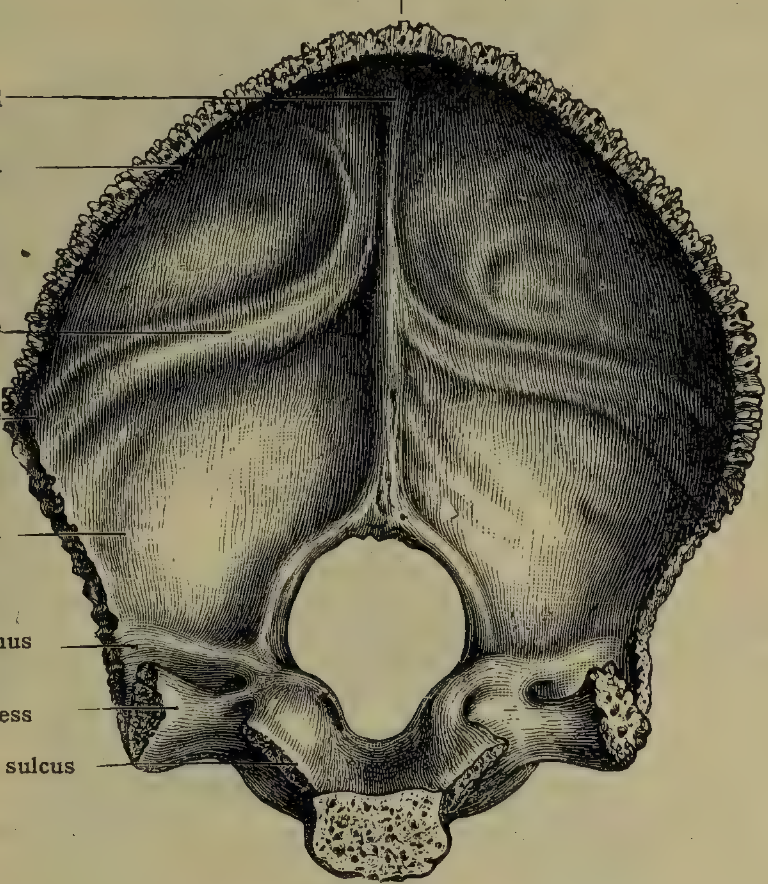


FIG. 141.—OCCIPITAL BONE, INTERNAL OR CEREBRAL SURFACE.

margins of the groove give attachment to the tentorium cerebelli. To one side of the internal occipital protuberance is a wide space, where the sagittal groove is continued into one of the lateral grooves (more frequently the right), for the **confluence of the sinuses** [confluens sinuum] (*torcular Herophili*); it is sometimes exactly in the middle line (figs. 141, 142).

The squamous portion has three angles and four borders. The **superior angle** forming the summit of the bone is received into the space bounded by the occipital margins of the two parietal bones. The **lateral angles** are very obtuse and correspond in situation with the lateral ends of the superior nuchal lines and the transverse grooves. Above the lateral angle on each side the margin is deeply serrated, forming the **lambdoid border** [margo lambdoideus] which extends to the superior angle and articulates with the occipital margin of the parietal in the lambdoid suture. The **mastoid border** [margo mastoideus] extends from the lateral angle to the jugular process and articulates with the mastoid portion of the temporal bone.

The **lateral portions** [partes laterales] (exoccipitals) form the lateral boundaries of the foramen magnum and bear the condyles on their inferior surfaces. The **occipital condyles** are two convex oval processes of bone with smooth articular surfaces, covered with cartilage in the recent state, for the superior articular pits of

the atlas. They converge in front, and are somewhat everted. Around and outside of their margins attachment is given to the capsular ligaments of the atlanto-occipital joints and on the medial side of each is a prominent tubercle for the alar (lateral odontoid) ligament. The anterior extremities of the condyles extend beyond the lateral parts on the basilar portion of the bone. The **hypoglossal canal** [canalis hypoglossi] perforates the bone at the base of the condyle, and is directed from the interior of the cranium, just above the foramen magnum, forward and laterally; it transmits the hypoglossal nerve and a twig of the posterior meningeal artery.

The hypoglossal foramen is sometimes double, being divided by a delicate spicule of bone. Above the canal is a smooth convexity known as the **tuberculum jugulare** sometimes marked by an oblique groove for the ninth, tenth and eleventh cerebral nerves. Posterior to each condyle is a pit, the **condylar fossa,** which receives the hinder edge of the superior articular process of the atlas when the head is extended. The floor of the depression is occasionally perforated by the **condylar canal** [canalis condyloideus], which transmits a vein from the transverse sinus. Projecting laterally opposite the condyle is a quadrilateral portion of bone known as the **jugular process,** the extremity of which is rough for articulation with the jugular facet on the petrous portion of the temporal bone. Up to twenty-five years the bones are united here by means of cartilage, petro-occipital synchondrosis; about this age ossification of the cartilage takes place, and the jugular process thus becomes fused with the temporal. Its anterior border participates

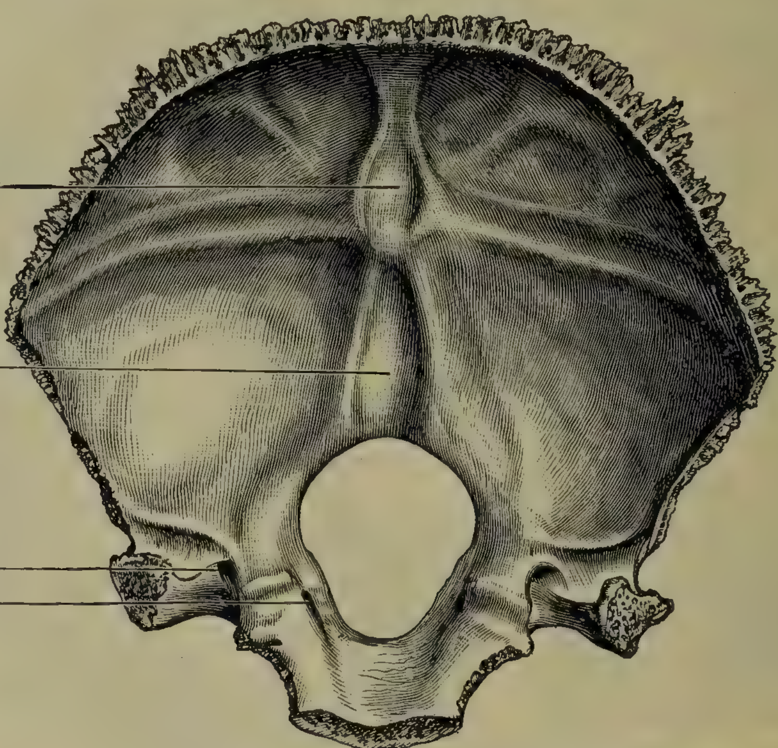


Fig. 142.—Cerebral Surface of the Occipital, Showing an Occasional Disposition of the Channels.

in the petro-occipital fissure and is deeply notched [incisura jugularis] to form the posterior boundary of the **jugular foramen,** and the notch is directly continuous with a groove on the upper surface which lodges the termination of the transverse sinus. The **jugular notch** is subdivided by the **intrajugular process** [processus intrajugularis], a small projection standing opposite the process of the same name in the jugular notch of the temporal bone. These processes partially subdivide jugular foramen into a lateral part containing the transverse sinus and a medial part occupied by the inferior petrosal sinus, the glossopharyngeal nerve and its superior ganglion, the vagus and its jugular ganglion and the accessory nerve. In or near the transverse groove is seen the inner opening of the condylar canal. The lower surface of the process gives attachment to the rectus capitis lateralis muscle. Occasionally the mastoid air-cells extend into this process and rarely a process of bone, representing the *paramastoid process* of many mammals, projects downward from its under aspect and may be so long as to join or articulate with the transverse process of the atlas.

The **basilar portion** is a quadrilateral plate of bone projecting forward and upward in front of the foramen magnum. Its superior surface, grooved and sloping upward [clivus], supports the medulla oblongata and gives attachment to the tectorial membrane. The lower surface presents in the middle line a small elevation known as the **pharyngeal tubercle** for the attachment of the fibrous raphé of the constrictor muscles of the pharynx.

On each side of the middle line, inferiorly, are impressions for the insertions of the longus capitis and rectus capitis anterior and near the foramen magnum this surface gives attachment to the anterior atlanto-occipital membrane. Anteriorly the basilar process articulates by synchrondrosis with the body of the sphenoid [synchondrosis sphenooccipitalis] up to twenty

years of age, after which there is complete bony union. Posteriorly it presents a smooth rounded border forming the anterior boundary of the foramen magnum. It gives attachment to the apical odontoid ligament, and above this to the ascending portion of the cruciate ligament of the atlas. In the occipital bone at the sixth year the lateral extremities of this border are enlarged to form the basilar portion of the condyles. The lateral borders are rough below for articulation with the petrous portion of the temporal bones, taking part in the petro-occipital fissure, but above, on either side of the basilar groove, is a half-groove, the **inferior petrosal sulcus** [sulcus petrosus inferior], which, with a similar half-groove on the petrous portion of the temporal bone, lodges the inferior petrosal sinus.

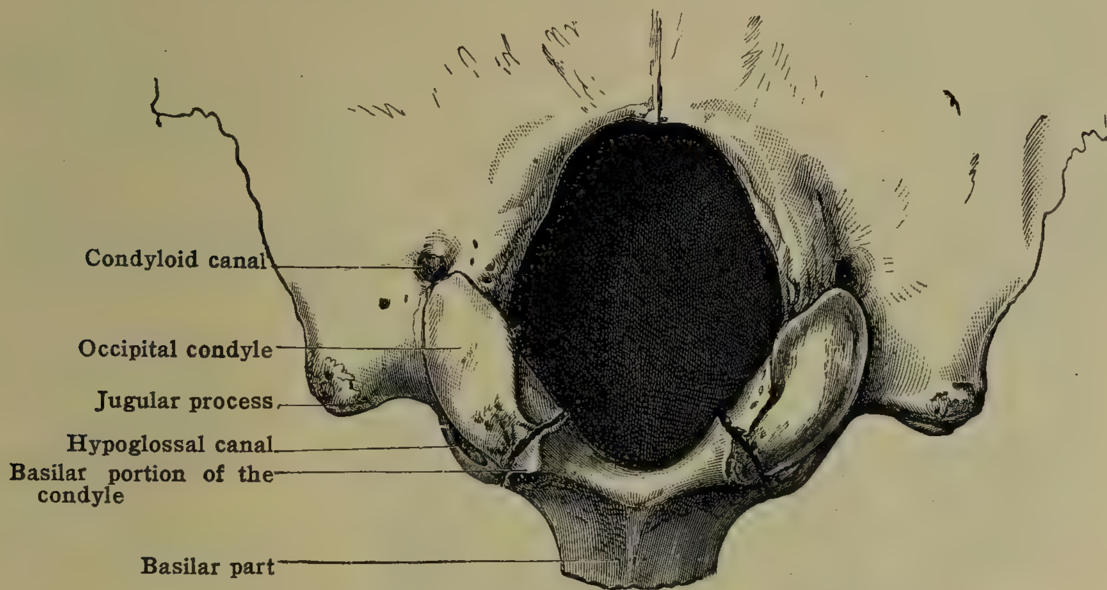


FIG. 143.—THE FORAMEN MAGNUM AT THE SIXTH YEAR.

The **foramen magnum** is oval in shape, with its long axis in a sagittal direction. It transmits the medulla oblongata and its membranes, the accessory nerves (spinal portions), the vertebral arteries, the anterior and posterior spinal arteries, and the tectorial membrane. It is widest behind, where it transmits the medulla, and is narrower in front, where it is encroached upon by the condyles.

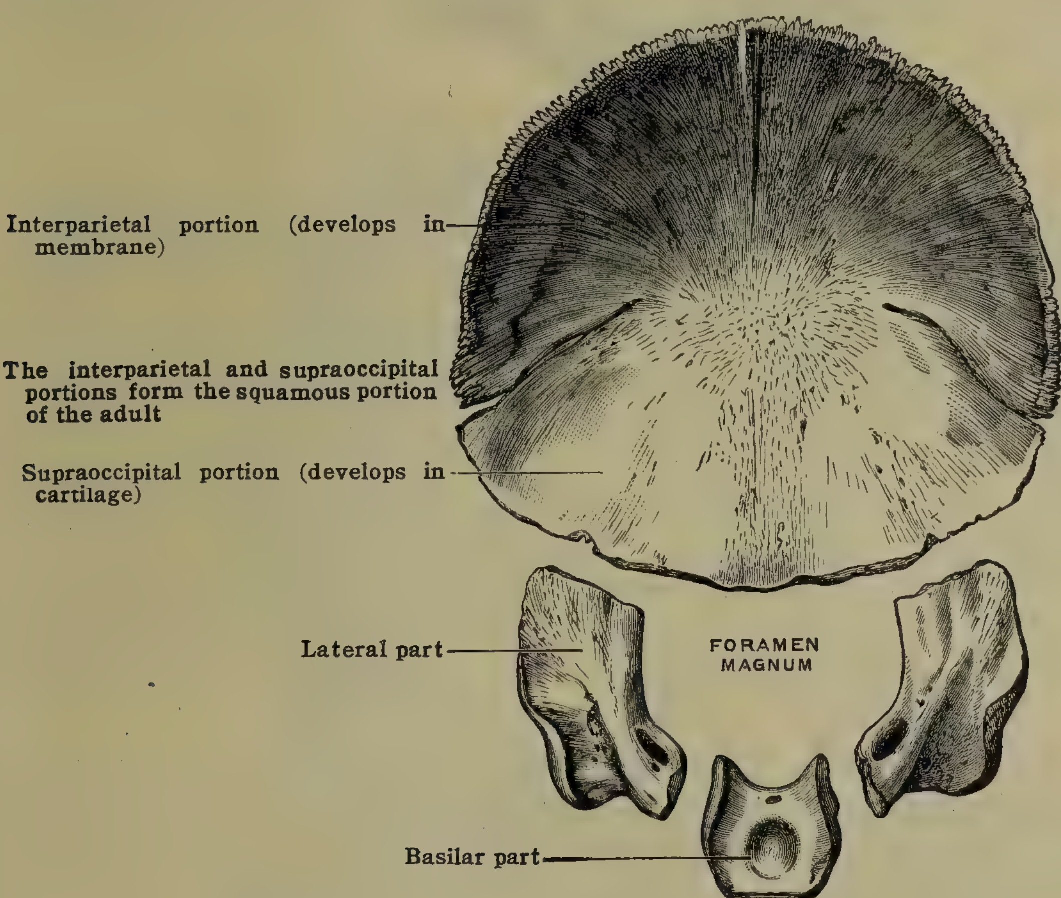


FIG. 144.—THE OCCIPITAL BONE AT BIRTH. (Internal view.)

Occasionally a facet is present on the anterior margin, forming a *third occipital condyle* for articulation with the dens. Between the condyles and behind the margin of the foramen magnum the posterior atlanto-occipital membrane obtains attachment.

Blood supply.—The occipital bone receives its blood-supply from the occipital, posterior auricular, middle meningeal, vertebral and the ascending pharyngeal arteries.

Articulations.—The occipital bone is connected by suture with the two parietals, the two temporals and the sphenoid; the condyles articulate with the atlas, and exceptionally the occipital articulates with the dens of the epistropheus by means of the third, occipital condyle.

Ossification.—The occipital bone develops in four pieces. The squamous portion is ossified from four centers, arranged in two pairs, which appear about the eighth week. The upper pair is deposited in membrane; this part of the squamous portion may represent the interparietal bone of other animals. The lower pair, deposited in cartilage, form the true supraoccipital element; the four parts quickly coalesce near the situation of the future occipital protuberance. For many weeks two deep lateral fissures separate the interparietal and supraoccipital portions, and a membranous space extending from the center of the squamous portion to the foramen mangnum partially separates the lateral portions of the supraoccipital. This space is occupied later by a spicule of bone, and is of interest as being the opening through which the form of hernia of the brain and its meninges, known as occipital meningocele or encephalocele, protrudes. The basilar part and the two lateral parts are ossified each from a single nucleus which appears in cartilage from the eighth to the tenth week.

At birth the bone consists of four parts united by strips of cartilage; in the squamous portion fissures running in from the upper and lateral angles are still noticeable (fig. 144). The osseous union of the squamous and lateral parts is completed in the fifth year, and that of the lateral parts with the basilar part before the seventh year. Up to the twentieth year the basilar part is united to the body of the sphenoid by an intervening piece of cartilage, but about that date ossific union begins and is completed in the course of two or three years.

FIG. 145.—THE OCCIPITAL BONE WITH A SEPARATE INTERPARIETAL.

Variations.—The occipital condyles vary considerably in their position relative to the sides of the foramen magnum, in some instances converging closer to the mid-line anteriorly, in others being removed farther backward than is normal. The articular surface may present a transverse ridge of cartilage corresponding to a groove on the articular surface of the atlas, or notches at the margins may partly divide the condyle in two. A shallow fossa occasionally found on the ventral surface of the basilar portion in front of the pharyngeal tubercle has been interpreted as a vestige of the canal of the notochord. The cerebral fossæ may be of unequal size and dissimilar in form; a larger left fossa with associated deviation of the sagittal sulcus to join the right transverse sulcus has been regarded as evidence of right handedness. Various structures comparable to parts of an atlas have been observed about the foramen magnum; the condition being known as *manifestation of an occipital vertebra.* The occipital bears many resemblances in its development to an atlas vertebra and some of its varieties become intelligible when seen from this standpoint. Elevation of the area between the highest two curved lines gives rise to a *torus occipitalis.* Occasionally the interparietal portion remains separate throughout life (fig. 145), forming what has been termed the *inca bone;* or it may be represented by numerous detached ossicles or Wormian bones. In some cases a large Wormian bone, named the *preinterparietal,* is found, partly replacing the interparietal bone. A preinterparietal bone is found in some mammals, and it has occasionally been observed in the human fetal skull, rarely in the adult.

THE PARIETAL BONE

The two **parietal bones** (figs. 146, 147), interposed between the frontal before and the occipital behind, form a large portion of the roof and sides of the cranium. Each parietal bone [os parietale] is quadrilateral in form, convex externally, concave internally, with two surfaces, four borders, and four angles.

The **parietal surface** [facies parietalis], is smooth and is crossed, from before backward, just below the middle, by two curved lines known as the **temporal lines.** The **superior temporal line** [linea temporalis superior] gives attachment to the temporal fascia; the **inferior temporal line** [linea temporalis inferior], frequently the better marked, limits the origin of the temporal muscle; the narrow

part of the surface enclosed between them is smoother than the rest. Immediately above the ridges is the most convex part of the bone, termed the **parietal**

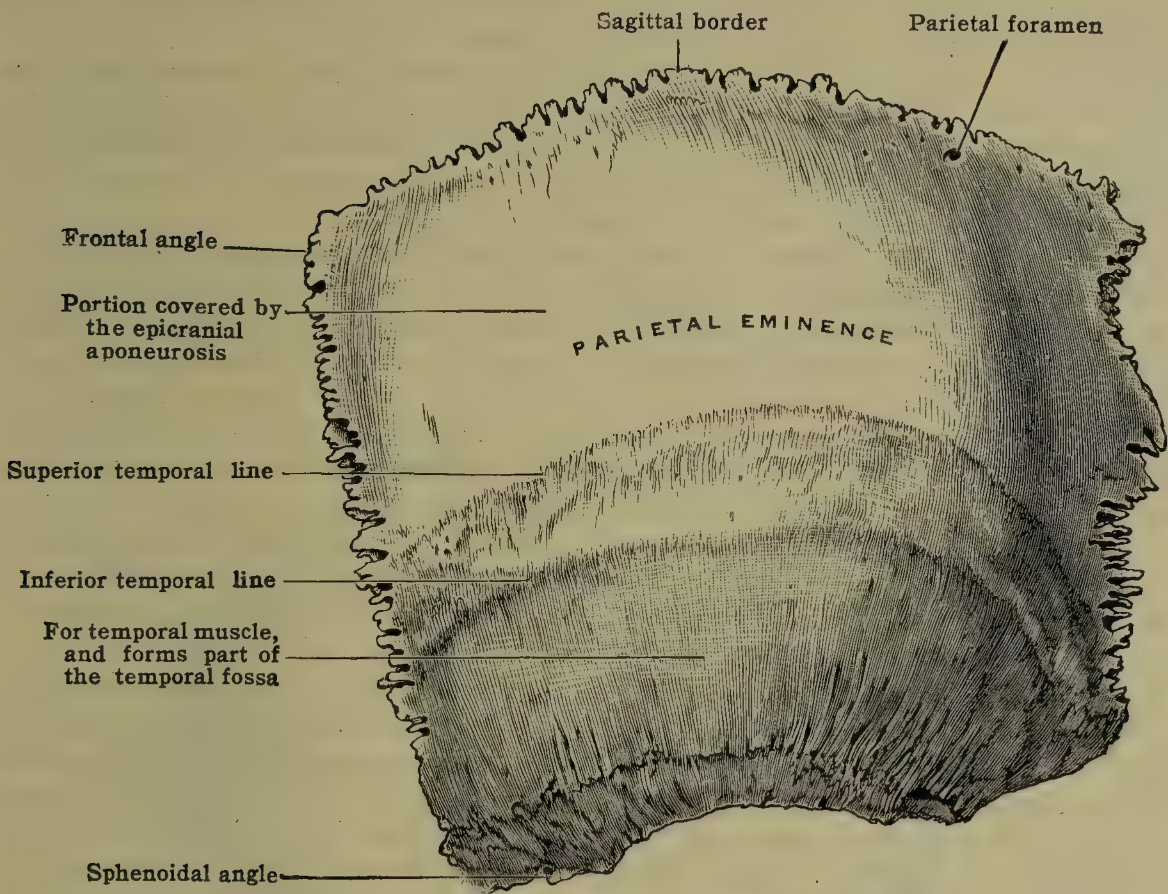


FIG. 146.—THE LEFT PARIETAL BONE. (Parietal surface.)

eminence [tuber parietale], best marked in young bones, and indicating the point where ossification began. Of the two divisions on the parietal surface marked off by the temporal lines, the upper is covered by the scalp, and the lower, somewhat striated, affords origin to the temporal muscle. Close to the upper margin

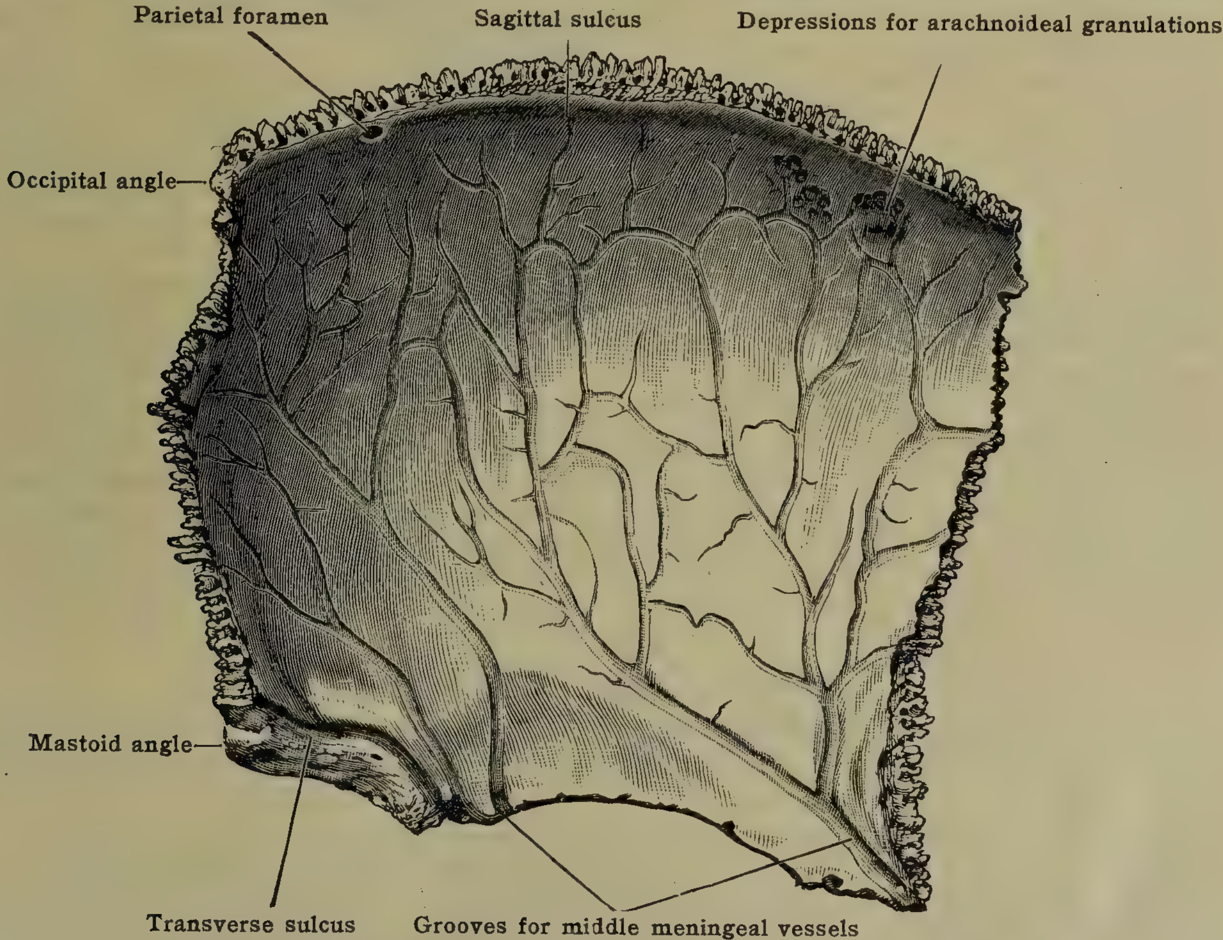


FIG. 147.—THE LEFT PARIETAL BONE. (Cerebral surface.)

and near to the occipital angle is a small opening—the **parietal foramen**—which opens into the sagittal sulcus and transmits a vein to the superior sagittal sinus.

The **cerebral surface** [facies cerebralis] is marked with slight depressions corresponding to the cerebral convolutions and by numerous deep, narrow furrows, running upward and backward from the sphenoidal angle and the lower border, for the middle meningeal vessels. The shallow **sagittal groove** running close to the superior border forms, with the one of the opposite side, a channel for the superior sagittal sinus, at the side of which are small irregular pits for the Pacchionian bodies [foveolæ granulares]. The pits are usually present in adult skulls, but are best marked in those of old persons. The margins of the groove for the superior sagittal sinus give attachment to the falx cerebri.

Borders.—The **sagittal border** [margo sagittalis], the longest and thickest, is deeply serrated to articulate with the opposite parietal bone, with which it forms the **sagittal suture.** The **frontal border** [margo frontalis] articulates with the frontal bone to form the **coronal suture.** It is deeply serrated and bevelled, so that it is overlapped by the frontal above, but overlaps the edge of that bone below. The **occipital border** [margo occipitalis] articulates with the occipital bone to form the **lambdoid suture,** and resembles the sagittal and frontal margins in being markedly serrated. The **squamosal border** [margo squamosus] is divided into three portions:—the anterior, thin and bevelled, is overlapped by the tip of the great wing of the sphenoid; the middle portion, arched and also bevelled, is overlapped by the temporal squama; and the posterior portion, thick and serrated, articulates with the mastoid portion of the temporal bone.

Angles.—The **frontal angle** [angulus frontalis], antero-superior in location and almost a right angle, occupies that part of the bone which at birth is membranous and forms part of the anterior fontanelle. The **sphenoidal angle** [angulus sphenoidalis], antero-inferior, is thin and prolonged downward to articulate with the tip of the great wing of the sphenoid. Its inner surface is marked by a deep groove, sometimes converted into a canal for a short distance for the middle meningeal vessels. The **occipital angle** [angulus occipitalis], postero-superior in position, is obtuse and occupies that part which during fetal life enters into the formation of the posterior fontanelle. The **mastoid angle** [angulus mastoideus] is thick and articulates with the mastoid portion of the temporal bone. Its inner surface presents a shallow groove, **transverse sulcus,** which lodges a part of the transverse sinus.

Blood-supply.—The parietal bone receives its blood-supply from the middle meningeal occipital and deep temporal arteries.

Articulations.—The parietal articulates with the occipital, frontal, sphenoid, temporal, its fellow of the opposite side, and the epipteric bone when present. Occasionally the temporal and epipteric bones exclude the parietal from articulation with the great wing of the sphenoid.

Ossification.—The parietal ossifies from two nuclei, one above the other, which appear in the outer layer of the membranous wall of the skull about the seventh week and fuse to form a single center in the third month. The ossification radiates in such a way as to leave a cleft at the upper part of the bone in front of the occipital angle, the cleft of the two sides forming a lozenge-shaped space across the sagittal suture known as the **sagittal fontanelle.** This is usually closed about the fifth month of intrauterine life, but traces may sometimes be recognized at the time of birth, and the parietal foramina are to be regarded as remains of the cleft. According to Dr. A. W. W. Lea, a well-developed sagittal fontanelle is present in 4.4 per cent. of infants at birth. In such cases it closes within the first two months of life, but at times it may remain open for at least eight months after birth and possibly longer (see p. 33).

Variations.—In addition to those referred to above, the following variations are of interest: conversion of the meningeal sulcus at the anteroinferior angle into a bony-walled canal; the occurrence of an *os bregmaticum;* symmetrical thinning over a large area of both parietals. Rarely the parietal bone is composed of two pieces, one above the other, and separated by an anteroposterior suture (subsagittal suture), more or less parallel with the sagittal suture. In such cases the two primary centers of ossification have failed to fuse.

THE FRONTAL BONE

The **frontal bone** closes the cranium in front and is situated above the skeleton of the face. It consists of two portions—a **frontal squama** [squama frontalis], forming the convexity of the forehead, and an **orbital portion** [pars orbitalis], which enters into the formation of the roof of each orbit (figs. 148–151).

Frontal (*vertical*) **portion.**—The **frontal surface** [facies frontalis] is smooth and convex, and usually presents in the middle line above the root of the nose some traces of the suture which in young subjects traverses the bone from the upper to the lower part. This **metopic suture** [sutura metopica], indicates the line of junction of the two lateral halves of which the bone consists at the time of birth; in the adult the suture is usually obliterated except at its lowest part. On each

side is a rounded elevation, the **frontal eminence**, very prominent in young bones, below which is a shallow groove separating the frontal eminence from the **superciliary arch.** The latter forms an arched projection above the margin of the orbit. The arches of the two sides converge toward the median line, but are separated by a smooth surface called the **glabella.** Below the superciliary arch the bone presents a sharp curved margin, the **supraorbital border,** forming the upper boundary of the opening of the orbit where the frontal and the orbital portions of the bone meet. At the junction of its medial and intermediate third is a notch, sometimes converted into a foramen, and known as the **supraorbital notch** or **foramen;** it transmits the supraorbital nerve, artery, and vein, and presents a small opening for a vein of the diploë. Sometimes, a second less marked notch is present, medial to the supraorbital, and known as the **frontal notch;** it transmits the frontal artery and nerve. The extremities of the supraorbital

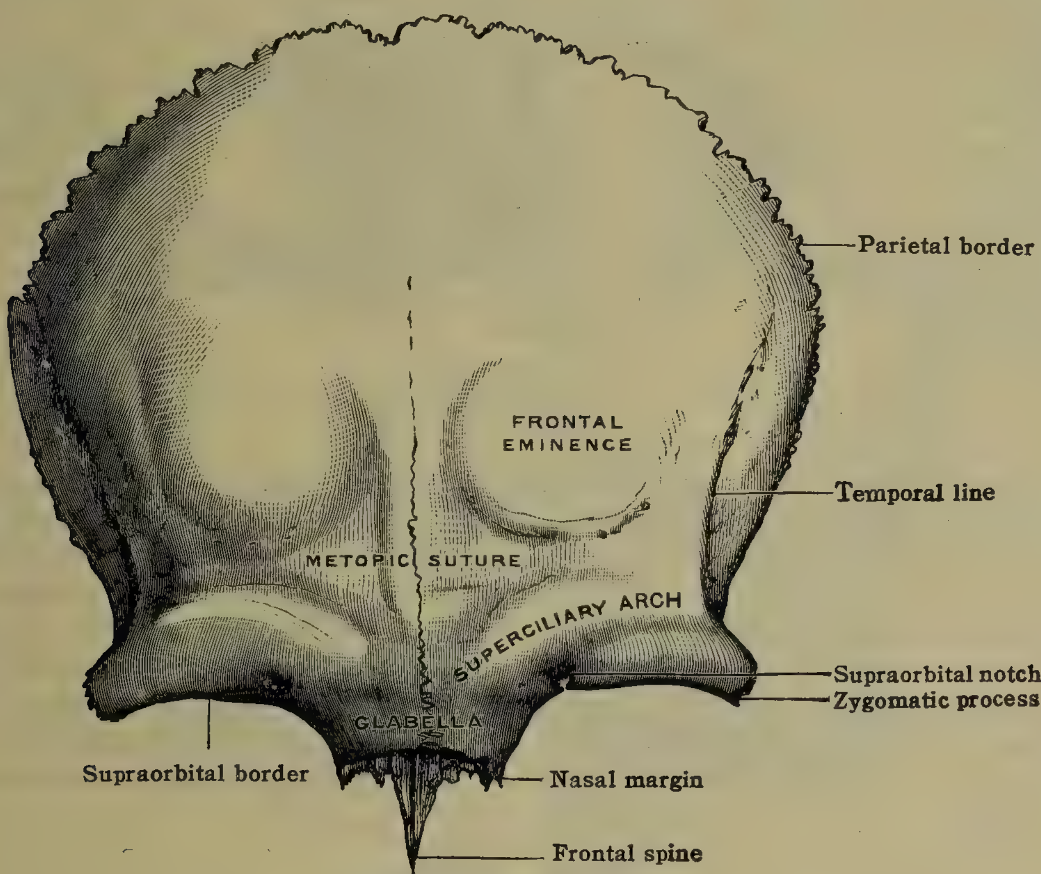


FIG. 148.—THE FRONTAL BONE. (Frontal surface.)

border are directed downward, the lateral ending in the **zygomatic process** [processus zygomaticus]. The prominent zygomatic process articulates with the zygomatic bone and receives superiorly two well-marked lines which converge somewhat as they curve downward and forward across the bone. These are the **superior** and **inferior temporal lines,** continuous with the temporal lines on the parietal bone, the upper giving attachment to the temporal fascia and the lower to the temporal muscle. Behind the lines is the slightly concave **temporal surface** [facies temporalis] which forms part of the floor of the temporal fossa and gives origin to the temporal muscle.

The **cerebral surface** [facies cerebralis] presents in the middle line a vertical groove—the **sagittal sulcus** [sulcus sagittalis]—which descends from the middle of the upper margin and lodges the superior sagittal sinus. Below, the groove is succeeded by the **frontal crest** [crista frontalis], which terminates at the lower margin of the squama at a small foramen.

The foramen, called the **foramen cecum,** is formed between the frontal crest and the crista galli, is generally closed below, but sometimes transmits a vein from the nasal fossæ to the superior sagittal sinus. The frontal crest serves for the attachment of the anterior part of the falx cerebri. On each side of the middle line the bone is deeply concave in adaptation to the frontal lobes of the cerebrum, presenting **digitate impressions** for the cerebral convolutions, **cerebral projections** [juga cerebralia] corresponding to cerebral sulci, and numerous small **arterial (venous) furrows** which, running medially from the lateral margin, lodge branches of the middle meningeal vessels. At the upper part of the surface, on either side of the sagittal sulcus, are some depressions for the arachnoideal (Pacchionian) granulations.

The **orbital part** consists of two somewhat triangular plates of bone extending backward at a right angle from the squama, which, separated from one another by the **ethmoidal notch** [incisura ethmoidalis], form the greater part of the roof of each orbit and of the floor of the anterior cranial fossa. When the bones are articulated, the notch is filled up by the cribriform plate of the ethmoid articulating in the frontoethmoidal suture. Between the ethmoidal notch and the orbital surface on either side is a border region presenting incomplete bony cells which are applied to the half-cells on the upper surface of the lateral mass of the ethmoid in the articulated skull. The lateral edge of the border region meets the lacrimal bone anteriorly and the lamina papyracea of the ethmoid in the rest of its extent. Traversing these borders transversely are two grooves which com-

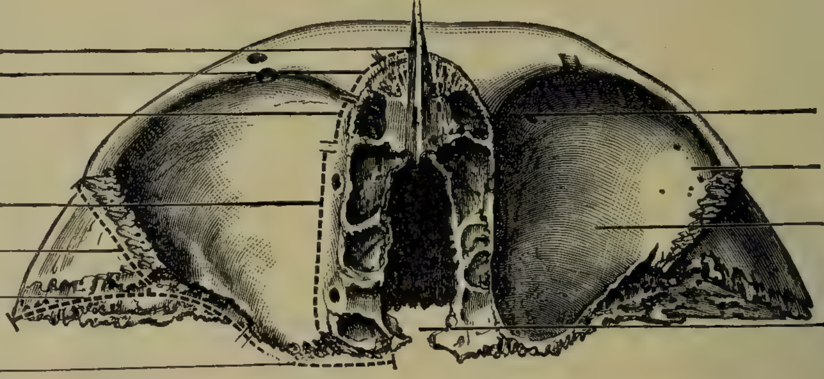


FIG. 149.—THE FRONTAL BONE. (Orbital surface.)

plete, with the ethmoid, the **anterior** and **posterior ethmoidal canals** opening into the orbit at the **anterior** and **posterior ethmoidal foramina** [foramen ethmoidale anterius; posterius]. The anterior transmits the anterior ethmoidal nerve and vessels; the posterior transmits the posterior ethmoidal nerve and vessels. Farther forward in the border region, on either side, are the openings of the **frontal sinuses** [sinus frontales], two irregular air-spaces (fig. 151) which extend within the bone at the junction of the squama and orbital parts for a variable distance and are separated by the (usually crooked) **septum of the frontal sinuses** [septum sinuum frontalium]. Each is lined by mucous membrane and communicates with the nasal fossa.

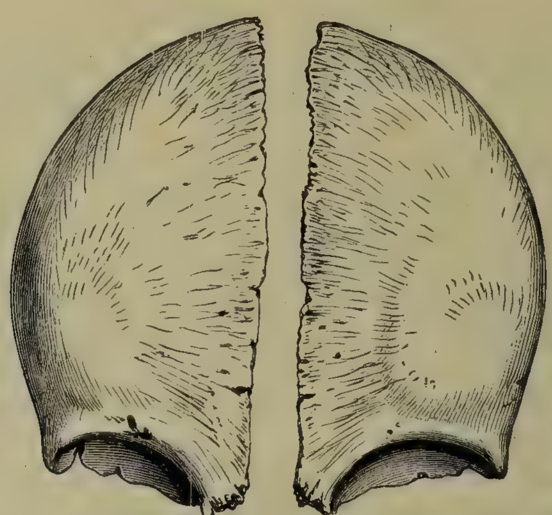


FIG. 150.—THE FRONTAL BONE AT BIRTH.

The **orbital surface** [facies orbitalis] of each orbital plate, smooth and concave, is limited anteriorly by the supraorbital arch, laterally at the zygomaticofrontal suture and sphenofrontal suture (greater wing), posteriorly uniting with the lesser wing of the sphenoid, medially terminating at the frontolacrimal and frontoethmoidal sutures. It presents immediately behind the supraorbital arch and medial to the zygomatic process the **lacrimal fossa** [fossa glandulæ lacrimalis], for the lacrimal gland. Close to the antero-medial angle is a depression called the **trochlear fossa** or **trochlear spine** [spina trochlearis], which gives attachment to the cartilaginous pulley for the superior oblique muscle. The **cerebral surface**

[facies cerebralis] of each plate is convex and strongly marked by eminences and depressions for the convolutions on the orbital surface of the cerebrum.

The **nasal part** [pars nasalis], small and of irregular contour, projects downward from the squama in the region anterior to the ethmoidal notch. The curved **nasal border** [margo nasalis] articulating with the nasal bones and frontal processes of the maxillæ, limits the nasal part in front. The latter is divisible into three parts;—a median **frontal spine** [spina frontalis], which descends in the nasal septum between the crests of the nasal bones in front and the vertical plate of the ethmoid behind, and, on either side of the spine, two grooved surfaces which enter into the formation of the roofs of the nasal fossæ.

Borders.—The articular border of the frontal portion, **parietal margin** [margo parietalis], forms a little more than a semicircle. It is thick, strongly serrated, and bevelled so as to overlap the parietal bone above and to be overlapped by the edge of that bone below. The border is continued inferiorly into a triangular rough surface on either side, which articulates with the great wing of the sphenoid. The posterior border of the orbital portion is thin and articulated with the lesser wing of the sphenoid. The curved nasal margin articulates with the nasal bones and frontal processes of the maxillæ.

Blood-supply.—The blood-vessels for the supply of the squamous portion are derived from the frontal and supraorbital arteries, which enter on the outer surface, and from the middle and

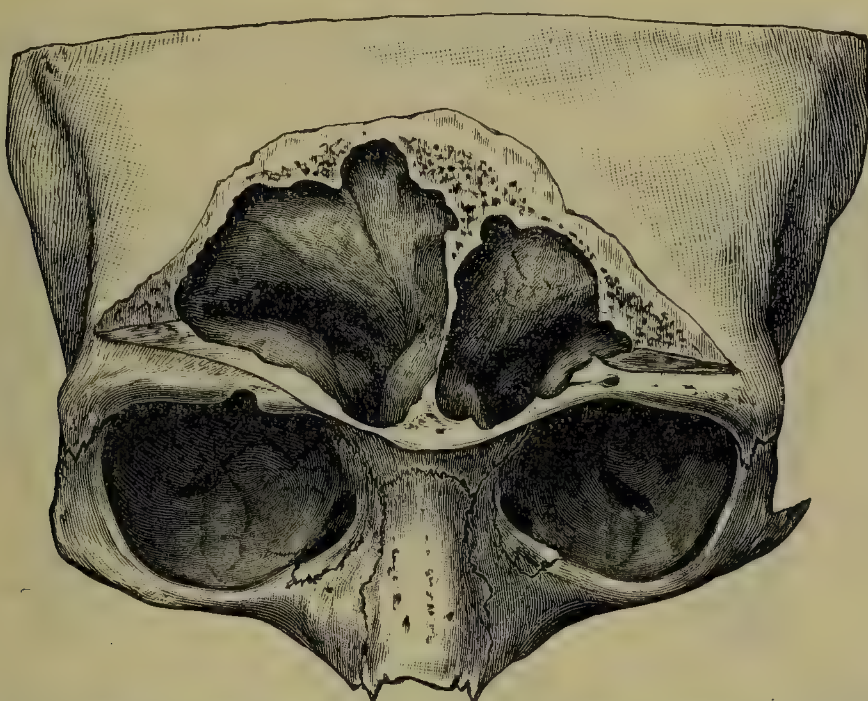


FIG. 151.—UNUSUALLY LARGE FRONTAL SINUSES.

small meningeal, which enter on the cerebral surface. The orbital portion receives branches from the ethmoidal, and other branches of the ophthalmic, as well as from the meningeal.

Articulations.—The frontal articulates with the parietal, sphenoid, ethmoid, lacrimal, zygomatic (malar), maxilla, and nasal bones. Also, with the epipteric bones when present, and occasionally with the squamous portion of the temporal, and with the sphenoidal concha when it reaches the orbit.

Ossification.—The frontal is ossified from two nuclei deposited in the outer layer of the membranous wall of the cranium, in the situations of the future frontal eminences. These nuclei appear about the eighth week, and ossification spreads quickly through the membrane. At birth the bones are quite distinct, but subsequently they articulate with each other in the median line to form the metopic suture. In the majority of cases the suture is obliterated by osseous union, which commences about the second year, though in a few cases the bones remain separate throughout life.

After the two halves of the bone have united, osseous material is deposited at the lower end of the metopic suture to form the frontal spine, which is one of the distinguishing features of the human frontal bone. The spine appears about the twelfth year, and soon consolidates with the frontal bone above. Accessory nuclei are sometimes seen between this bone and the lacrimal and may persist as Wormian ossicles.

The frontal sinuses appear in the fetus but do not become conspicuous until the seventh year as prolongations upward from the middle nasal meatus (see p. 1308). They increase in size up to old age. As they grow they extend in three directions, viz., upward, laterally, and backward along the orbital roof. They are larger in the male than in the female. A bony septum, usually complete, separates the sinuses of the two sides.

Variations.—The frontal sinuses may be extraordinarily large (fig. 151), extending through the orbital plates, into the zygomatic processes and high up into the squama: or they may be quite small or absent entirely. Metopism occurs most frequently in the white races.

THE SPHENOID BONE

The **sphenoid bone** [os sphenoidale] (figs. 152–159) is situated in the base of the skull and takes part in the formation of the floor of the anterior, middle, and posterior cranial fossæ, of the temporal and nasal fossæ, and of the cavity of the orbit. It is very irregular in shape and is described as consisting of a central part or **body,** two pairs of lateral expansions called the **great** and **small** (or lesser) **wings,** and a pair of processes which project downward, called the **pterygoid processes.**

The **body** [corpus], irregularly cuboidal in shape, is hollowed out into two large cavities known as the **sphenoidal sinuses** [sinus sphenoidales], separated by a thin **sphenoidal septum** [septum sinuum sphenoidalium] and opening in front by two large **apertures** [aperturæ sinuum sphenoidalium] into the nasal fossæ. The **superior surface** presents the following points of interest: In front is seen a prominent spine, the upper end of the **sphenoidal crest** [crista sphenoidalis] which articulates with the hinder edge of the cribriform plate of the ethmoid. The surface behind this is smooth and frequently presents two longitudinal grooves, one on either side of the median line, for the olfactory tracts; it is limited posteriorly by a ridge, the **limbus sphenoidalis,** which forms the anterior border of

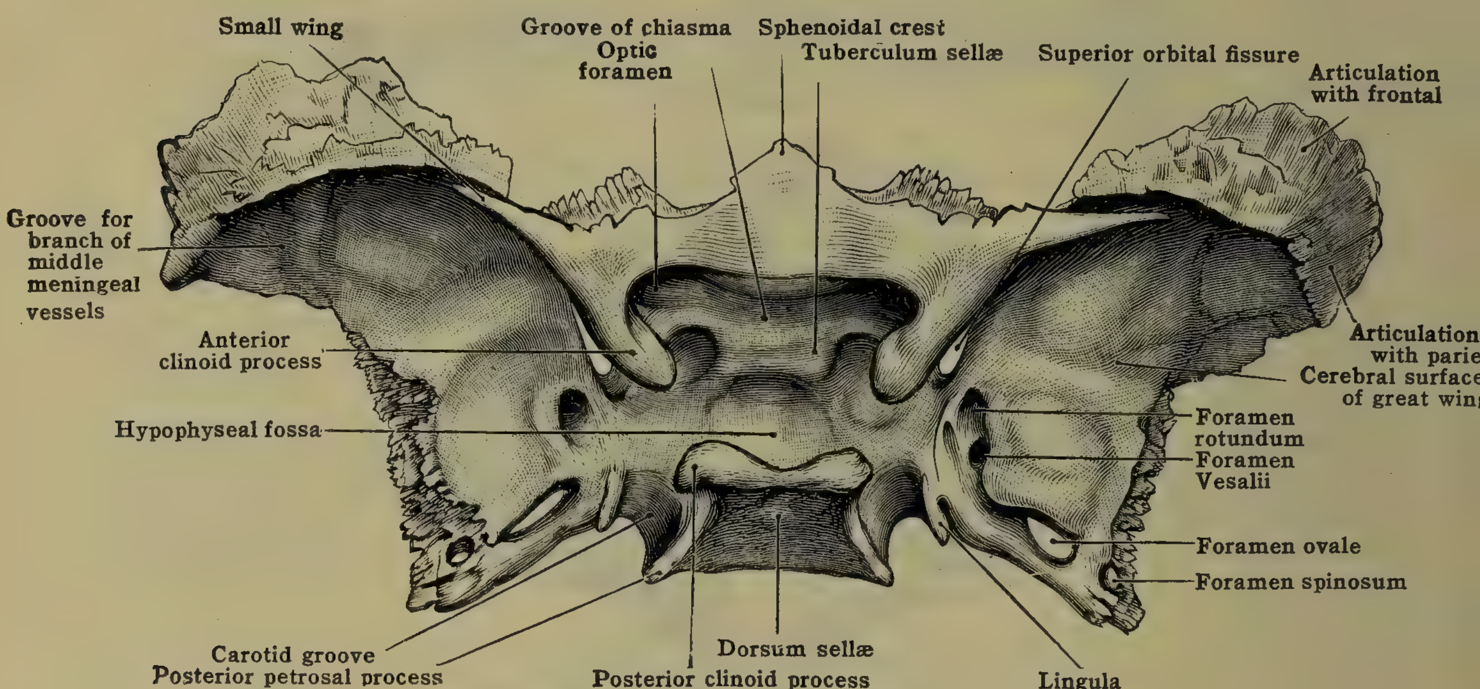


FIG. 152.—THE SPHENOID BONE, FROM ABOVE.

the narrow transverse **groove of the chiasma,** above and behind which lies the optic commissure. The groove terminates on each side in the **optic foramen** [foramen opticum], which perforates the root of the small wing and transmits the optic nerve and the ophthalmic artery. Behind the groove of the chiasma is the formation aptly named the **Turkish saddle** [sella turica], ending anteriorly in the rounded elevation called the **tuberculum sellæ.** The latter indicates the line of junction of the two parts of which the body is formed (pre- and post-sphenoid). Further back, laterally, are the inconstant **middle clinoid processes** [processus clinoidei medii]; in the middle of the sella is a deep depression, the **hypophyseal fossa,** which lodges the hypophysis cerebri. The floor of the fossa presents numerous foramina for blood-vessels, and in the fetus the superior orifice of a narrow passage called the **craniopharyngeal canal.** The posterior boundary of the sella turcica is formed by a quadrilateral plate of bone, the **dorsum sellæ,** the posterior surface of which is sloped (**clivus**) in continuation with the dorsal surface of the basilar part of the occipital bone and supports the pons, and the vertebral and basilar arteries. The superior angles of the plate are surmounted by the **posterior clinoid processes** which give attachment to the tentorium cerebelli. Below the clinoid process, on each side of the dorsum sellæ (sometimes at the fissure between the sphenoid and apex of petrosal), a notch is seen, converted into a foramen by the dura mater, for the passage of the abducent nerve; at the inferior angle is the **posterior petrosal process,** which articulates

with the apex of the petrous portion of the temporal bone, forming the medial boundary of the **foramen lacerum.**

The **inferior surface** presents in the middle line a prominent ridge known as the **sphenoidal rostrum** [rostrum sphenoidale], which is received into a deep depression between the alæ of the vomer. On each side is the **vaginal process** of the medial pterygoid plate, and the sphenoidal process of the palate, which, with the alæ of the vomer, cover the greater part of this surface. The remainder is rough and clothed by the mucous membrane of the roof of the pharynx.

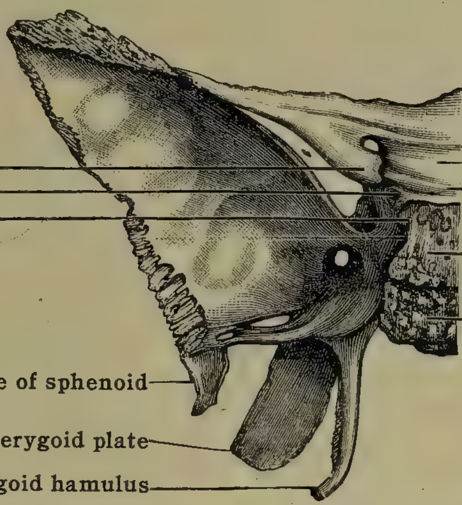


FIG. 153.—THE LEFT HALF OF THE SPHENOID BONE. (Posterior view.)

The **anterior surface** is divided into two lateral halves by the **sphenoidal crest,** a vertical ridge of bone continuous below with the rostrum, and articulating in front with the perpendicular plate of the ethmoid. The surface on each side presents a rough lateral margin for articulation with the lateral mass of the ethmoid (sphenoethmoidal suture) and with the orbital process of the palate bone in the **spheno-orbital suture.** Elsewhere it is smooth, and enters into the formation of the roof of the nasal fossæ, presenting superiorly the irregular **apertures of the sphenoidal sinuses.**

The body is not much hollowed until after the sixth year, but from that time the sinuses increase in size as age advances. Except for the apertures just mentioned, they are closed below and in front by the two **sphenoidal conchæ** [conchæ sphenoidales] originally distinct, but in the adult usually incorporated with the sphenoid.

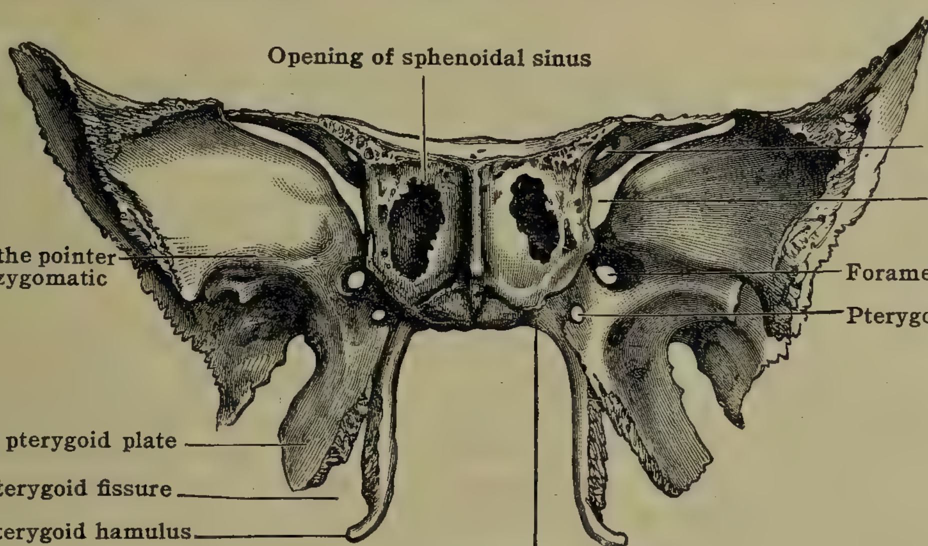


FIG. 154.—THE SPHENOID BONE. (Anterior view.)

The **posterior surface** is united to the basioccipital, up to the twentieth year, by a disk of hyaline cartilage forming the **spheno-occipital synchondrosis,** but afterward this becomes ossified and the two bones then form one piece.

The **lateral surface** of the body gives attachment to the two wings, and its fore part is free where it forms the medial boundary of the superior orbital fissure and the posterior part of the medial wall of the orbit. Above the line of attachment of the great wing is a broad groove which lodges the internal carotid artery and the cavernous sinus, called the **carotid groove.** It is deepest where it curves

behind the root of the process, and this part is bounded along its lateral margin by a slender ridge of bone named the **lingula** (fig. 152), which projects backward in the angle between the body and the great wing.

The **small wings** [alæ parvæ] (alæ orbitales NK) are two thin, triangular plates of bone extending nearly horizontally and laterally on a level with the front part of the upper surface of the body. Each arises medially by two processes or roots, the upper thin and flat, the lower thick and rounded.

Near the junction of the lower root with the body anteriorly, is a small tubercle for the attachment of the common tendon of three ocular muscles—viz., the superior, medial, and upper head of the lateral rectus—and between the two roots is the **optic foramen** (canalis tractus optici NK). The lateral extremity, slender and pointed, approaches the great wing, but, as a rule, does not actually touch it. The superior surface, smooth and slightly concave, forms the posterior part of the anterior fossa of the cranium. The inferior surface constitutes a portion of the roof of each orbit and overhangs **the superior orbital fissure**, the elongated opening between the small and great wings. The anterior border is serrated for articulation with the orbital plate of the frontal (sphenofrontal suture), and the posterior border, smooth and rounded, is received into the Sylvian fissure of the cerebrum. Moreover, the posterior border forms the boundary between the anterior and middle cranial fossæ and is prolonged at its medial extremity to form the **anterior clinoid process.** Between the tuberculum sellæ and the anterior clinoid process is a semicircular notch which represents the termination of the carotid groove. It is sometimes converted into a foramen, the **caroticoclinoid foramen**, by a spicule of bone which bridges across from the anterior clinoid to the **middle clinoid process**; the latter is a small tubercle frequently seen on each side, in front of the hypophyseal fossa, and lateral to the tuberculum sellæ; the foramen transmits the internal carotid artery, and the spicule of bone which may complete the foramen is formed by ossification of the caroticoclinoid ligament.

The **great wings** [alæ magnæ] (alæ temporales NK), arising from the lateral surface of the body, extend laterally and then upward and forward. The posterior part is placed horizontally and projects backward into the angle between the squama and the petrous portions of the temporal bone. From the under aspect of its pointed extremity the **angular spine**, which is grooved medially by the chorda tympani nerve (Lucas), projects downward. The spine serves for the attachment of the sphenomandibular ligament and a few fibers of the tensor veli palatini muscle. Each wing presents four surfaces and four borders.

The **cerebral surface** is smooth and concave. It enters into the formation of the middle cranial fossa, supports the temporal lobe of the cerebrum, and presents cerebral projections and digitate impressions. At the anterior and medial part is the **foramen rotundum** (canalis rotundus NK) for the second division of the fifth nerve, and behind and lateral to it, near the posterior margin of the great wing, is the large **foramen ovale,** transmitting the third division of the trigeminal nerve, the small meningeal artery, and an emissary vein from the cavernous sinus.

Behind and lateral to the foramen ovale is the small circular **foramen spinosum** (foramen spinæ angularis NK), sometimes incomplete, for the passage of the middle meningeal vessels, and the recurrent branch of the third division of the trigeminal. Between the foramen ovale and the foramen rotundum is the inconstant **foramen Vesalii,** which transmits a small emissary vein from the cavernous sinus; and on the plate of bone, behind and medial to the foramen ovale (sphenopetrosal lamina), a minute canal is occasionally seen—the **canaliculus innominatus**—through which the small superficial petrosal nerve escapes from the skull. When the canaliculus is absent, the nerve passes through the foramen ovale.

The anterior surface looks medially and forward and consists of two divisions—a quadrilateral or **orbital surface** [facies orbitalis], which forms the chief part of the lateral wall of the orbit, and a smaller, inferior or **sphenomaxillary surface** [facies sphenomaxillaris], situated above the pterygoid process and perforated by the foramen rotundum; this inferior part forms the posterior wall of the pterygopalatine fossa.

The **temporal surface** [facies temporalis] is divided by a prominent **infratemporal ridge** into a superior portion, which forms part of the temporal fossa and affords attachment to the temporal muscle, and an inferior part the **infratemporal surface,** which looks downward into the infratemporal fossa and gives attachment to the external pterygoid muscle; the infratemporal surface joins the lateral surface of the lateral pterygoid plate, and presents the inferior orifices of the foramen ovale, foramen spinosum, and foramen of Vesalius.

Borders of the great wing.—The **posterior border** extends from the body to the spine. By its lateral third it articulates with the petrous portion of the temporal bone, whilst the medial two-thirds form the anterior boundary of the foramen lacerum. The **squamosal border** [margo squamosus] is serrated behind and bevelled in front for articulation with the squama

of the temporal bone, whilst its upper extremity, or **parietal angle** [angulus parietalis], is bevelled on its inner aspect, for the antero-inferior angle of the parietal bone. Immediately in front of the upper extremity is a rough, triangular, sutural area the **frontal border** [margo frontalis], for the frontal bone, the sides of which are formed by the upper margins of the cerebral, orbital, and temporal surfaces respectively. The **zygomatic border** [margo zygomaticus] separates the orbital and temporal surfaces and articulates with the zygomatic, and by its lower angle, in many skulls, also with the maxilla. Below the zygomatic border is a short horizontal ridge, non-articular, which separates the sphenomaxillary and infratemporal surfaces. Above and medially, where the orbital and cerebral surfaces meet, is the sharp **medial border,** which forms the lower boundary of the **superior orbital fissure,** serving for the passage of the third, fourth, three branches of the first division of the trigeminal, and the abducent cranial nerves, the orbital branch of the middle meningeal artery, a recurrent branch from the lacrimal artery, some twigs from the cavernous plexus of the sympathetic, and one or two ophthalmic veins. Near the middle of the border is a small tubercle for the origin of the lower head of the lateral rectus muscle.

The **pterygoid processes** project downward from the junction of the body and the great wings. Each consists of two plates, one shorter and broader, the **lateral pterygoid plate** [lamina lateralis processus pterygoidei], the other longer and narrower, the **medial pterygoid plate** [lamina medialis processus pterygoidei]. They are united in front, but diverge behind so as to enclose between them the **pterygoid fossa** [fossa pterygoidea] in which lie the internal pterygoid and tensor veli palatini muscles. The lateral pterygoid plate is turned a little laterally and by its lateral surface, which looks into the infratemporal fossa, affords origin to the external pterygoid muscle, and from its medial surface the internal pterygoid takes origin.

In front, the two plates are joined above, but diverge below, leaving a gap—the **pterygoid fissure** [fissura pterygoidea]—occupied, in the articulated skull, by the pyramidal process of the palate. Superiorly, they form a triangular surface which looks into the pterygopalatine fossa and presents the anterior orifice of the pterygoid canal. The anterior border of the medial pterygoid plate articulates with the posterior border of the vertical plate of the palate. The medial pterygoid plate is prolonged below into a slender, hook-like **pterygoid hamulus** [hamulus pterygoideus], smooth on the lateral aspect [sulcus hamuli pterygoidei] for the tendon of the tensor veli palatini muscle, which plays round it. Superiorly, the medial plate extends medially on the under surface of the body, forming the **vaginal process,** which articulates with the ala of the vomer and the sphenoidal process of the palate. The vaginal process presents, on the under surface, a small groove which, with the sphenoidal process of the palate, forms the **pharyngeal canal** for the transmission of branches of the sphenopalatine vessels and ganglion. The medial surface of the medial pterygoid plate forms part of the lateral boundary of the nasal fossa, and the lateral surface, the medial boundary of the pterygoid fossa. The posterior border presents superiorly a well-marked prominence, the **pterygoid tubercle,** above and to the lateral side of which is the posterior orifice of the **pterygoid canal.** The latter pierces the bone in the sagittal direction at the root of the medial pterygoid plate and transmits the pterygoid (Vidian) vessels and nerve. Some distance below the tubercle is a projection, called the **processus tubarius,** which supports the cartilage of the auditory (Eustachian) tube. From the lower third of the posterior margin and from the pterygoid hamulus, the superior constrictor muscle of the pharynx takes origin, and from the depression known as the **scaphoid fossa,** situated in the upper part of the recess between the two pterygoid plates, the tensor veli palatini muscle arises.

Blood-supply.—The sphenoid is supplied by branches of the middle and accessory meningeal arteries, the deep temporal and other branches of the internal maxillary artery—viz., the pterygoid and sphenopalatine. The body of the bone also receives twigs from the internal carotid.

Articulations.—The sphenoid articulates with all the bones of the cranium—viz., occipital, parietal, frontal, ethmoid, temporal, and sphenoidal conchæ; also with the palate, vomer zygomatic, epipteric bone when present, and occasionally with the maxilla.

Ossification.—The sphenoid is divided, up to the seventh or eighth month of intrauterine life, into an anterior or **presphenoid** portion, including the part of the body in front of the tuberculum sellæ and the small wings, and a **postsphenoid** portion, the part behind the tuberculum sellæ including the hypophyseal fossa and the great wings. The two portions of the body join together before birth, but in many animals the division is persistent throughout life.

The presphenoid portion ossifies in cartilage from four centers, one of which gives rise to each small wing (**orbitosphenoid**) and a pair to the body of the presphenoid. In the formation of the postsphenoidal portion both cartilage and membrane bone participate, the pterygoid plates being formed in membrane, while the rest of the portion, together with the pterygoid hamulus, ossifies from cartilage (Fawcett). At about the eighth week a center appears at the base of each great wing (**alisphenoid**), and at about the same time a pair of centers appear in the body (**basisphenoid**) and later one in each lingula (**sphenotic**). The medial pterygoid plates are formed from membrane investing the cartilage, in which a center appears for the hamulus. The lateral plate is formed in membrane and a considerable part of the greater wing is also membranous in origin (see epipteric bone).

At birth (fig. 155) the bone consists of three pieces. The median piece includes the basisphenoid and lingulæ, conjoined with the presphenoid, carrying the orbitosphenoids. The two lateral pieces are the alisphenoids, carrying the medial pterygoid plates. The dorsum sellæ is cartilaginous. A canal, known as the **craniopharyngeal canal,** extends into the body from

the sella turcica and sometimes reaches its under surface. It contains a process of dura mater and represents the remains of the canal in the base of the cranium, through which the hypophyseal stalk extended upward to the hypophysis.

The great wings are joined to the lingulæ by cartilage, but in the course of the first year bony union takes place. About the same time the orbitosphenoids meet and fuse in the midline to form the **jugum sphenoidale** (fig. 156), which thus excludes the anterior part of the

FIG. 155.—THE SPHENOID BONE AT BIRTH.

FIG. 156.—THE JUGUM SPHENOIDALE.

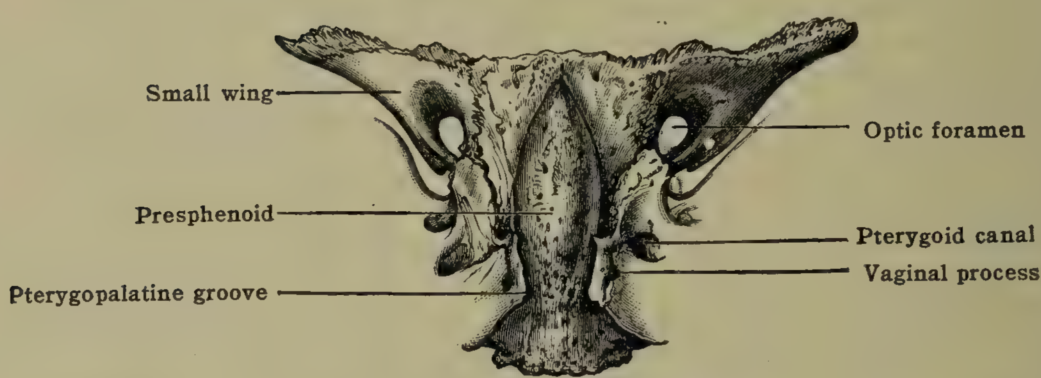


FIG. 157.—THE INFERIOR SURFACE OF PRESPHENOID AT THE SIXTH YEAR.

presphenoid from the cranial cavity. For some years the body of the presphenoid is broad and rounded inferiorly (fig. 157). The posterior clinoid processes chondrify separately, a fact which throws some light on the occasional absence of these processes.

THE SPHENOIDAL CONCHÆ

The **sphenoidal conchæ** (figs. 158, 159) may be obtained as distinct ossicles about the fifth year, and resemble in shape two hollow cones flattened in three planes. At this date each is wedged in between the under surface of the presphenoid and the orbital and sphenoidal proc-

FIG. 158.—THE SPHENOIDAL CONCHA AT THE SIXTH YEAR.

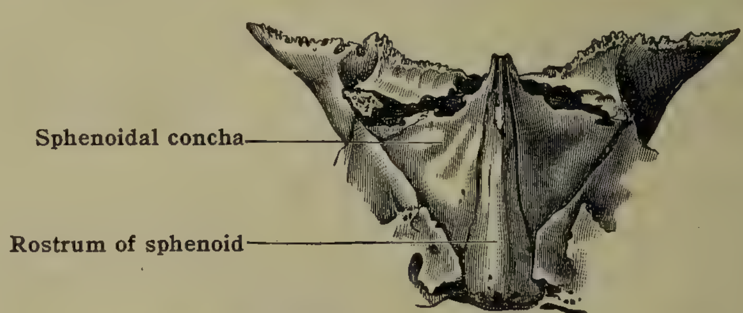


FIG. 159.—THE SPHENOIDAL CONCHÆ FROM AN OLD SKULL.

esses of the palate bone, with the apex of the cone directed backward as far as the vaginal process of the medial pterygoid plate. Of its three surfaces, the lateral is in relation with the pterygopalatine fossa, and occasionally extends upward between the sphenoid and the lamina papyracea of the ethmoid, to appear on the medial wall of the orbit. The inferior surface

forms the upper boundary of the sphenopalatine foramen and enters into formation of the posterior part of the roof of the nasal fossa. The superior surface lies flattened against the under surface of the presphenoid, while the base of the cone is in contact with the lateral mass of the ethmoid.

The deposits of earthy matter from which the sphenoidal conchæ are formed appear at the fifth month. At birth each forms a small triangular lamina in the perichondrium of the ethmovomerine plate near its junction with the presphenoid, and partially encloses a small recess from the mucous membrane of the nose, which becomes the sphenoidal sinus. By the third year the bone has surrounded the sinus, forming an osseous capsule, conical in shape, the circular orifice which represents the base becoming the sphenoidal foramen. As the cavity enlarges the medial wall is absorbed, and the medial wall of the sinus is then formed by the presphenoid. The bones are subsequently ankylosed in many skulls with the ethmoid, whence they are often regarded as parts of that bone. More frequently they fuse with the presphenoid, and less frequently with the palate bones. After the twelfth year they can rarely be separated from the skull without damage. In many disarticulated skulls they are so broken up that a portion is found on the sphenoid, fragments on the palate bones, and the remainder attached to the ethmoid. Sometimes, even in old skulls, they are represented by a very thin triangular plate on each side of the rostrum of the sphenoid (fig. 159).

Variations.—The variability of the middle clinoid process has been mentioned. The superior part of the dorsum sellæ may consist of a separate bar of bone, or may be connected with the apex of the petrous bone. Foramina brought about by bridges of bone between the posterior margin of the lateral pterygoid plate and the angular spine (pterygospinous foramen of Civinini), transmitting the nerve of the internal pterygoid) and between the pterygospinous process and the great wing (porus crotaphitico-buccinatorius, for the lesser division of the mandibular nerve) are rarely observed. Persistence of the cranio-pharyngeal canal is sometimes seen.

THE EPIPTERIC AND SUTURAL BONES

The **epipteric bones,** scale-like, occupy the sphenoidal fontanelles. Each epipteric bone is wedged between the temporal squama, frontal, great wing of sphenoid, and the parietal, and is present in most skulls between the second and fifteenth year. After that date it may persist as a separate ossicle, or unite with the sphenoid, the frontal, or the temporal bone. The epipteric bone is preformed in membrane, and appears as a series of bony granules in the course of the first year.

The **sutural bones** [ossa suturarum] or Wormian bones are small, irregularly shaped ossicles, often found in the sutures of the cranium, especially those in relation with the parietal bones. They sometimes occur in great numbers; as many as a hundred have been counted in one skull. They are rarely present in the sutures of the face.

THE TEMPORAL BONE

The **temporal bone,** situated at the side and the base of the cranium, contains the organ of hearing and presents the cranial articular surface for the lower jaw. It is usually divided into three parts—viz., the **squamous portion,** forming the anterior and superior part of the bone, thin and expanded and prolonged externally into the zygomatic process; the **mastoid portion,** the thick conical posterior part, behind the external aperture of the ear; and a pyramidal projection named the **petrous portion,** situated to the medial side of the two parts already mentioned, and forming part of the base of the skull.

When it is considered in reference to its mode of development, the temporal bone is found to be built up of three parts (figs. 160–162), which, however, do not altogether correspond to the arbitrary divisions of the adult bone. The three parts are named **squamosal, petrosal** (pars petromastoidea NK), and **tympanic,** and a knowledge of their arrangement in the early stages of growth greatly facilitates the study of the fully formed bone.

The more important division of the temporal bone is the **petrous portion.** It is pyramidal in shape, and contains the essential part of the organ of hearing, around which it is developed as a cartilaginous capsule. This is known as the **periotic capsule** or **petrosal** element, and its **base** abuts on the outer aspect of the cranium, where it forms a large part of the so-called mastoid portion of the temporal bone. Besides containing the internal ear, it bears on its cranial side a foramen (internal acoustic opening) for the facial and auditory nerves, and on its outer side two openings—the fenestra vestibuli and fenestra cochleæ (fig. 163). The **squamosal** is a superadded element and is formed as a membrane bone in the lateral wall of the cranium. It is especially developed in man in consequence of the large size of the brain, and forms the squamous division of the adult bone; and by a triangular shaped process which is prolonged behind the aperture of the ear it also contributes to the formation of the mastoid portion. It is obvious, therefore, that the mastoid is not an independent element, but belongs in part to the petrous and in part to the squama. The **tympanic** portion, also superadded, is a ring of bone developed in connection with the external auditory meatus, and eventually forms a plate constituting part of the bony wall of this passage. These three

parts are easily separable at birth, but eventually become firmly united to form a single bone which affords little trace of its complex origin. Lastly a process of bone, developed in the second visceral arch, coalesces with the under surface of the temporal bone and forms the **styloid process.**

FIG. 160.—THE TEMPORAL BONE AT BIRTH. (Constituent parts.)

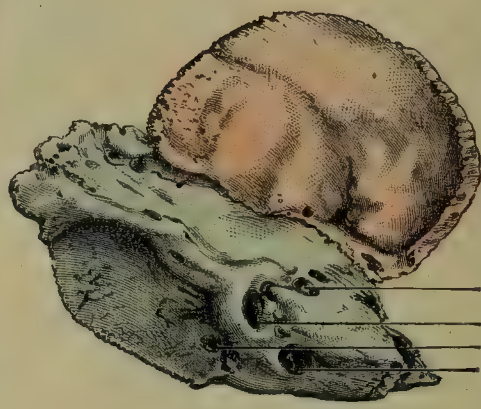


FIG. 161.—TEMPORAL BONE AT BIRTH. (Medial view.)

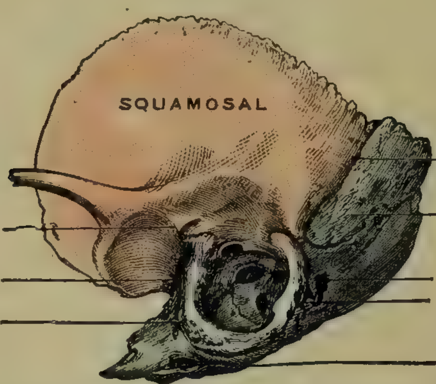


FIG. 162.—THE TEMPORAL BONE AT BIRTH. (Lateral view.)

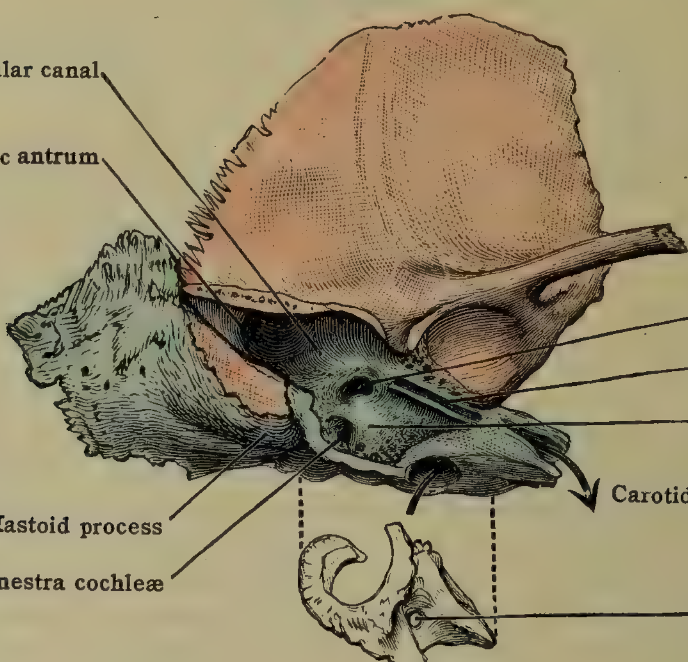


FIG. 163.—RIGHT TEMPORAL BONE AT ABOUT SIX YEARS

The tympanic plate has been separated and drawn below. A portion of the postauditory process of the squama has been removed to show the tympanic (mastoid) antrum.

The **squamous portion** is flat, scale-like, thin, and translucent. It is attached almost at right angles to the petrous portion, forms part of the side wall of the skull and is limited above by an uneven border which describes about two-thirds

of a circle. The **temporal surface** [facies temporalis] is smooth, slightly convex near the middle, and forms part of the temporal fossa. Above the external auditory meatus it presents a nearly vertical **groove for the middle temporal artery.** Connected with its lower part is a narrow projecting bar of bone known as the **zygomatic process.** At its base the process is broad, directed laterally, and flattened from above downward. It soon, however, becomes twisted on itself and runs forward, almost parallel with the squama. This part is much narrower and compressed laterally so as to present medial and lateral surfaces with upper and lower margins. The lateral surface is subcutaneous; the medial looks toward the temporal fossa and gives origin to the masseter muscle. The lower border is concave and rough for fibers of the same muscle, whilst the upper border, thin and prolonged further forward than the lower, receives the temporal fascia. The extremity of the process is serrated for articulation with the zygomatic bone. At its base the zygomatic process presents three roots—anterior, middle, and posterior.

The *anterior root* continuous with the lower border is short, broad, convex, and directed medially to terminate in the **articular tubercle,** which is covered with cartilage in the recent state, for articulation with the condyle of the lower jaw. The *middle root,* sometimes very prominent, forms the **postglenoid process.** It separates the mandibular fossa from the external

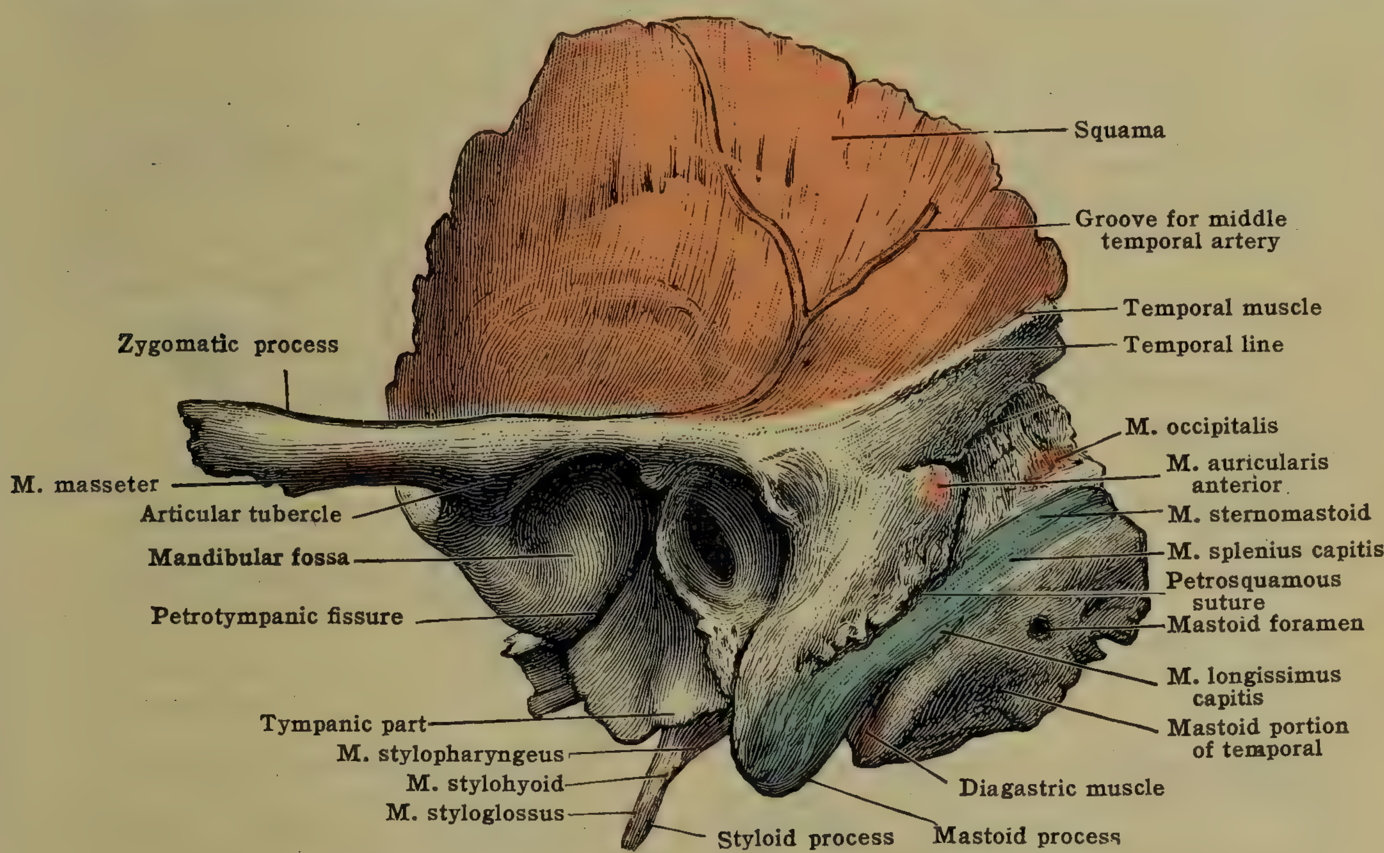


FIG. 164.—THE LEFT TEMPORAL BONE. (Lateral view.)

auditory meatus and is situated immediately in front of the **petrotympanic (Glaserian) fissure.** The *posterior root,* prolonged from the upper border, is strongly marked and extends backward as a line above the external auditory meatus. It is called the **temporal line** (supramastoid crest), and marks the arbitrary line of division between the squamous and mastoid portions of the adult bone. It forms part of the posterior boundary of the temporal fossa, from which, as well as from the line, fibers of the temporal muscle arise. Where the anterior root joins the zygomatic process is a slight tubercle—the **preglenoid tubercle**—for the attachment of the temporomandibular ligament, and between the anterior and middle roots is a deep oval depression, forming the part of the mandibular fossa for the condyle of the lower jaw. The **mandibular fossa** is an oval hollow, bounded in front by the articular tubercle and limited behind by the petrotympanic fissure which separates it from the tympanic part of the bone. The **articular surface** [facies articularis], is coated with fibro-cartilage and is continued forward upon the articular tubercle. The long axis of the fossa is directed medially and somewhat backward; the axes of the two fossæ if prolonged would meet in the mid-line at the anterior margin of the foramen magnum. Immediately in front of the articular tubercle is a small triangular surface which enters into the formation of the roof of the infratemporal fossa.

The inner or **cerebral surface** [facies cerebralis] of the squama is marked by furrows for the convolutions of the brain and grooves for the middle meningeal vessels.

At the upper part of the surface the inner table of the bone is deficient and the outer table is prolonged some distance upward, forming a thin scale, with the bevelled surface looking

inward to overlap the corresponding edge of the parietal. Anteriorly the border is thicker serrated, and slightly bevelled on the outer side for articulation with the posterior border of the great wing of the sphenoid. Posteriorly it joins the rough serrated margin of the mastoid portion to form the **parietal notch** [incisura parietalis]. The line separating the squamous from the petrous portion is indicated at the lower part of the inner surface by a narrow cleft, the internal **petrosquamous fissure** [fissura petrosquamosa], the appearance of which varies in different bones according to the degree of persistence of the original line of division.

The **mastoid portion** [pars mastoidea] is rough and convex. It is limited above by the temporal line and a free rough margin which articulates with the parietal bone in the parietomastoid suture; in front, by the external auditory meatus and the **tympanomastoid fissure** [fissura tympanomastoidea]; and behind, by a broad jagged occipital border meeting the occipital bone in the **occipito-mastoid suture.** As already pointed out, it is formed by the squamous portion in front and by the base of the petrosal behind, the line of junction of the two component parts being indicated on the outer surface by the **external petrosquamous suture** (incorrectly, squamomastoid). The appearance of the suture varies, being in some bones scarcely distinguishable, in others, a series of irregular

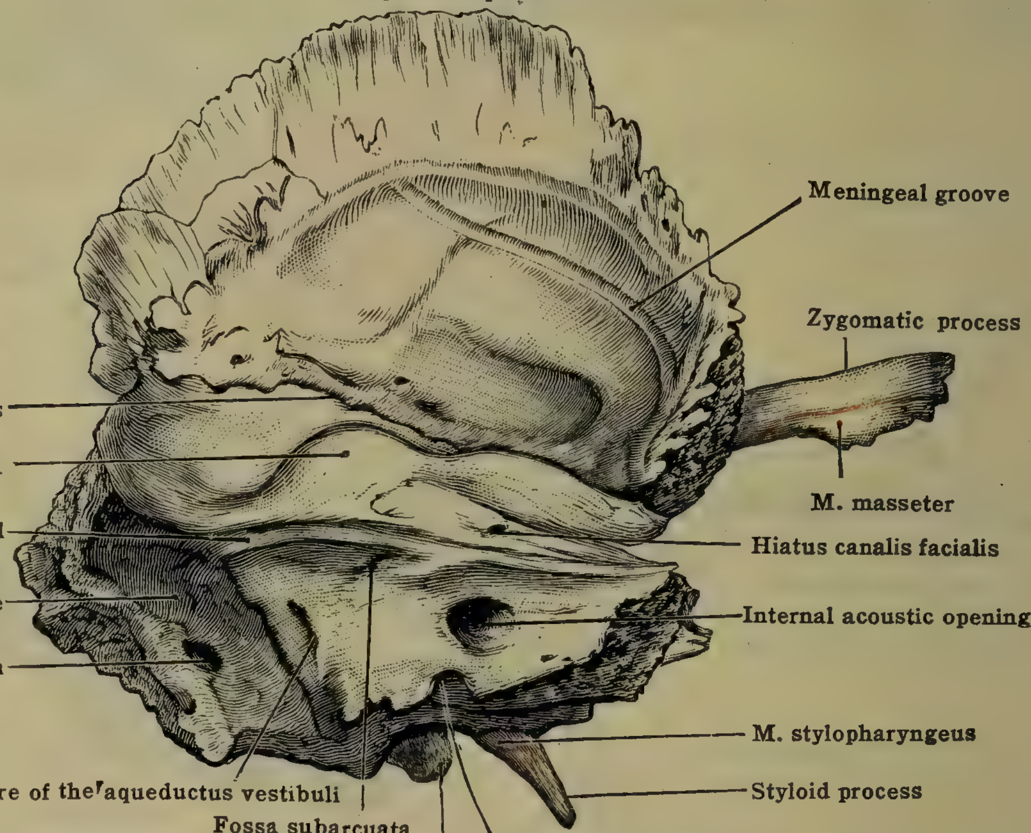


FIG. 165.—THE LEFT TEMPORAL BONE. (Seen from the inner side and above.)

depressions, whilst occasionally it is present as a well-marked fissure (fig. 164) directed obliquely downward and forward. The mastoid portion is prolonged downward behind the external acoustic meatus into a nipple-shaped projection, the **mastoid process,** the tip of which points forward as well as downward. The process is marked, on its medial surface, by a deep groove, the **mastoid notch** (diagastric fossa), for the origin of the digastric muscle, and again medially by the **occipital groove** for the occipital artery.

The *outer surface* is perforated by numerous foramina, one, of large size, being usually situated near the posterior border and called the **mastoid foramen.** It transmits a vein to the transverse (lateral) sinus and the mastoid branch of the occipital artery. The mastoid portion gives attachment externally to the auricularis posterior and occipitalis muscles, and, along with the mastoid process, to the sternomastoid, splenius capitis, and longissimus capitis muscles. Projecting from the postero-superior margin of the external acoustic meatus there is frequently a small tubercle—the **suprameatal spine** [spina suprameatum] (of Henle)—behind which the surface is depressed to form the **mastoid (suprameatal) fossa** [fossa mastoidea].

The *inner surface* of the mastoid portion presents a deep curved **sigmoid groove,** in which is lodged a part of the transverse sinus; the mastoid foramen is seen opening into the groove. The interior of the mastoid portion, in the adult, is usually occupied by cavities, of which some are lined by mucous membrane,

contain air and are known as the **mastoid cells** [cellulæ mastoideæ] (fig. 168). These open into a small chamber—the **mastoid antrum**—which communicates with the upper part of the tympanic cavity. The mastoid cells are arranged in three groups: (1) anterosuperior, (2) middle, and (3) apical. The apical cells, situated at the apex of the mastoid process, are small and usually contain marrow.

Borders.—The superior or **parietal border** [margo parietalis] is broad and rough for articulation with the hinder part of the inferior border of the parietal bone. The posterior border, very uneven and serrated, articulates with the inferior border of the occipital bone, extending from the lateral angle to the jugular process.

The **petrous portion** [pars petrosa] (pyramis NK) is a pyramid of very dense bone presenting a base, an apex, three (or four) surfaces, and three (or four) borders or angles. Two sides of the pyramid look into the cranial cavity, the posterior into the posterior cranial fossa, and the anterior into the middle cranial fossa. The inferior surface appears on the under surface of the cranium. The medial and posterior walls of the tympanic cavity in the temporal bone are sometimes described as a fourth side, or base of the pyramid. The base faces the lateral surface of the cranium; the apex is placed medially.

The **posterior surface of the pyramid** [facies posterior pyramidis] is triangular in form, bounded above by the **superior angle** [angulus superior] and below by the **posterior angle** [angulus posterior]. Near the middle is the obliquely directed **internal acoustic opening** [porus acusticus internus] leading into a short canal—the **internal acoustic meatus** [meatus acusticus internus]—at the bottom of which is a plate of bone, pierced by numerous foramina. The canal transmits the facial, auditory and glossopalatine (pars intermedia) nerves, and the internal auditory artery. The **bottom of the internal acoustic meatus** [fundus meatus acustici interni] can be most advantageously studied in a temporal bone of the newborn, when the canal is shallow and the openings relatively wide.

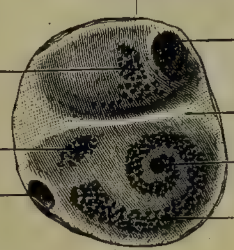


FIG. 166.—THE FORAMINA IN THE FUNDUS OF THE LEFT INTERNAL ACOUSTIC MEATUS OF A CHILD AT BIRTH (×4). (Diagrammatic.)

The fundus of the meatus (fig. 166) is divided by a transverse ridge of bone, the transverse crest [crista transversa], into a superior and inferior fossa. Of these, the superior is the smaller, and presents anteriorly the beginning of the **facial canal** (aqueduct of Fallopius) [canalis facialis Falloppii], which transmits the facial nerve. The rest of the surface above the crest is dotted with small foramina, the **superior vestibular area** [area vestibularis superior] which transmit nerve-twigs to the **recessus ellipticus** (fovea hemielliptica) and the ampullæ of the superior and lateral semicircular ducts (vestibular division of the acoustic nerve). Below the crest there are two depressions and an opening. Of these, an anterior curled tract, the **spiral cribriform tract** [tractus spiralis foraminosus] with a central foramen (foramen centrale cochleare) marks the base of the cochlea; the central foramen indicates the orifice of the canal of the modiolus, and the smaller foramina transmit the cochlear twigs of the auditory nerve. The posterior opening, **foramen singulare,** is for the nerve to the ampulla of the posterior semicircular canal. The middle depression, **inferior vestibular area** [area vestibularis inferior] is dotted with minute foramina for the nerve-twigs to the saccule, which is lodged in the recessus sphæricus (fovea hemisphærica). The inferior fossa is subdivided by a low vertical crest. The depression in front of the crest is the *fossula cochlearis,* and the recess behind it is the *fossula vestibularis.*

Behind and lateral to the meatus is a narrow fissure, the **aqueductus vestibuli,** covered by a scale of bone. In the fissure lie the ductus endolymphaticus, a small arteriole and venule, and a process of connective tissue. Occasionally a bristle can be passed through it into the vestibule. Near the upper margin, and opposite a point about midway between the meatus and the aqueduct of the vestibule, is an irregular opening, the **fossa subarcuata,** the remains of the **floccular fossa,** a conspicuous depression in the fetal bone. In the adult the depression usually lodges a process of dura mater and transmits a small vein, though in some bones it is almost obliterated.

The **anterior surface of the pyramid** [facies anterior pyramidis], sloping downward and forward, forms the back part of the floor of the middle fossa of the cranium (fig. 135).

Upon the anterior surface of the pyramid will be found the following points of interest, proceeding from the apex toward the base of the pyramid:—(1) a shallow **trigeminal impression** for the semilunar (Gasserian) ganglion of the trigeminal nerve; (2) two small grooves running backward and laterally toward two small foramina overhung by a thin osseous lip, the larger and medial of which, known as the **hiatus canalis facialis,** transmits the great superficial petrosal nerve and the petrosal branch of the middle meningeal artery, whilst the smaller and lateral foramen is for the small superficial petrosal nerve; (3) behind and lateral to these is an eminence —the **eminentia arcuata**—best seen in young bones, corresponding to the superior semicircular canal in the interior; (4) still more laterally is a thin transulcent plate of bone, roofing in the tympanic cavity, and named the **tegmen tympani.**

The **inferior surface of the pyramid** [facies inferior pyramidis] is very irregular and presents numerous important structures, including the carotid canal, jugular fossa, stylomastoid process and foramen (fig. 167).

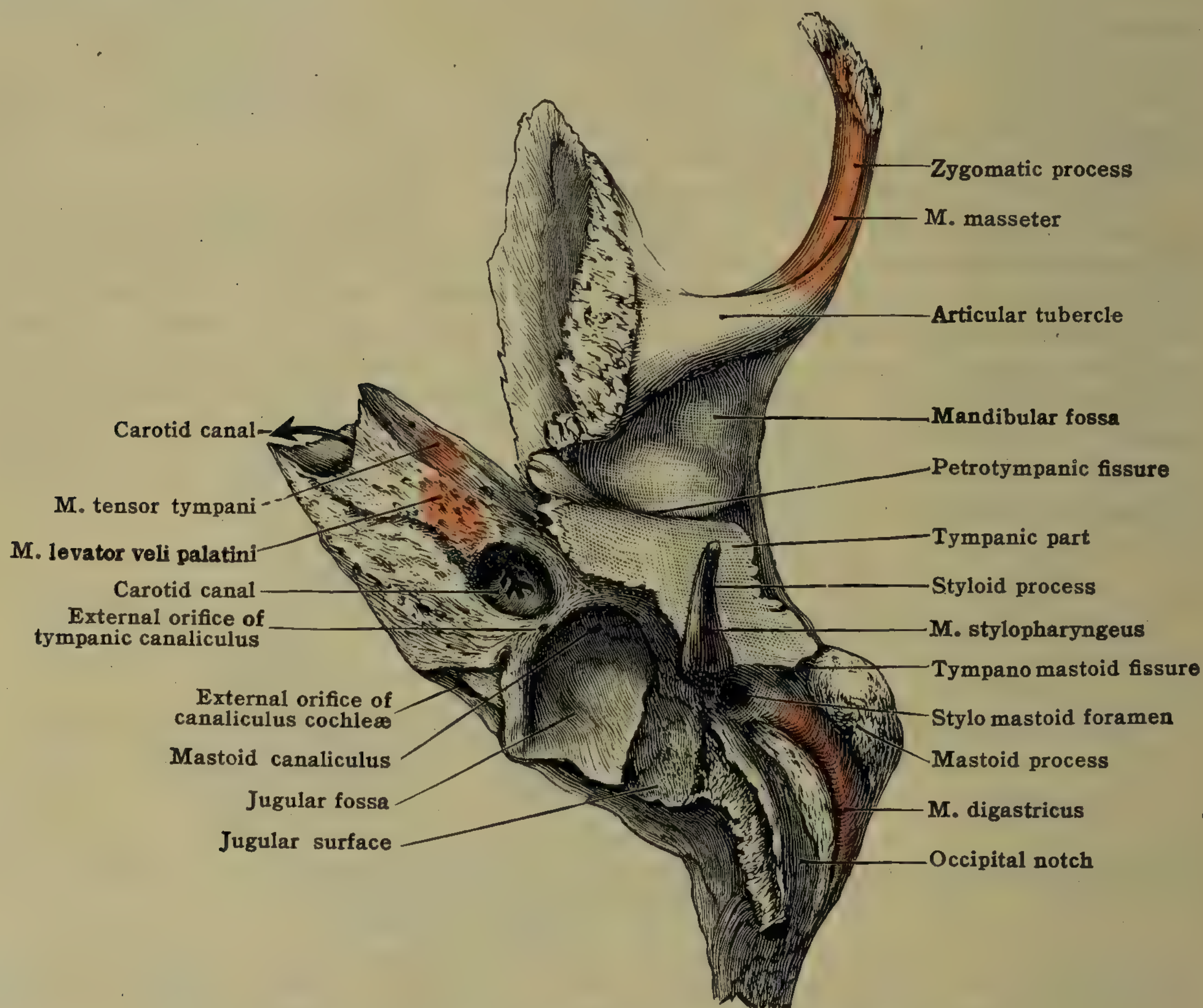


Fig. 167.—The Left Temporal Bone. (Inferior view.)

At the apex the basilar surface is rough, quadrilateral, and gives attachment to the tensor tympani, levator veli palatini muscles and the pharyngeal aponeurosis. Behind this is seen the large circular orifice of the **carotid canal** for the transmission of the carotid artery and a plexus of sympathetic nerves. On the same level, near the posterior border, is a small three-sided depression, the external opening of the **canaliculus cochleæ,** which transmits a small vein from the cochlea to the internal jugular vein. Behind these two openings is the large elliptical **jugular fossa** which forms the anterior and lateral part of the bony wall of the jugular foramen, in which is contained a dilation on the commencement of the internal jugular vein; on the lateral wall of the jugular fossa is a minute foramen, the **mastoid canaliculus,** for the entrance of the auricular branch of the vagus (Arnold's nerve) into the interior of the bone. Between the inferior aperture of the carotid canal and the jugular fossa is the sharp **carotid ridge,** on which is a small depression, the **fossula petrosa,** and at the bottom of this a minute opening, the **tympanic canaliculus,** for Jacobson's nerve (tympanic branch of the glossopharyngeal) and the small tympanic branch from the ascending pharyngeal artery.

Behind the jugular fossa is the rough **jugular surface** for articulation with the jugular process of the occipital bone, on the lateral side of which is the prominent cylindrical spur known as the **styloid process** with the **stylomastoid** foramen at its base. This foramen, which is the external orifice of the facial canal, transmits the facial nerve, the stylomastoid artery and sometimes the auricular branch of the vagus. Running backward from the foramen are the mastoid notch and occipital groove already described.

The **base or tympanic surface** of the pyramid, forming the media land osterior walls [paries labyrinthica] of the tympanic cavity, is shown by removing the tympanic part of the bone (fig. 168).

The tympanic surface presents superiorly an excavation, known as the **tympanic antrum** [antrum tympanicum], covered by the triangular part of the squamous below and behind the temporal line. The opening of the antrum into the tympanic cavity is situated immediately above the **fenestra vestibuli,** an oval-shaped opening which receives the base of the stapes; below the fenestra vestibuli is a convex projection or **promontory** [promontorium], marked by grooves for the tympanic plexus of nerves and containing the commencement of the first turn of the cochlea. In the lower and posterior part of the promontory is the **fenestra cochleæ,** closed in the recent state by the secondary membrane of the tympanum. Running downward and forward from the front of the fenestra vestibuli is a thin curved plate of bone [**septum canalis musculotubarii**], separating two grooves converted into canals by the overlying tympanic plate. The lower is the **groove for the auditory (Eustachian) tube** [semicanalis tubæ auditivæ], the communicating passage between the tympanum and the pharynx; the upper is the **semicanalis m. tensoris tympani**; the medial apertures of both canals are visible in the retiring angle, between the petrous and squamous portions of the bone.

The **apex of the pyramid** [apex pyramidis] is truncated and presents the medial opening of the carotid canal. The latter commences on the inferior surface, and, after ascending for a short distance, turns forward and medially, tunnelling the bone as far as the apex, and finally opens into the cranial cavity opposite the **foramen lacerum** which is formed between the temporal and sphenoid bones.

One or two minute openings in the wall of the carotid canal, known as the **caroticotympanic canaliculi,** transmit communicating twigs between the carotid and tympanic plexuses. The upper part of the apex is joined by cartilage to the posterior petrosal process of the sphenoid.

The **base** is the part of the pyramid which appears laterally at the side of the cranium and takes part in the formation of the mastoid portion. It is described above with that division of the bone.

FIG. 168.—THE MEDIAL WALL OF THE TYMPANIC CAVITY.

Angles.—The **superior angle of the pyramid** is the longest and separates the posterior from the anterior surface. It is grooved for the superior petrosal sinus [sulcus petrosus superior], gives attachment to the tentorium cerebelli, and presents near the apex a semilunar notch upon which the trigeminal nerve lies. Near its medial end there is often a small projection for the attachment of the petrosphenoidal ligament, which arches over the inferior petrosal sinus and the abducent nerve. The **posterior angle of the pyramid** [angulus posterior pyramidis] separates the posterior from the inferior surface, and when articulated with the occipital, forms the groove for the inferior petrosal sinus [sulcus petrosus inferior], and completes the **jugular foramen** formed by the **jugular notch** [incisura jugularis] of the temporal bone in front and on the lateral side, and by the jugular notch of the occipital bone behind and on the medial side. The **jugular notch** is divisible into two parts by the intrajugular process: an anterior for the inferior petrosal sinus, the glossopharyngeal, vagus and accessory nerves, and a posterior for the internal jugular vein and some meningeal branches from the occipital and ascending pharyngeal arteries. The **anterior angle of the pyramid** [angulus anterior pyramidis], is the shortest and consists of two parts, one joined to the squama in the petrosquamous suture and a small free part medially which articulates with the great wing of the sphenoid. A fourth or inferior border may be distinguished which runs along the line of junction with the tympanic plate and is continued on to the rough area below the apex.

The **tympanic portion** [pars tympanica] is quadrilateral in form, hollowed out above and behind, and nearly flat, or somewhat concave, in front and below. It forms the whole of the anterior and inferior walls, and part of the posterior wall, of the external auditory meatus, and is separated behind from the mastoid process by the **tympanomastoid** (auricular) **fissure** through which the auricular branch of the vagus in some cases leaves the bone.

In front it is separated by the **petrotympanic** fissure from the edge of the tegmen tympani. Through the petrotympanic fissure the tympanic branch of the internal maxillary artery passes. The processus gracilis of the malleus is lodged within it, and it transmits the chorda tympani nerve. The tympanic part presents for examination two surfaces and four borders.

The **anteroinferior surface,** directed downward and forward, lodges part of the parotid gland. Near the middle it is usually very thin, and sometimes presents a small foramen (the foramen of Huschke), which represents a non-ossified portion of the plate. The **postero-superior surface** looks into the external auditory meatus and tympanic cavity, and at its medial end is a narrow groove, the **sulcus tympanicus,** deficient above, which receives the membrana tympani.

The **lateral border** is rough and everted, forming the **external auditory process** for the attachment of the cartilage of the pinna; the **superior border** enters into the formation of the petrotympanic fissure; the **inferior border** is uneven and prolonged into the **vaginal process** [vagina processus styloidei] which surrounds the lateral aspect of the base of the styloid process and gives attachment to the front part of the fascial sheath of the carotid vessels; the **medial border,** short and irregular, lies immediately below and to the lateral side of the opening of the Eustachian tube, and becomes continuous with the rough quadrilateral area on the inferior aspect of the apex.

The **external acoustic (auditory) meatus** is formed partly by the tympanic and partly by the squamous portion. It is a bony tube leading into the tympanum, the entrance of which is bounded throughout the greater part of its circumference by the external auditory process of the tympanic part. Above, the entrance is limited by the temporal line or posterior root of the zygomatic process.

The **styloid process** is a slender, cylindrical spur of bone fused with the inferior aspect of the temporal immediately in front of the stylomastoid foramen. It consists of two parts, **basal** (tympanohyal), which in the adult lies under cover of the tympanic part, and a **projecting** portion (stylohyal), which varies in length from five to fifty millimeters. When short, it is hidden by the vaginal process, but, on the other hand, it may reach to the hyoid bone. The projecting portion gives attachment to three muscles and two ligaments.

The stylopharyngeus muscle arises near the base from the medial and slightly from the posterior aspect; the stylohyoid from the posterior and lateral aspect near the middle; and the styloglossus from the front near the tip. The tip is continuous with the stylohyoid ligament, which runs down to the lesser cornu of the hyoid bone. A band of fibrous tissue—the stylomandibular ligament—passes from the process below the origin of the styloglossus to the angle of the lower jaw.

Blood-supply.—The arteries supplying the temporal bone are derived from various sources. The chief are:

Stylomastoid from posterior auricular: it enters the stylomastoid foramen.

Anterior tympanic from internal maxillary: it passes through the petrotympanic fissure.

Superficial petrosal from middle meningeal: transmitted by the hiatus canalis facialis.

Caroticotympanic from internal carotid whilst in the carotid canal.

Internal auditory from the basilar: it enters the internal acoustic meatus, and is distributed to the cochlea and vestibule.

Other less important twigs are furnished by the middle meningeal, the meningeal branches of the occipital, and by the ascending pharyngeal artery. The squama is supplied, on its internal surface, by the middle meningeal, and externally by the branches of the deep temporal from the internal maxillary.

Articulations.—The temporal bone articulates with the occipital, parietal, sphenoid and zygomatic bones, and, by a movable joint, with the mandible. Occasionally the squamous portion presents a process which articulates with the frontal. A **frontosquamosal** suture occurs in the skulls of some of the colored races, and is normal in the skulls of the chimpanzee, gorilla, and gibbon. Articulations are formed also with the auditory ossicles and the hyoid bone.

Ossification.—Of the three parts which constitute the temporal bone at birth, the squama and tympanic part develop in membrane and the petrous part in cartilage. The squama is formed from one center, which appears as early as the eighth week, and ossification extends into the zygomatic process, which grows concurrently with the squama. At first the tympanic border is nearly straight, but soon assumes its characteristic horseshoe shape. At birth the postglenoid tubercle is conspicuous, and at the hinder end of the squama there is a process which comes into relation with the mastoid antrum. The center for the tympanic element appears about the twelfth week. At birth it forms an incomplete ring, open above, and slightly ankylosed to the lower border of the squama. The anterior extremity terminates in a small irregular process, and the medial aspect presents, in the lower half of its circumference, a groove for the reception of the tympanic membrane.

Up to the middle of the fifth month the periotic capsule is cartilaginous; it then ossifies so rapidly that by the end of the sixth month its chief portion is converted into porous bone. The ossific material is deposited in four centers, or groups of centers, named according to their relation to the ear-capsule in its embryonic position.

The nuclei are deposited in the following order:

1. The **opisthotic** appears at the end of the fifth month. The osseous material is seen first on the promontory, and it quickly surrounds the fenestra cochleæ from above downward, and forms the floor of the vestibule, the lower part of the fenestra vestibuli, and the internal acoustic meatus; it also invests the cochlea. Subsequently a plate of bone arises from it to surround the internal carotid artery and form the floor of the tympanum.

2. The **pro-otic** nucleus is deposited behind the internal acoustic meatus near the medial limb of the superior semicircular canal. It covers in a part of the cochlea, the vestibule, and the internal acoustic meatus, completes the fenestra vestibuli, and invests the superior semicircular canal.

3. From the **pterotic** nucleus is ossified the tegmen tympani and the investment of the lateral semicircular canal; the ossific matter is first deposited over the lateral limb of this canal.

4. The **epiotic,** often double, is the last to appear, and is first seen at the most posterior part of the posterior semicircular canal.

At birth (figs. 160–162) the bone is of loose and open texture, thus offering a striking contrast to the dense and ivory-like petrosal of the adult. It also differs from the adult bone in several other particulars. The subarcuate fossa is widely open and conspicuous. Voltolini has pointed out that a small canal leads from the floor of the subarcuate fossa and opens posteriorly on the mastoid surface of the bone; it may open in the mastoid antrum. The hiatus canalis facialis is unclosed and the tympanum is filled with gelatinous connective tissue. The mastoid process is not developed, and the jugular fossa is a shallow depression.

After birth the parts grow rapidly. The tympanum becomes permeated with air, the various elements fuse, and the tympanic annulus grows rapidly and forms the tympanic plate. Development of the tympanic plate takes place by an outgrowth of bone from the lateral aspect of the tympanic annulus. This outgrowth proceeds most rapidly from the tubercles or spines at its upper extremities, and in consequence of the slow growth of the lower segment a deep notch is formed; gradually the tubercles coalesce, lateral to the notch, so as to enclose a foramen which persists until puberty, and sometimes even in the adult. In most skulls a cleft (tympanomastoid fissure) remains between the tympanic element and the mastoid process. Between the anterior portion of the tympanic plate and the inferior border of the squama is a cleft which is subsequently encroached upon by the growth of the petrosal; the crevice remaining between the latter and the tympanic is the petrotympanic fissure. As the tympanic plate increases in size it joins the lateral wall of the carotid canal and presents a prominent lower edge, known as the vaginal process (sheath of the styloid).

The **mastoid process** becomes distinct about the first year, coincident with the obliteration of the petrosquamous suture, and increases in thickness by deposit from the periosteum. According to most writers, the process becomes pneumatic about the time of puberty, but it has been shown by Young and Milligan that the mastoid air-cells develop at a much earlier period than is usually supposed. Air-cells were present, as small pit-like diverticula from the mastoid antrum, in a nine months' fetus and in an infant one year old. In old skulls the air-cells may extend into the jugular process of the occipital bone.

At birth the mastoid antrum is relatively large and bounded laterally by a thin plate of bone belonging to the squama (postauditory process). As the mastoid increases in thickness the antrum comes to lie at a greater depth from the surface and becomes relatively smaller.

The styloid process is ossified in cartilage from two centers, one of which appears at the base in the tympanohyal before birth. This soon joins with the temporal bone, and in the second year a center appears for the stylohyal, which, however, remains very small until puberty. In the adult it usually becomes firmly united with the tympanohyal, but it may remain permanently separate.

Variations.—A bar of bone in the dura over the trigeminal nerve has been interpreted as a vestige of the primitive cranial wall as presented in the reptilia. The petrosquamous suture may persist. In the heritable defect, known as *cleidocranial dysostosis,* the temporal squama is rudimentary and the zygomatic arch is incomplete. The mastoid cells vary greatly in extent and may even invade the squamous part.

THE TYMPANUM

The **tympanic cavity** [cavum tympani] is a space of irregular form in the temporal bone, situated over the jugular fossa, between the petrous portion medially and the tympanic and squamous portions laterally. When fully developed, it is completely surrounded by bone except where it communicates with the external acoustic meatus, and presents six walls—lateral, medial, posterior, anterior, superior (roof), and inferior (floor). The lateral and medial walls are relatively flat, but the remainder are curved, so that they run into adjoining surfaces, without sharp limits.

The **roof** or **tegmen tympani** [paries tegmentalis] is a translucent plate of bone, forming part of the anterior surface of the petrous portion and separating the tympanum from the middle fossa of the skull. The **floor** [paries jugularis] is the plate of bone which forms also the roof of the jugular fossa. The **medial wall** [paries labyrinthica] (figs. 163, 168) is formed by the tympanic surface of the petrous portion. In the angle between it and the roof is a horizontal ridge which extends backward as far as the posterior wall and then turns downward in the angle between the medial and posterior walls. It corresponds to the subjacent **facial (Fallopian) canal,** occupied by the facial nerve. The other features of this surface—viz., the **fenestra vestibuli,** the **fenestra cochleæ,** and the **promontory**—have been previously described with the tympanic surface of the petrous portion of the temporal bone (See also The Tympanic Cavity, p. 1174). The **posterior wall** [paries mastoidea] of the tympanum is also formed by the surface of the petrous portion. At the superior and lateral angle of this wall an opening leads into the **tympanic antrum.** Immediately below this opening there is a small hollow cone, the **pyramidal eminence** [eminentia pyramidalis] the cavity of which is continuous with the descending limb of the facial canal. The cavity is occupied by the stapedius muscle and the tendon emerges at the apex. One or more bony spicules often connect the apex of the pyramid with the promontory.

The roof and floor converge toward the **anterior extremity** (wall) of the tympanum [paries carotica], which is, in consequence, very low; it is occupied by two semicanals, the lower for the Eustachian tube, the upper for the tensor tympani muscle. These channels are sometimes described together as the **canalis musculotubarius.** In carefully prepared bones the upper

semicanal is a small horizontal hollow cone (anterior pyramid), 12 mm. in length; the apex is just in front of the fenestra vestibuli, and is perforated to permit the passage of the tendon of the muscle. As a rule, the thin walls of the canal are damaged, and represented merely by a thin ridge of bone. The posterior portion of this ridge projects into the tympanum, and is known as the **processus cochleariformis.** The thin septum between the semicanal for the tensor tympani and the tube is pierced by a minute opening which transmits the small deep petrosal nerve.

The **lateral wall** [paries membranacea] is occupied mainly by the inner end of the external acoustic meatus. This opening is closed in the recent state by the tympanic membrane. The rim of bone to which the membrane is attached is incomplete above, and the defect is known as the **tympanic notch** [incisura tympanica Rivini]. Anterior to this notch, in the angle between the tegmen tympani and the tympanic plate, is the **petrotympanic (Glaserian) fissure,** the small passage which transmits the chorda tympani nerve.

Up to this point the description of the middle ear conforms to that in general usage. But Young and Milligan have laid stress on the fact that the middle ear is really a cleft, named by them the '*middle-ear cleft,*' which intervenes between the periotic capsule, on the one hand, and the squamozygomatic and tympanic elements of the temporal bone on the other. This cleft, as development proceeds, gives rise to three cavities:—(1) the tympanic antrum; (2) tympanum; and (3) the Eustachian tube. They point out that "the cleft is primarily continuous, and however much it may be altered in shape and modified in parts to form these three cavities, that continuity is never lost." It will be clear that the tympanic antrum, according to this view, is not an outgrowth from the tympanum, but is simply the lateral end of the middle-ear cleft.

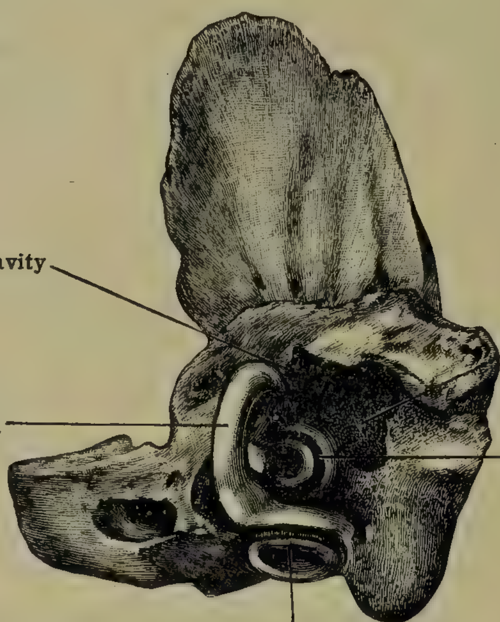


FIG. 169.—TEMPORAL BONE AT BIRTH DISSECTED FROM ABOVE AND BEHIND TO SHOW THE SEMICIRCULAR CANALS AND THE TYMPANIC ANTRUM. (Enlarged ⅓.)

The tympanic cavity may be divided into three parts. The part below the level of the superior margin of the external auditory meatus is the **tympanic cavity proper;** the portion above this level is the **epitympanic recess** [recessus epitympanicus] or **attic;** it receives the head of the malleus, the body of the incus, and leads posteriorly into the recess known as the **tympanic antrum** [antrum tympanicum]. The third part is the downward extension known as the **hypotympanic recess.** (For additional details and figures of the tympanic cavity, see p. 1174.)

The tympanic (mastoid) antrum.—The air-cells which in the adult are found in the interior of the mastoid portion of the temporal bone open into a small cavity termed the **tympanic antrum** (figs. 163, 168, 169). This is an air-chamber, communicating with the epitympanic recess, and separated from the middle cranial fossa by the posterior portion of the tegmen tympani. The floor is formed by the mastoid portion of the petrosal, and the lateral wall by the squama below the temporal ridge. In children the outer wall is exceedingly thin, but in the adult it is of considerable thickness. The eminence made by the **lateral semicircular canal** projects into the antrum on its medial wall, and is very conspicuous in the fetus. Immediately below and in front of this elevation is the ridge corresponding to the facial canal containing the facial nerve.

The tympanic antrum has somewhat the form of the bulb of a retort (Thane and Godlee) compressed laterally, and opening by its narrowed neck into the epitympanic recess. Its dimensions vary at different periods of life. It is well developed at birth, attains its maximum size about the third year, and diminishes somewhat up to adult life. In the adult the plate of bone which forms the lateral wall of the antrum is 12 to 18 mm. (½ to ¾ in.) in thickness, whereas at birth it is about 1.8 mm. or less. The deposition of bone laterally occurs, therefore, at average rate of nearly 1 mm. a year in thickness. In the adult the antrum is about 12 mm. from front to back, 9 mm. from above downward, and 4.5 mm. from side to side.

A canal occasionally leads from the tympanic antrum through the petrous bone to open in the recess which indicates the position of the subarcuate fossa; it is termed the petromastoid canal. (Gruber.)

The facial (Fallopian) canal.—This canal begins at the anterior angle of the superior fossa of the internal acoustic meatus, and passes forward and laterally above the vestibular portion of the internal ear for a distance of 1.5–2.0 mm. At the lateral end of this portion of its course it becomes dilated to accommodate the geniculate ganglion, and then turns abruptly backward and runs in a horizontal ridge on the medial wall of the tympanum, lying in the angle between it and the tegmen tympani, immediately above the fenestra vestibuli, and extending as far backward as the entrance to the tympanic antrum. Here it comes into contact with the inferior aspect of the projection formed by the lateral semicircular canal, and then turns vertically downward, running in the angle between the medial and posterior walls of the tympanic cavity to terminate at the stylomastoid foramen.

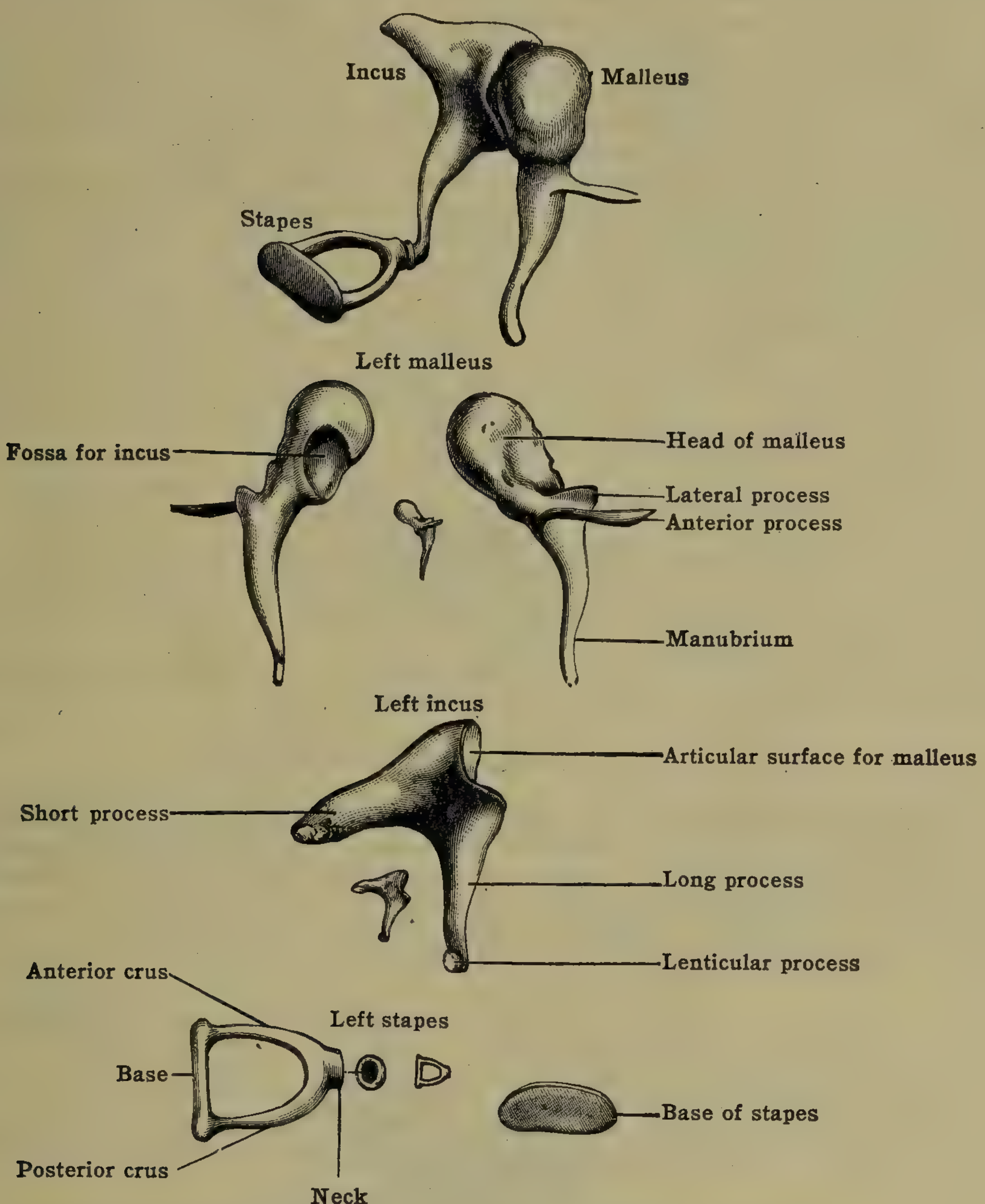


FIG. 170.—THE AUDITORY OSSICLES. (Modified from Henle.)

The canal is traversed by the facial nerve. Numerous openings exist in the walls of this passage. At its abrupt bend, or **genu** [geniculum canalis facialis], the greater superficial petrosal nerve escapes from, and a branch from the middle meningeal artery enters, the canal, and in the vertical part of its course the cavity of the pyramidal eminence opens into it. There is also a small orifice by which the auricular branch of the vagus joins the facial and near its termination the **iter chordæ posterius** for the chorda tympani nerve leads from the facia lcanal into the tympanum.

The auditory ossicles [ossicula auditus], named from their fancied resemblances the malleus, incus and stapes, are contained in the upper part of the tympanic cavity. Together they form a jointed column of bone connecting the membrana tympani with the fenestra vestibuli (fig. 170).

The malleus.—This is the most external of the auditory ossicles, and lies in relation with the tympanic membrane. Its upper portion, or **head** [capitulum mallei], is lodged in the epitympanic recess. It is of rounded shape, and presents posteriorly an elliptical depression for articulation with the incus. Below the head is a constricted portion or **neck** [collum mallei], from which three processes diverge. The largest is the **handle** [manubrium mallei], which is

slightly twisted and flattened. It forms an obtuse angle with the head of the bone, and lies between the membrana tympani and the mucous membrane covering its inner surface. The tensor tympani tendon is inserted into the manubrium near its junction with the neck on the medial side. The **anterior process** [processus anterior Folii] is a long, slender, delicate spiculum of bone (rarely seen of full length except in the fetus), projecting nearly at right angles to the anterior aspect of the neck, and extending obliquely downward. It lies in the petrotympanic fissure, and in the adult usually becomes converted into connective tissue, except a small basal stump. The **lateral process** [processus lateralis] is a conical projection from the lateral aspect of the base of the manubrium. Its apex is connected to the upper part of the tympanic membrane, and its base receives the lateral ligament of the malleus. The malleus also gives attachment to a superior and an anterior ligament.

The incus.—This bone is situated between the malleus externally and the stapes internally. It presents for examination a body and two processes. The **body** [corpus incudis] is deeply excavated anteriorly for the reception of the head of the malleus. The **short process** [crus breve] projects backward, and is connected by means of ligamentous fibers to the posterior wall of the tympanum, near the entrance to the tympanic antrum. The **long process** [crus longum] is slender, and directed downward and inward, and lies parallel with the manubrium of the malleus. On the medial aspect of the distal extremity of this process is the **lenticular process** [processus lenticularis] separate in early life, but subsequently joined to the process by a narrow neck. Its free surface articulates with the head of the stapes.

The **stapes** is the innermost ossicle. It has a **head** [capitulum stapedis] directed horizontally outward, capped at its outer extremity by a disk resembling the head of the radius. The cup-shaped depression receives the lenticular process of the incus. The **base** [basis stapedis] occupies the fenestra vestibuli, and like this opening, the inferior border is straight, and the superior curved. The base is connected with the head by means of two **crura** [crus anterius; posterius] and a narrow piece of bone called the neck. Of the two crura, the anterior is the shorter and straighter. The crura with the base form a stirrup-shaped arch, of which the inner margin presents a groove for the reception of the membrane stretched across the hollow of the stapes. In the early embryo this hollow is traversed by the stapedial artery. The **neck** is very short, and receives on its posterior border the tendon of the stapedius muscle.

Development.—For the early development of the auditory tube and tympanic cavity from the first branchial pouch, see p. 19. The auditory ossicles are formed from the upper extremities of the axial skeletons of the first and second branchial arches, the malleus and incus belonging to the first arch and the stapes to the second (Reichert). The ossicles consequently lie originally in the walls of the cavity, but they are surrounded by a loose spongy tissue, which, on the entrance of air into the cavity, becomes compressed, allowing the cavity to enfold the ossicles. These therefore are enclosed within an epithelium which is continuous with that lining the tympanic cavity.

The mastoid cells are outgrowths of the cavity into the adjacent bone, and are therefore lined with an epithelium continuous with that of the cavity.

THE OSSEOUS LABYRINTH

The **osseous labyrinth** [labyrinthus osseus] (figs. 169, 171, 922) is a complex cavity hollowed out of the petrous portion of the temporal bone and containing the membranous labyrinth, parts of the organ of hearing and of equilibration. The osseous labyrinth is incompletely divided into three parts, named the vestibule, the semicircular canals, and the cochlea.

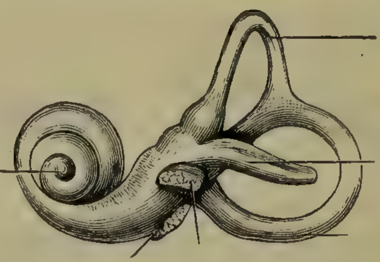


Fig. 171.—The Left Osseous Labyrinth. (After Henle. From a cast.)

The vestibule [vestibulum].—This is an oval chamber situated between the base of the internal acoustic meatus and the medial wall of the tympanic cavity, with which it communicates by way of the fenestra vestibuli. Anteriorly, the vestibule leads into the cochlea, and posteriorly it receives the extremities of the semicircular canals. It measures about 3 mm. transversely, and is somewhat longer anteroposteriorly.

Its medial wall presents at the anterior part a circular depression, the **spherical recess** [recessus sphaericus], which is perforated for the passage of nerve-twigs. This recess is separated by a vertical ridge (the **crista vestibuli**) from the vestibular orifice of the **aqueductus vestibuli**, which passes obliquely backward to open on the posterior surface of the pars petrosa. The roof contains an oval depression—the **elliptical recess** [recessus ellipticus].

The **osseous semicircular canals** [canales semicirculares ossei] are three in number. Arranged in different planes, each forms about two-thirds of a circle. One extremity of each canal is dilated to form an **osseous ampulla** [ampulla ossea].

The **superior canal** [canalis semicircularis superior] lies transversely to the long axis of the petrosal, and is nearly vertical; its highest limb makes a projection on the anterior surface of the bone. The **ampulla** [ampulla ossea superior] is at the lateral end; the medial end opens

into the vestibule conjointly with the superior limb of the posterior canal. The **posterior canal** [canalis semicircularis posterior] is nearly vertical and lies in a plane nearly parallel to the posterior surface of the petrosal. It is the longest of the three; its upper extremity joins the medial limb of the superior canal, and opens in common with it into the vestibule. The lower is the ampullated end [ampulla ossea posterior]. The **lateral canal** [canalis semicircularis lateralis] is placed horizontally and arches laterally; its lateral limb forms a prominence in the tympanic antrum. This canal is the shortest; its ampulla [ampulla ossea lateralis] is at the lateral end near the fenestra vestibuli.

The cochlea.—This is a cone-shaped cavity lying with its **base** [basis cochleæ] upon the internal acoustic meatus, and the apex [cupola cochleæ] directed forward and laterally. It measures about five mm. in length, and the diameter of its base is about the same. The center of this cavity is occupied by a column of bone—the **modiolus**—around which a canal is wound in a spiral manner, making about two and a half turns. This is the **spiral canal of the cochlea** [canalis spiralis cochleæ]; its first turn is the largest and forms a bulging, the **promontory**, on the medial wall of the tympanic cavity. Projecting into the canal throughout its entire length there is a horizontal, shelf-like lamella, the **lamina spiralis ossea,** which terminates at the apex of the cochlea in a hook-like process, the hamulus laminæ spiralis. The free edge of the lamina spiralis gives attachment to the membranous cochlea, a canal having in section the form of a triangle whose base is attached to the lateral wall of the spiral canal. By this the spiral canal is divided into a portion above the lamina spiralis, termed the **scala vestibuli,** which communicates at its lower end with the osseous vestibule, and a portion below, termed the **scala tympani,** which abuts at its lower end upon the fenestra cochleæ. The two scalæ communicate at the apex of the cochlea by the **helicotrema.** Near the commencement of the scala tympani, and close to the fenestra cochleæ, is the cochlear orifice of the **canaliculus cochleæ** (for the ductus perilymphaticus). In the adult this opens below, near the middle of the posterior border of the petrous bone, and transmits a small vein from the cochlea to the jugular fossa.

FIG. 172.—THE COCHLEA IN SAGITTAL SECTION. (After Henle.)

Measurements of the principal parts connected with the auditory organs:—
Internal acoustic meatus: Length of anterior wall, 13–14 mm.; of posterior wall, 6.7 mm.
External acoustic meatus: 14–16 mm. (Gruber.)
Tympanic cavity: Length, 13 mm.; height in center of cavity, 15 mm.; width opposite the membrana tympani, 2 mm.; width opposite the tubal orifice, 3–4 mm. (Von Tröltsch.)
The capsule of the osseous labyrinth is in length 22 mm. (Schwalbe.)
The superior semicircular canal measures along its convexity 20 mm.
The posterior semicircular canal measures along its convexity 22 mm.
The lateral semicircular canal measures along its convexity 15 mm.
The canal is in diameter 1.5 mm. (Huschke.) The ampulla of the canal, 2.5 mm.

Development.—For the origin of the otocyst from the surface ectoderm, see p. 41. The mesodermal tissue which surrounds the otocyst becomes later the petrous portion of the temporal bone, the perilymph and the internal periosteal layer; the osseous labyrinth is therefore merely the portions of the petrous which enclose the cavity occupied by the membranous internal ear.

THE ETHMOID BONE

The **ethmoid** [os ethmoidale] is a bone of delicate texture, situated at the anterior part of the base of the cranium (figs. 173–174). Projecting downward from the ethmoidal notch of the frontal, it enters into the formation of the orbital and nasal fossæ. It is cubical in form, and its extreme lightness and delicacy are due to an arrangement of very thin plates of bone surrounding irregular spaces known as air-cells. The ethmoid consists of four parts: the horizontal or cribriform plate, the ethmoidal labyrinth on each side, and a perpendicular plate.

The **cribriform plate** forms part of the anterior cranial fossa, and is received into the ethmoidal notch of the frontal bone. It presents on its upper surface, in the median plane the **crista galli,** a thick, vertical, triangular process with the highest point in front, and a sloping border behind which gives attachment to the falx cerebri. The anterior border is short and in its lower part broadens out to form two **alar processes** [processus alares] which articulate with the frontal bone and complete the **foramen cæcum.** The crista galli is continuous behind

with a median ridge, and on each side of the midline is a groove which lodges the olfactory bulb.

The cribriform plate is pierced, on each side, by numerous foramina, arranged in two or three rows, which transmit the filaments of the olfactory nerves ascending to the olfactory bulb. Those in the middle of the groove are few and are simple perforations, through which pass the nerves from the roof of the nose; the medial and lateral series are more numerous and constitute the upper ends of small canals, which subdivide as they course downward to the upper parts of the septum and the lateral wall of the nasal fossa. At the front part of the cribriform plate is

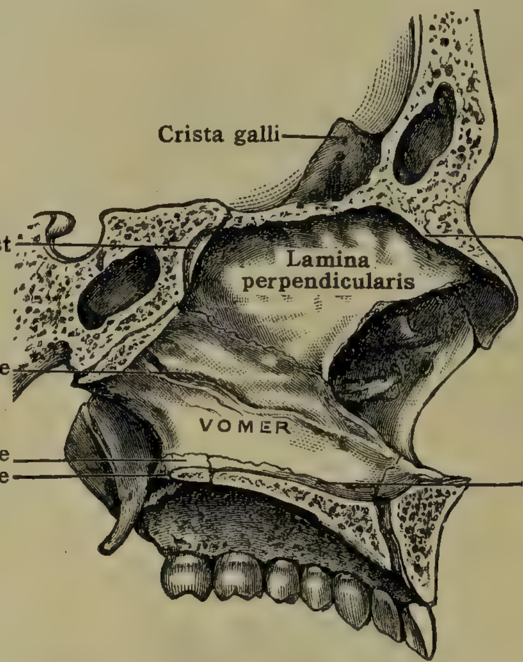


Fig. 173.—Sagittal Section through the Nasal Fossa to Show the Lamina Perpendicularis.

a narrow longitudinal slit, on each side of the crista galli, which transmits the anterior ethmoidal branch of the nasociliary nerve. The posterior border articulates with the body of the sphenoid.

The **perpendicular plate** [lamina perpendicularis] (lamina mediana NK) hangs below the crista galli from the under aspect of the cribiform plate, so that the two plates cross each other at right angles. The perpendicular plate forms the upper third of the septum of the nose, and is quadrangular in form with unequal sides.

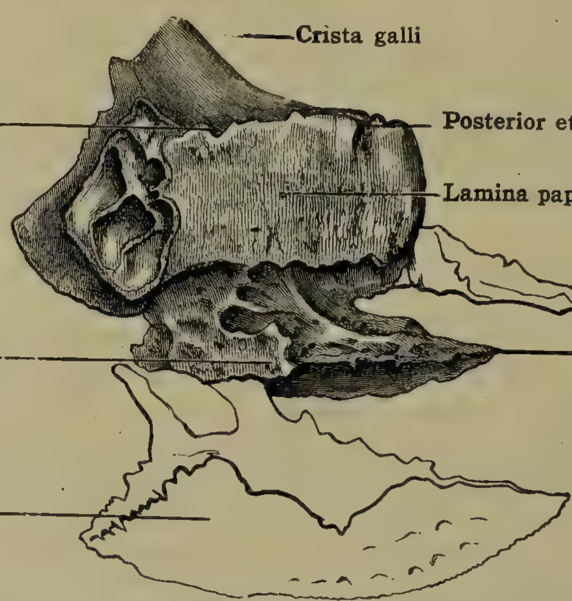


Fig. 174.—The Ethmoid Bone. (Lateral view.)

The **anterior border** articulates with the spine of the frontal and the crests of the nasal bones. The **inferior border** articulates in front with the septal cartilage of the nose and behind with the anterior margin of the vomer. The **posterior border** is very thin and articulates with the sphenoidal crest. This plate, which is generally deflected a little to one side, presents above a number of grooves and minute canals which lead from the inner set of foramina in the cribriform plate and transmit the olfactory nerves from the septum.

The **ethmoidal labyrinth** [labyrinthus ethmoidalis] (lateral mass) is oblong in shape and suspended from the under aspect of the lateral part of the cribriform plate. It includes two scroll-like pieces of bone, the **superior** and **middle nasal conchæ** (turbinate bones), and encloses numerous irregularly shaped air-spaces, known as the **ethmoidal cells.** These are arranged in two main sets—anterior and posterior ethmoidal cells—and, in the recent state, are lined with prolongations of the nasal mucous membrane. Laterally the labyrinth presents a thin, smooth, quadrilateral plate of bone—the **lamina papyracea**—which closes in the ethmoidal cells and forms a large part of the medial wall of the orbit (figs. 136, 174).

By its anterior border the lamina articulates with the lacrimal, and by its posterior border with the sphenoid bone; the inferior border articulates with the medial margin of the orbital plain of the maxilla and the orbital process of the palate bone, whilst the superior border articulates with the orbital part of the frontal. Two notches in the superior border lead into grooves running horizontally across the lateral mass to the cribriform plate, which complete, with the frontal bone, the **ethmoidal canals.** The anterior canal (canalis orbitocranialis NK) transmits the anterior ethmoidal vessels and nerve; the posterior (canalis orbitoethmoidalis NK) transmits the posterior ethmoidal vessels and nerve.

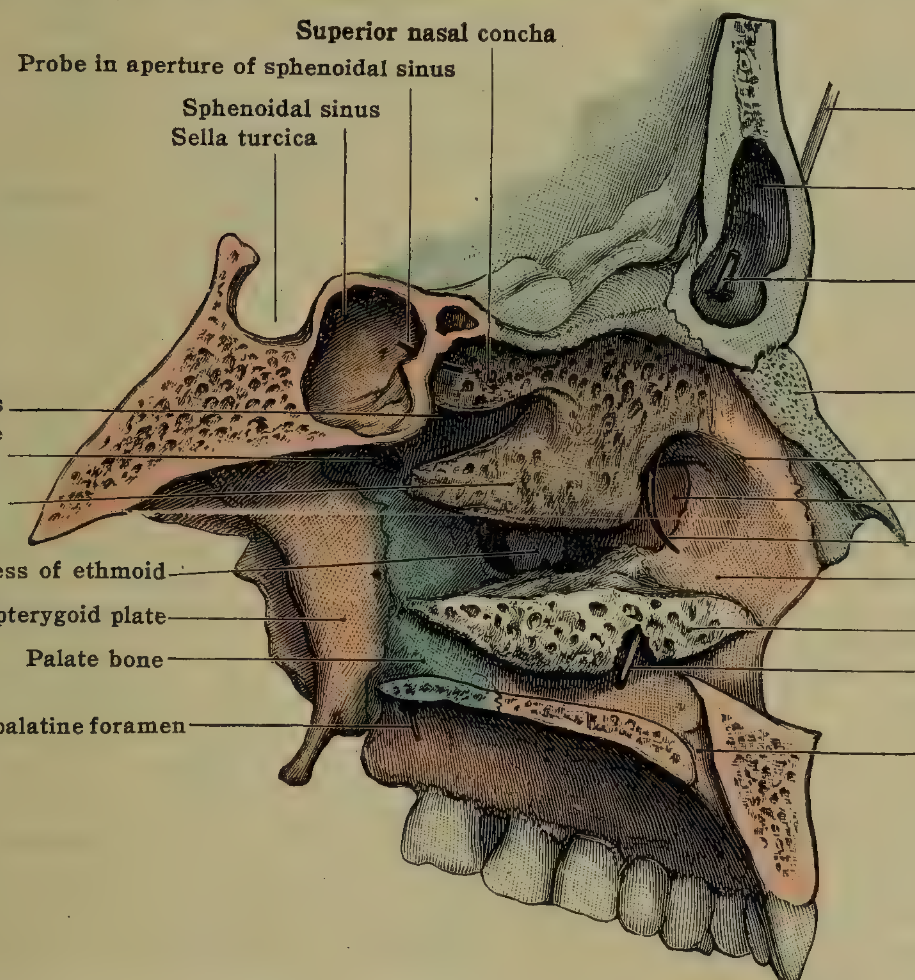


Fig. 175.—Sagittal Section Showing the Ethmoid, and Lateral Wall of the Nasal Fossa.

At the lower part of the lateral surface is a deep groove, which belongs to the middle meatus of the nose, and is bounded below by the thick curved margin of the inferior nasal concha. Anteriorly the middle meatus forms the **ethmoidal infundibulum,** a sinuous passage communicating with the frontal sinus through the anterior part of the labyrinth. The anterior ethmoidal cells in part open into the lower portion of the infundibulum, and in this way communicate with the nasal cavity; through the infundibulum the maxillary sinus opens into the middle meatus by the aperture named hiatus maxillaris. In front of the lamina papyracea are seen a few broken cells, which extend under, and are completed by, the lacrimal bone and the frontal process of the maxilla; from this part of the labyrinth an irregular lamina, known as the **uncinate process,** projects downward and backward. The uncinate process articulates with the ethmoidal process of the inferior nasal concha and forms a small part of the medial wall of the maxillary sinus.

Medially the labyrinth takes part in the formation of the lateral wall of the nasal fossa, and presents the **superior** and **middle nasal conchæ** (turbinate processes; laminæ ethmoturbinales NK), continuous anteriorly, but separated behind by a space directed forward from the posterior margin (fig. 175). This channel is the **superior meatus** of the nose and communicates with the posterior

ethmoidal cells. A supreme nasal concha [concha nasalis suprema] is often present, situated posteriorly above the superior concha.

The conchæ are covered in the recent state with mucous membrane and present numerous foramina for blood-vessels and, above, grooves for twigs of the olfactory nerves. Each concha has an attached upper border and a free, slightly convoluted, lower border, and in the case of the middle concha, the lower margin has already been noticed on the outer aspect, where it overhangs the middle meatus of the nose. The posterior extremity of the labyrinth articulates with the anterior surface of the body of the sphenoid and is commonly united with the sphenoidal concha.

A rounded prominence on the lateral wall of the middle meatus, inclosing an air cell, is known as the **bulla ethmoidalis.** Anteroinferior to the bulla, between it and the uncinate process, is a large semilunar depression, **hiatus semilunaris,** leading from the infundibulum.

Many of the ethmoidal cells are imperfect and are completed by adjacent bones. Those along the superior edge of the labyrinth are the **frontoethmoidal;** those at the anterior border, usually two in number, are known as **lacrimoethmoidal.** Those along the lower edge of the lamina papyracea are the **maxilloethmoidal;** and posteriorly, are the **sphenoethmoidal,** completed by the sphenoidal concha, and a **palatoethmoidal** cell. The anterior extremity presents one or two incomplete cells closed by the nasal process of the maxilla. For further details concerning the ethmoidal cells, see p. 1308.

Blood-supply.—The ethmoid receives its **blood-supply** from the anterior and posterior ethmoidal arteries and from the sphenopalatine branch of the internal maxillary.

Articulations.—With the frontal, sphenoid, two palate bones, two nasals, vomer, two inferior nasal conchæ, two sphenoidal conchæ, two maxillæ, and two lacrimal bones. The posterior surface of each labyrinth is in relation with the sphenoid on each side of the crest and rostrum, and helps to close in the aperture of the sphenoidal sinus.

Ossification.—The ethmoid has three centers of ossification. Of these, a nucleus appears in the fourth month of intrauterine life in each labyrinth, first in the lamina papyracea and afterward extending into the middle concha. At birth each lateral portion is represented by two scroll-like bones, very delicate and covered with irregular depressions, which give it a worm-eaten appearance. Six months after birth a nucleus appears in the ethmovomerine cartilage for the vertical plate which gradually extends into the crista galli, and the cribriform plate is formed by ossification extending laterally from this center, and medially from the labyrinth. The three parts coalesce to form one piece in the fifth or sixth year.

The ethmoidal cells arise before birth and become more prominent about the third year, gradually invading the labyrinths. In many places there is so much absorption of bone that the cells perforate the ethmoid. Along the lower border, near its articulation with the maxilla the absorption leads to the partial detachment of a narrow strip known as the uncinate process. Sometimes a second but smaller hook-like process is formed, above and anterior to this, so fragile that it is difficult to preserve it in disarticulated bones. The relations of the uncinate process are best studied by removing the lateral wall of the maxillary sinus.

Variations.—Secondary foramina of the lamina papyracea are not infrequent in the aged. Reduction of this plate is met with where either the maxilla or the frontal or both send processes to participate in forming the medial wall of the orbit. Increase in the number of conchæ is not uncommon.

THE INFERIOR NASAL CONCHA

The **inferior nasal concha** (inferior turbinate; os maxilloturbinale NK) (fig. 176) is a slender, scroll-like lamina, attached by its upper margin to the lateral wall of the nasal fossa, and hanging into the cavity in such a way as to separate the middle from the inferior meatus of the nose. It presents two surfaces, two borders, and two extremities.

The **lateral surface** is concave, looks toward the lateral wall of the nasal fossa, and is over hung by the **maxillary process** [processus maxillaris]. The **medial surface** is convex, pitted with depressions, and grooved for vessels, which, for the most part, run longitudinally. The **superior or attached border** articulates in front with the conchal crest of the maxilla, then ascends to form the **lacrimal process** [processus lacrimalis], which articulates with the lacrimal bone and forms part of the wall of the lacrimal canal. Behind this, it is turned downward to form the maxillary process, already mentioned, which overhangs the orifice of the maxillary sinus and serves to fix the bone firmly to the lateral wall of the nasal fossa. The projection above and behind the maxillary process is the **ethmoidal process** [processus ethmoidalis], joined in the articulated skull with the uncinate process of the ethmoid across the opening of the maxillary sinus. Posteriorly the upper border articulates with the conchal crest of the palate. The **inferior border** is free, rounded, and somewhat thickened. The **anterior extremity** is blunt and flattened, and broader than the **posterior extremity,** which is elongated, narrow, and pointed.

Articulations.—With the maxilla, lacrimal, palate, and ethmoid.

Ossification.—The inferior nasal concha is ossified in cartilage from a single nucleus which appears in the fifth month of intrauterine life. At birth it is a relatively large bone and fills up the lower part of the nasal fossa.

Variation.—A more or less prominent line, running the length of the medial surface, may be elevated to form a ridge or give rise to an additional scroll. It is probable that this is a persistence of the maxilloturbinal of the chondrocranium, from the base of which the inferior concha is derived.

THE LACRIMAL BONE

The **lacrimal bone** [os lacrimale] (figs. 136, 176) is extremely thin and delicate, quadrilateral in shape, and situated at the anterior part of the medial wall of the orbit. It is the smallest of the facial bones.

The **orbital surface** is divided by a vertical ridge, the **posterior lacrimal crest,** into two unequal portions. The anterior, smaller portion is deeply grooved to form the **lacrimal groove** [sulcus lacrimalis], which lodges the lacrimal sac and forms the commencement of the canal for the nasolacrimal duct. The portion behind the ridge is smooth, and forms part of the medial wall of the orbit. The ridge gives origin to the orbicularis oculi (pars lacrimalis) muscle and ends below in a hook-like process, the **lacrimal hamulus** [hamulus lacrimalis], which curves forward to articulate with the orbital surface of the maxilla and completes the superior orifice of the nasolacrimal canal. The **medial surface** is in relation with the two anterior cells of the ethmoid (lacrimoethmoidal), forms part of the infundibulum, and inferiorly looks into the middle meatus of the nose.

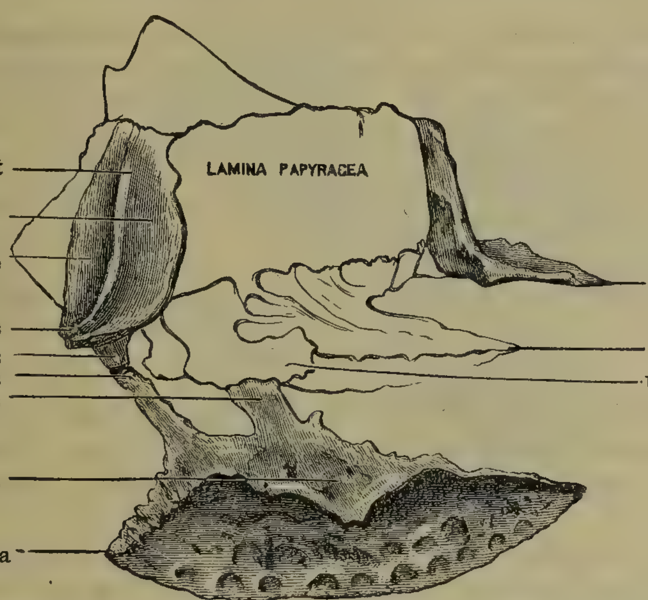


Fig. 176.—The Inferior Nasal Concha, Sphenoidal Concha and Lacrimal Bone (Lateral view.)

The **superior border** is short, and articulates with the orbital part of the frontal (frontolacrimal suture). The **inferior border** posterior to the crest joins the medial edge of the orbital plate of the maxilla (lacrimomaxillary suture). The narrow piece, anterior to the ridge, is prolonged downward as the **conchal process** to join the lacrimal process of the inferior nasal concha (lacrimoconchal suture). The **anterior border** articulates with the posterior border of the frontal process of the maxilla and the **posterior border** with the lamina papyracea of the ethmoid.

The vessels of the lacrimal bone are derived from the infraorbital, dorsal nasal branch of the ophthalmic, and anterior ethmoidal arteries.

Articulations.—The lacrimal articulates with the ethmoid, maxilla, frontal, and inferior nasal concha.

Ossification.—This bone arises in the membrane overlying the cartilage of the frontonasal plate, and in its mode of ossification is very variable. As a rule, it is formed from a single nucleus which appears in the third or fourth month of intrauterine life.

Variations.—Division into two or more parts; fusion with neighboring bones; absence and extensive development of the hamulus to project out of the orbit are the chief variations of the lacrimal.

The lacrimal hamulus is regarded as representing the remains of the facial part of the lacrimal bone seen in lower animals.

THE VOMER

The **vomer** (figs. 173, 177) (ploughshare bone) is an unpaired flat bone, which lies in the median plane and forms the lower part of the nasal septum. It is thin and irregularly quadrilateral in form, and is usually bent somewhat to one side, though the deflection rarely involves the posterior margin. Each **lateral surface** is covered in the recent state by the nasal mucous membrane, and is traversed by a narrow but well-marked groove, which lodges the nasopalatine nerve.

The **superior border,** by far the thickest part of the bone, is expanded laterally into the two alæ. The groove between them receives the rostrum of the sphenoid, and the margin of each ala comes into contact with the sphenoidal process of the palate and the vaginal process of the medial pterygoid plate. The **inferior border** is uneven and lies in the groove formed by the

crests of the maxillary and palate bones of the two sides. The **anterior border** slopes downward and forward and is grooved below for the septal cartilage of the nose; above it is united with the perpendicular plate of the ethmoid. The **posterior border**, smooth, rounded, and covered by mucus membrane, separates the choanæ (posterior nares). The anterior and inferior borders meet at the anterior extremity of the bone which forms a short vertical ridge behind the anterior prominence of the nasal crest of the maxillæ. From near the anterior extremity, a small projection passes downward between the incisive foramina.

Blood-supply.—The arterial supply of the vomer is derived from the anterior and posterior ethmoidal and the sphenopalatine arteries. Branches are also derived from the greater palatine through the foramen incisivum.

FIG. 177.—THE VOMER. (Side view.)

Ossification.—The vomer is ossified from two bilaterally located centers which appear about the eighth week in the membrane investing the ethmovomerine cartilage. The two lamellæ formed from them, unite below during the third month and form a shallow bony trough in which the cartilage lies. In the process of growth the lamellæ extend upward and gradually fuse to form a rectangular plate of bone, the cartilage enclosed between them undergoing absorption at the same time. The alæ on the superior margin and the groove in front are evidence of the original bilaminar condition. However, a bilateral origin of the vomer is not the general rule among mammals.

Variation.—The inferior margin of the vomer has been observed in the intermaxillary suture participating with the palatal processes in the formation of the hard palate.

THE NASAL BONES

The **nasal bones** (figs. 178, 179) are two small oblong bones situated at the upper part of the face and forming the bridge of the nose. Each bone is thicker and narrower above, thinner and broader below, and presents two surfaces and four margins.

The **facial surface** is concave from above downward, convex from side to side, and near the center is perforated by one or two small **nasal foramina** [foramina nasalia], which transmit tributaries to the anterior facial vein. The posterior or **nasal surface**, covered in the recent state by mucous membrane, is concave laterally, and traversed by a longitudinal **ethmoidal groove** [sulcus ethmoidalis] for the external nasal branch of the anterior ethmoidal nerve.

The short **superior border** is thick and serrated for articulation with the medial part of the nasal notch of the frontal (nasofrontal suture). The **inferior border** is thin, and serves for the attachment of the lateral nasal cartilage. It is notched for the external nasal branch of the anterior ethmoidal nerve. The nasal bones of the two sides are united by their **medial borders**, forming the internasal suture. The contiguous borders are prolonged backward to form a crest which rests on the frontal spine and the anterior border of the perpendicular plate of the ethmoid. The **lateral border** articulates with the frontal process of the maxilla (nasomaxillary suture).

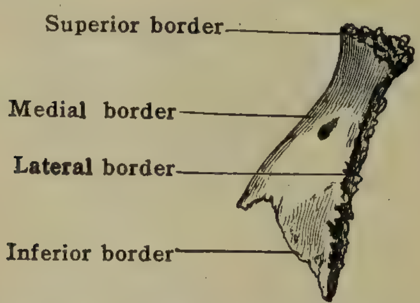


FIG. 178.—THE LEFT NASAL BONE, FACIAL SURFACE.

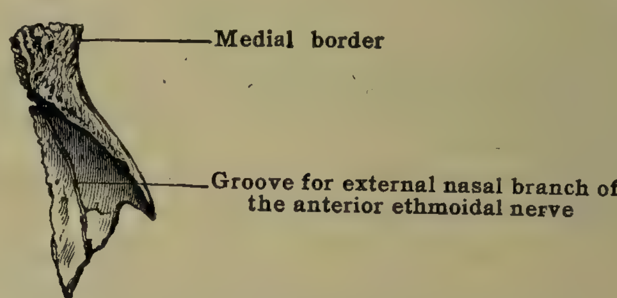


FIG. 179.—THE LEFT NASAL BONE NASAL SURFACE.

Blood-supply.—Arteries are supplied to this bone by the nasal branch of the ophthalmic, the frontal, the angular, and the anterior ethmoidal arteries.

Articulations.—With the frontal, maxilla, ethmoid, and its fellow of the opposite side.

Ossification.—Each nasal bone is developed from a single center which appears about the eighth week in the membrane overlying the frontonasal cartilage. The cartilage, which is continuous with the ethmoid cartilage above and the lateral cartilage of the nose below, subsequently undergoes absorption. At birth the nasal bones are nearly as wide as they are long, whereas in the adult the length is three times greater than the width.

Variations.—Reduction of the nasal bones with concavity of the lateral margins and accompanied by expansion of the frontal process of the maxilla is not uncommon. Rarely the nasal bones are absent.

THE MAXILLA

The **maxilla** or upper jaw-bone (figs. 180–184) is one of the largest and most important of the bones of the face. It supports the upper teeth and takes part in the formation of the orbit, the hard palate, and the nasal fossa. It is divisible into a **body** and four processes, of which two—the **frontal** and **zygomatic**—belong to the upper part, and the **palatine** amd **alveolar** to the lower part of the bone.

The **body of the maxilla** [corpus maxillæ] is somewhat pyramidal in shape and hollowed by a large cavity known as the **sinus maxillaris** (antrum of Highmore), lined by mucous membrane in the recent state, and opening at the base of the

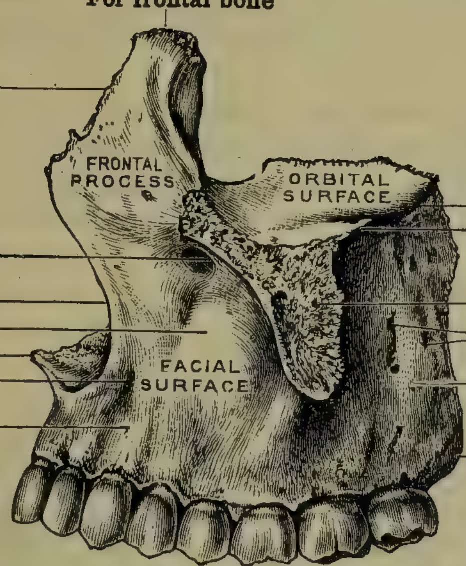


Fig. 180.—The Left Maxilla. (Lateral view.)

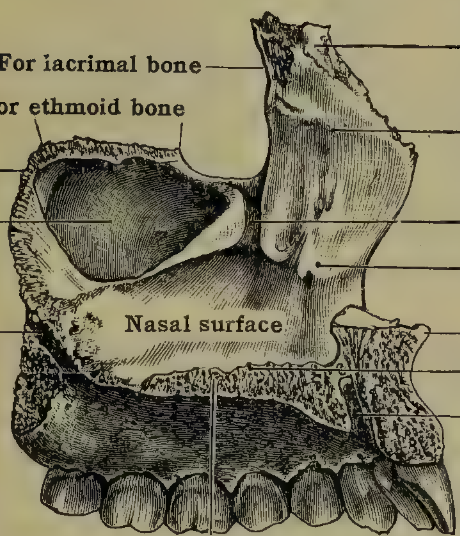


Fig. 181.—The Left Maxilla. (Medial view.)

pyramid into the nasal cavity, the zygomatic process forming the apex. The **anterior** or (facial) **surface** looks forward and laterally. The eminence produced by the fang of the canine tooth is very prominent and together with the prominence of the lateral incisor gives origin to the alar portion of the nasalis muscle. On the lateral side of the canine eminence is the **canine fossa,** from which the caninus muscle arises. Above the canine fossa, and close to the margin of the orbit, is the **infraorbital foramen,** through which the terminal branches of the infraorbital nerve and vessels emerge; and from the ridge immediately above the foramen the infraorbital head of the quadratus labii superioris muscle takes origin. The medial margin of the anterior surface is deeply concave, forming the **nasal notch,** the lateral boundary of the **piriform aperture** (fig. 129), and is prolonged below into the **anterior nasal spine.**

A ridge of bone extending upward from the socket of the first molar tooth separates the anterior from the **infratemporal** (zygomatic) **surface** [facies infratemporalis]. This latter surface is convex and presents near the middle the orifices of the **alveolar canals,** transmitting the posterior superior alveolar vessels and nerves. The posterior inferior angle, known as the **tuberosity of the maxilla** [tuber maxillare], is rough and is most prominent after eruption of the wisdom tooth. It gives origin to a few fibers of the internal pterygoid muscle and articulates with the pyramidal process of the palate bone.

The **orbital surface** [facies orbitalis] is smooth, irregularly triangular, and forms the greater part of the floor of the orbit [planum orbitale].

Anteriorly, it is rounded and reaches the orbital circumference for a short distance at the root of the frontal process (infraorbital margin); laterally is the rough surface for the zygomatic bone. The posterior border, smooth and rounded, forms the inferior boundary of the inferior orbital fissure. The medial border is nearly straight and presents, behind the frontal process, a smooth rounded angle forming part of the circumference of the orbital orifice of the nasolacrimal canal, and a notch [incisura lacrimalis] which receives the lacrimal bone (lacrimomaxillary suture). The rest of the medial border is rough for articulation with the lamina papyracea of the ethmoid (ethmoideomaxillary suture) and the orbital process of the palate bone.

The orbital surface is traversed by the **infraorbital groove** [sulcus infraorbitalis], which, commencing at the posterior border, deepens as it passes forward and finally becomes closed in to form the **infraorbital canal.** It transmits the infraorbital nerve and vessels and terminates on the anterior surface in the infraorbital foramen. From the infraorbital, other canals—the **anterior** and **middle alveolar**—run downward in the wall of the antrum and transmit the anterior superior alveolar vessels and the anterior and middle superior alveolar nerves. Lateral to the commencement of the lacrimal canal is in some cases a shallow depression for the origin of the inferior oblique muscle of the eye.

The **nasal surface** [facies nasalis] takes part in the formation of the lateral wall of the nasal fossa. It presents a large irregular aperture the **hiatus maxillaris** which leads into the maxillary sinus and, immediately in front of this, the **lacrimal groove** [sulcus lacrimalis], directed downward, backward, and laterally into the inferior meatus of the nose. The groove is converted into the **nasolacrimal canal** [canalis nasolacrimalis] by the lacrimal and inferior nasal concha and transmits the nasolacrimal duct.

In front of the groove is a smooth surface crossed obliquely by a ridge, the **conchal crest** [crista conchalis], for articulation with the inferior nasal concha. The surface below the crest is smooth, concave, and belongs to the inferior meatus; the surface above the crest extends on to the lower part of the frontal process and forms the wall of the atrium of the middle meatus. Behind the opening of the maxillary sinus the surface is rough for articulation with the perpendicular part of the palate bone and crossing it obliquely is a smooth groove, the pterygopalatine sulcus [sulcus pterygopalatinus], converted by a corresponding groove on the palate into the **pterygopalatine canal** for the passage of the (descending) palatine nerves and the descending palatine artery.

The **frontal process** [processus frontalis], somewhat triangular in shape, rises vertically from the body of the maxilla. Its lateral surface is continuous with the anterior surface of the body, and gives attachment to the orbicularis oculi, the medial palpebral ligament and the quadratus labii superioris (caput angulare). The medial surface forms part of the lateral boundary of the nasal fossa and is crossed obliquely by the low ethmoidal crest [crista ethmoidalis], which supports the middle nasal concha anteriorly.

The hinder part of this surface rests on the anterior extremity of the labyrinth of the ethmoid and completes the maxilloethmoidal cells. The superior border articulates with the frontal; the anterior border articulates with the nasal bone; the posterior border is thick and vertically grooved, in continuation with the **lacrimal groove,** and lodges the lacrimal sac. The medial margin of the groove articulates with the lacrimal bone, and the junction of its lateral margin with the orbital surface is indicated by the **anterior lacrimal crest** [crista lacrimalis anterior].

The **zygomatic process,** rough and triangular, forms the summit of the prominent ridge of bone separating the anterior and infratemporal surfaces. It articulates above with the zygomatic bone, and from its inferior angle a few fibers of the masseter muscle take origin. The anterior and posterior surfaces are continuous with the anterior and infratemporal surfaces of the body.

The **palatine process** projects horizontally from the medial surface and with the corresponding process of the opposite side, forms about three-fourths of the

hard palate. The superior surface is smooth, concave from side to side, and constitutes the larger part of the floor of the nasal fossa. The inferior surface is vaulted, rough, and perforated with foramina for nutrient vessels. Near its lateral margin are longitudinal **palatine grooves** [sulci palatinæ] separated by **palatine spines** [spinæ palatinæ] adapted to the palatine vessels and nerves which issue at the palatine foramina and course along the lower aspect of the palate.

When the bones of the two sides are placed in apposition, a large orifice may be seen in the middle line immediately behind the incisor teeth. This is the **incisive foramen,** at the bottom of which is the lower aperture of the **incisive canals** leading from the floor of the nose; they transmit some terminal branches of the greater palatine artery to the nasal fossæ, and may contain remnants of the nasal mucous membrane.

Running laterally from the incisive foramen to the space between the second incisor and canine tooth, an indistinct suture may sometimes be seen, indicating the line of junction of the maxillary and premaxillary portions of the bone. The **incisive bone** [os incisivum] is the part which bears the incisor teeth and in some animals exists throughout life as an independent element. The posterior border of the palate process is rough and serrated for articulation with the horizontal part of the palate bone (transverse palatine suture) which completes the hard palate. The medial border joins with its fellow (in the median palatine suture) to form the **nasal crest** [crista nasalis] upon which the vomer is received. The elevated anterior portion of this crest is continued forward into the **anterior nasal spine.** The septal cartilage of the nose rests on its summit and the anterior extremity of the vomer lies immediately behind it. At the side of the incisor crest is seen the upper aperture of a canal leading from the nose to the mouth, which in its course downward becomes a groove by a deficiency of its medial wall. Thus when the two bones are articulated the incisive canal is formed, communicating above with the nasal fossa on either side.

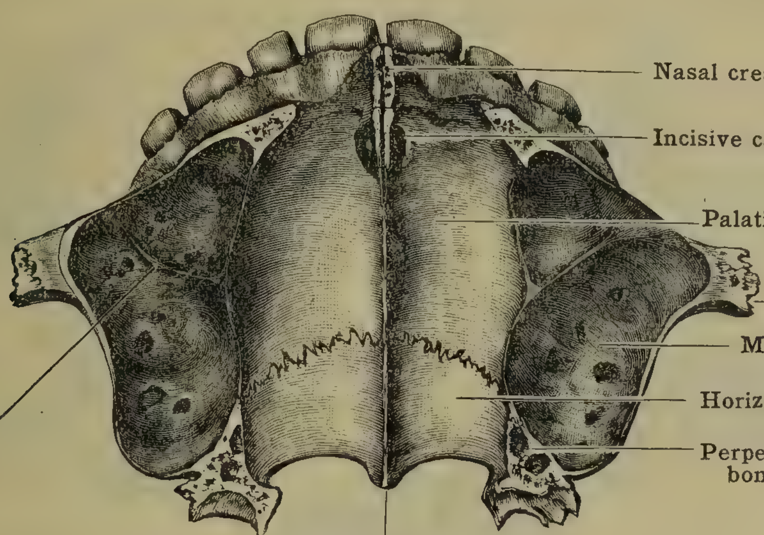


Fig. 182.—Transverse Section of Maxillæ to Show the Floor of the Maxillary Sinuses. (Reduced ¼.)

The **alveolar process** is crescentic in shape, spongy in texture, and presents cavities in which the upper teeth are lodged. When complete there are eight sockets (alveoli), with wide mouths, gradually narrowing as they pass into the substance of the bone, and forming exact impressions of the corresponding roots of the teeth. The pit for the canine tooth is the deepest; those for the molars are the widest and subdivided. Along the lateral aspect of the alveolar process the buccinator muscle arises as far forward as the first molar tooth.

To the free inferior margin the name **limbus alveolaris** is given, and to the partitions between the alveoli, the term **septa interalveolaria** is applied. Corresponding to the alveoli of the five anterior teeth are **juga alveolaria** upon the external aspect of the alveolar process. The alveolar processes of the two sides meet in the **intermaxillary suture.**

The **maxillary sinus** or antrum of Highmore (figs. 181, 182), the air-chamber occupying the body of the bone, is somewhat pyramidal in shape, the **base** being represented by the nasal or medial surface, and the **apex** corresponding to the zygomatic process. In addition it has four walls: the superior is formed by the orbital plate, and the inferior by the alveolar ridge. The anterior wall corresponds to the anterior surface of the maxilla, and the posterior is formed by the infratemporal surface. The medial boundary or base presents a very irregular orifice, hiatus maxillaris, at its posterior part; this is partially filled in by the perpendicular plate of the palate bone, the uncinate process of the ethmoid, the

maxillary process of the inferior nasal concha, and a small portion of the lacrimal bone. Even when these bones are in their relative positions, the orifice is very irregular in shape, and requires the mucous membrane to form the definite rounded aperture (or apertures, for they are often multiple) known as the **opening of the sinus** through which the cavity communicates with the middle meatus of the nose.

The cavity of the sinus varies considerably in size and shape. In the young, it is small and the walls are thick; as life advances it enlarges at the expense of its walls (in old age they are often extremely thin), so that occasionally the cavity extends even into the substance of the zygomatic bone. The floor of the sinus is usually very uneven, due to prominences cor-

FIG. 183.—THE MAXILLA AT BIRTH.

responding to the roots of the molar teeth. In most cases the bone separating the teeth from the sinus is very thin, and occasionally the roots project into it. The teeth which come into closest relationship with the sinus are the first and second molars, but the sockets of any of the teeth lodged in the maxilla may, under diseased conditions, communicate with it. As a rule, the cavity of the sinus is single, but occasionally specimens are seen in which it is divided by bony septa into chambers, and it is not uncommon to find recesses separated by bony processes. The roof of the sinus presents near its anterior aspect what appears to be a thick rib of bone; this is hollow and corresponds to the infraorbital canal. For further details, see p. 1306.

Blood-supply.—The maxilla is a very vascular bone and its arteries are numerous and large. They are derived from the infraorbital, alveolar, descending palatine, sphenopalatine, ethmoidal, frontal, nasal, and external maxillary vessels.

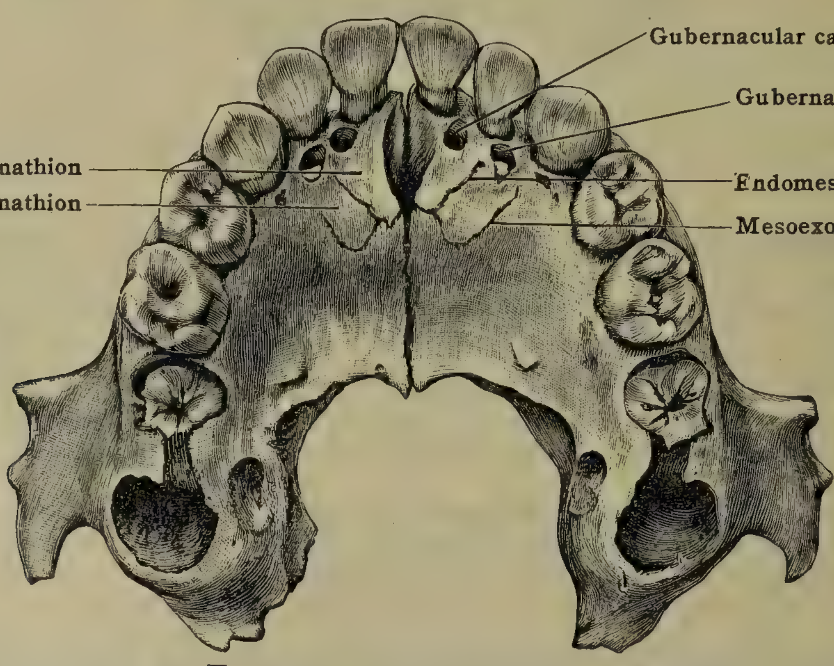


FIG. 184.—MAXILLÆ AT THE END OF THE FIRST DENTITION SHOWING THE SUTURES BETWEEN MAXILLA AND INCISIVE BONE AND THE TWO PARTS OF THE INCISIVE BONE.

Articulations.—With the frontal, nasal, lacrimal, ethmoid, palate, vomer, zygomatic, inferior nasal concha and its fellow of the opposite side. Occasionally it articulates with the great wing, and the pterygoid process, of the sphenoid.

Ossification.—The maxilla is developed from several centers which are deposited in membrane during the second month of intrauterine life. Several pieces are formed which speedily fuse, so that at birth, with the exception of the incisive fissure separating the maxilla from the incisive bone, there is no trace of the composite character of the bone. The centers of ossifica-

tion comprise—(1) the **malar,** which gives rise to the portion of bone outside the infraorbital canal; (2) the **maxillary,** from which the greater part of the body and the frontal process is developed; (3) the **palatine,** forming the hinder three-fourths of the palatal process and adjoining part of the nasal wall; (4) the **premaxillary,** giving rise to the independent os incisivum, which lodges the incisor teeth and completes the anterior fourth of the hard palate; (5) the **prepalatine,** corresponding to the **infravomerine** center of Rambaud and Renault, forms a portion of bone interposed between the premaxillary in front and the palatine process behind. It gives rise to a part of the nasal surface and completes the medial wall of the incisive canal.

At birth the maxillary sinus is narrow from side to side and does not extend laterally to any appreciable extent between the orbit and the alveoli of the teeth. During the early years of life it gradually enlarges, but does not attain its full growth until after the period of the second dentition. For further description of the maxillary sinus, see Respiratory System.

Variations.—The walls of the infraorbital canal may be incomplete toward the maxillary sinus, putting the nerve into direct contact with the lining mucosa. The infraorbital foramen may be double. Cleft palate is apparently due to non-union of the embryonic palatine shelves (p. 42). The cleft which occurs to one side of the midline, falls through the incisive bone and germ of the lateral incisor tooth and not as a rule in the plane of the suture between the incisive and maxillary bones.

THE PALATE BONE

The **palate bone** [os palatinum] (figs. 185, 186) forms the posterior part of the hard palate, the lateral wall of the nasal fossa between the maxilla and the

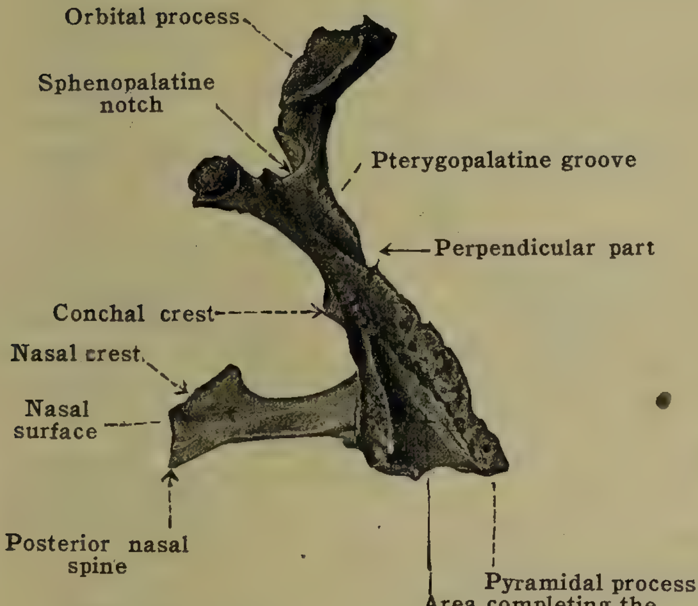


FIG. 185.—RIGHT PALATE BONE. (Posterior view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

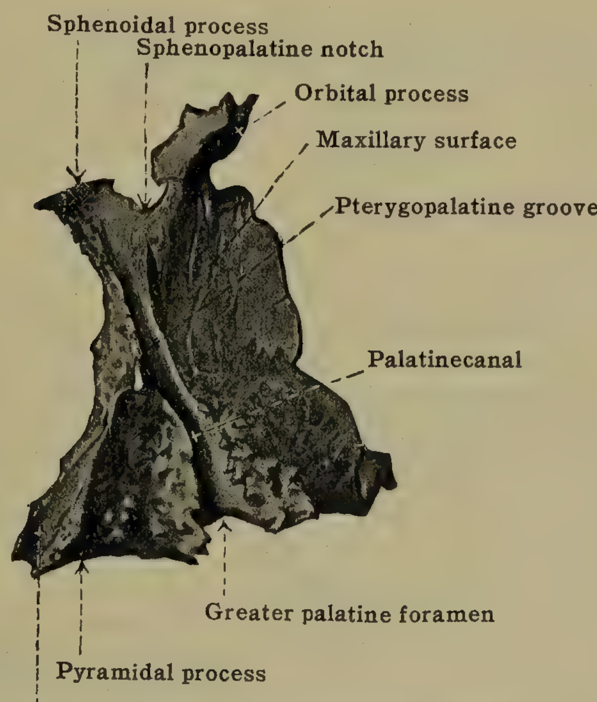


FIG. 186.—RIGHT PALATE BONE. (Lateral view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

medial pterygoid plate, and, by its orbital process, the hinder part of the floor of the orbit. It is somewhat L-shaped and presents for examination a **horizontal part** and a **perpendicular part**; at their place of junction is the **pyramidal process,** and surmounting the top of the vertical plate are the **orbital** and **sphenoidal processes,** separated by the **sphenopalatine notch.**

The **horizontal part** resembles the palatine process of the maxilla, but is much shorter. The superior **nasal surface** [facies nasalis] is smooth, concave from side to side, and forms the back part of the floor of the nasal fossa; the inferior **palatine surface** [facies palatina] completes the hard palate behind and presents near its posterior border a transverse ridge which gives attachment to the tensor veli palatini muscle.

The anterior border is rough for articulation with the palatine process of the maxilla; the posterior is free curved, and sharp, giving attachment to the soft palate. Medially it is thick and broad for articulation with its fellow of the opposite side, forming a continuation of the **nasal crest** of the palatal processes of the maxillæ and supporting the vomer. The posterior extremity of the crest is the **posterior nasal spine,** from which the muscle of the uvula arises. Laterally, at its junction with the perpendicular part, it is grooved by the pterygopalatine canal.

The **perpendicular part** is longer and thinner than the horizontal part. The lateral or **maxillary surface** [facies maxillaris] is in relation with the maxilla and is divided into two parts by a vertical groove, the **pterygopalatine sulcus** [sulcus pterygopalatinus] which forms with the corresponding groove in the maxilla the **pterygopalatine canal** for the transmission of the palatine nerve and the descending palatine artery. The part of the surface in front of the groove articulates with the nasal surface of the maxilla and overlaps the orifice of the antrum by the **maxillary process**, a variable projection on the anterior border. Behind the groove the surface is rough for articulation with the maxilla below and the medial pterygoid plate above.

The medial or **nasal surface** [facies nasalis] presents two nearly horizontal ridges separating three shallow depressions. Of the depressions, the lower forms part of the inferior meatus of the nose, and the limiting ridge or **conchal** (inferior turbinate) **crest** [crista conchalis] articulates with the inferior nasal concha. Above this is the depression forming part of the middle meatus, and the ridge or **ethmoidal** (superior turbinate) **crest** [crista ethmoidalis], constituting its upper boundary, articulates with the middle nasal concha.

The upper groove is narrower and deeper than the other two and forms a large part of the superior meatus of the nose. The anterior border of the vertical plate is thin and bears the **maxillary process**, a tongue-like piece of bone, which extends over the opening of the maxillary sinus from behind. This border is continuous above with the orbital process. The posterior border is rough and articulates with the anterior border of the medial pterygoid plate. It is continuous superiorly with the sphenoidal process.

The **pyramidal process** [processus pyramidalis] or tuberosity fits into the notch between the lower extremities of the pterygoid plates and presents posteriorly three grooves. The middle, smooth and concave, completes the pterygoid fossa, and gives origin to a few fibers of the internal pterygoid muscle; the medial and lateral grooves are rough for articulation with the anterior border of the corresponding pterygoid plate. Inferiorly, close to its junction with the horizontal plate, are the **greater palatine foramen** and **smaller palatine foramina**; the openings of **palatine canals**; they transmit the palatine nerves. Medially the pyramidal process gives origin to a few fibers of the superior constrictor of the pharynx, and laterally a small part appears in the infratemporal fossa between the tuberosity of the maxilla and the pterygoid process of the sphenoid.

The **sphenoidal process** [processus sphenoidalis], the smaller of the two processes surmounting the perpendicular part, curves upward and medially and presents three surfaces and two borders. The **superior surface** is in contact with the body of the sphenoid, and the top of the medial pterygoid plate, where it completes the **pharyngeal canal.** The **medial** or **inferior surface** forms part of the lateral wall and roof of the nasal fossa, and at its medial end touches the ala of the vomer. The **lateral surface** looks forward and laterally into the pterygopalatine (spheno-maxillary) fossa. Of the two borders, the posterior is thin and articulates with the pterygoid plate; the anterior border forms the posterior boundary of the **sphenopalatine foramen.**

The **orbital process** [processus orbitalis] is somewhat pyramidal in shape, and presents for examination five surfaces, three of which—the posterior, anterior, and medial—are articular and the rest non-articular. The **posterior** or **sphenoidal surface** is small and joins the anterior surface of the body of the sphenoid; the **medial** or **ethmoidal** articulates with the labyrinth of the ethmoid; and the **anterior** or **maxillary**, which is continuous with the lateral surface of the perpendicular part, is joined with the maxilla. Of the two non-articular surfaces, the **superior** or **orbital,** directed upward and laterally, is slightly concave, and forms the posterior angle of the floor of the orbit; the **lateral** or **zygomatic,** smooth and directed laterally looks into the pterygopalatine and infratemporal fossæ, and forms the anterior boundary of the spheno-palatine foramen. The process is usually hollow and the cavity completes one of the posterior ethmoidal cells or communicates with the sphenoidal sinus.

Between the orbital and sphenoidal processes is the **sphenopalatine notch** [incisura spheno-palatina], converted by the body of the sphenoid, into a complete foramen. It leads from the pterygopalatine fossa into the back part of the nasal cavity close to its roof, and transmits the medial branches from the sphenopalatine ganglion and the sphenopalatine vessels.

Blood-supply.—The palate bone receives branches from the descending palatine and the sphenopalatine arteries.

Articulations.—With the sphenoid, maxilla, vomer, inferior nasal concha, ethmoid, and its fellow of the opposite side.

Ossification.—The palate is ossified in membrane from a single center which appears about the eighth week at the angle between the horizontal and perpendicular parts. At birth the two parts are nearly equal in length, but as the nasal fossæ increase in vertical depth, the perpendicular part is lengthened until it becomes about twice as long as the horizontal part.

Variations.—Conversion of the sphenopalatine notch into a foramen is rather frequent. Variation in the size of the orbital process is often observed; by enlargement it may reach the frontal bone in the medial wall of the orbit. The air-cell of this process may communicate with one of the posterior ethmoidal cells. The horizontal plate may be invaded by the maxillary sinus.

THE ZYGOMATIC BONE

The **zygomatic** or **malar bone** (fig. 187) forms the prominence of the cheek and joins the zygomatic process of the temporal with the maxilla. It is quad-

rangular in form with the angles directed vertically and horizontally. The **malar** (or external) **surface** is convex and presents one or two small orifices, zygomaticofacial formina, for the transmission of the zygomaticofacial nerves and vessels. It is largely covered by the orbicularis oculi muscle and near the middle is slightly elevated to form the **malar tuberosity,** which gives origin to the zygomaticus and zygomatic head of the quadratus labii superioris muscle.

The **temporal** (or internal) **surface** [facies temporalis] is concave and looks into the temporal and infratemporal fossæ; it is excluded from the orbit by a prominent curved plate of bone, the **orbital process,** which forms the anterior boundary of the temporal fossa. The upper part gives origin to a few fibers of the temporal muscle, while at the lower part is a large rough area for articulation with the zygomatic process of the maxilla. On this surface is the **zygomaticotemporal foramen,** for the zygomaticotemporal nerve.

The **orbital process** is placed at right angles to the remaining part of the bone and presents surfaces toward the temporal fossa and toward the orbit. The **orbital surface** [facies orbitalis] enters into the formation of the lateral orbital wall; on it are seen the foramina of two **zygomaticoorbital canals,** which transmit the zygomaticofacial and zygomaticotemporal branches of the zygomatic nerve, together with two small branches from the lacrimal artery. In some cases, however, the canal is single at its commencement on the orbital surface and bifurcates as it traverses the bone. The rough free edge of the process articulates

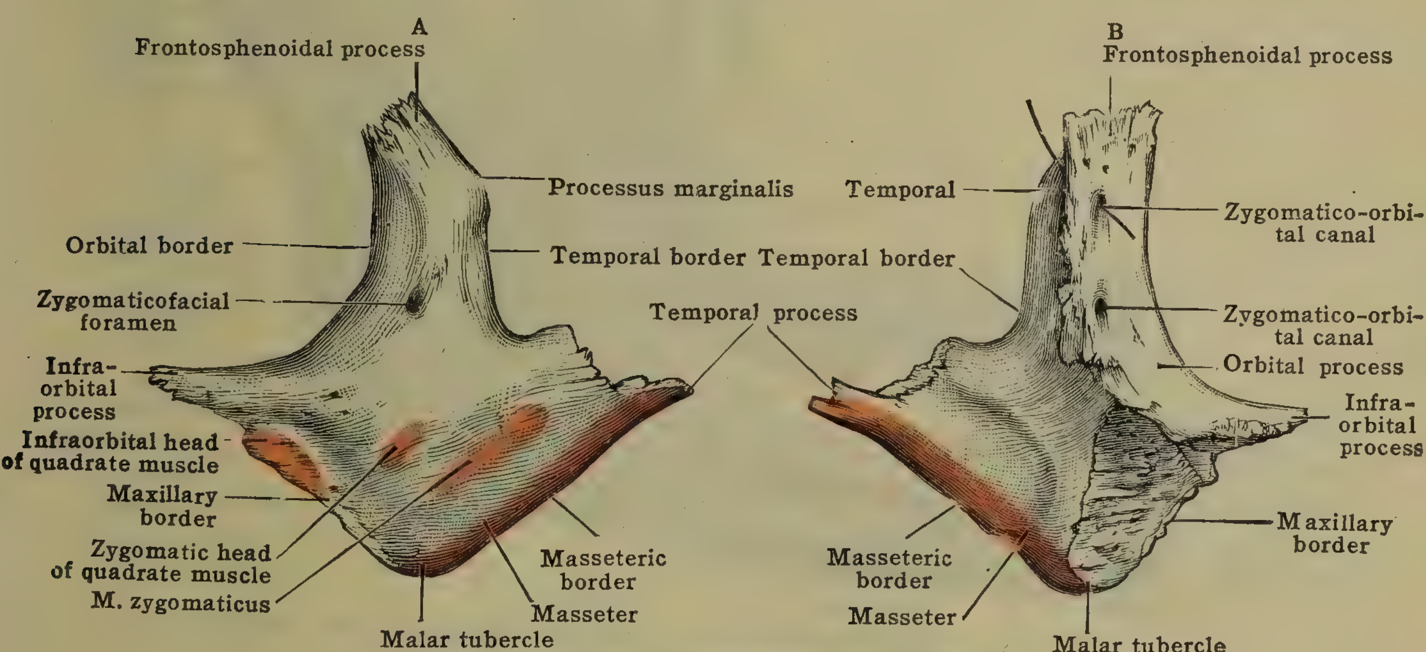


FIG. 187.—THE LEFT ZYGOMATIC BONE.
A, the malar surface. B, the temporal and orbital surfaces.

above with the zygomatic border of the great wing of the sphenoid, and below with the maxilla. When the orbital process is large, it excludes the great wing of the sphenoid from articulation with the maxilla, and the border then presents near the middle a short, non-serrated portion which closes the anterior extremity of the inferior orbital (sphenomaxillary) fissure.

All the four angles of the zygomatic bone have distinguishing features. The superior, forming the **frontosphenoidal process** is the most prominent, and is serrate for articulation with the zygomatic process of the frontal (zygomaticofrontal suture); the anterior or **infraorbital process,** sharp and pointed, articulates with the maxilla and occasionally forms the superior boundary of the infraorbital foramen; the posterior or **temporal process** is blunt and serrated mainly on its medial aspect for articulation with the zygomatic process of the temporal; the inferior angle, blunt and rounded, is known as the **malar tubercle.**

Of the four borders, the **orbital** is the longest and extends from the frontosphenoidal to the infraorbital process. It is thick, rounded, and forms more than one-third of the circumference of the orbit; the **temporal border,** extending from the frontosphenoidal to the temporal process, is sinuously curved and gives attachment to the temporal fascia. Near the frontal angle is usually seen a slight elevation, the **processus marginalis,** to which a strong slip of the fascia is attached; the **masseteric** border, thick and rough, completes the lower edge of the zygomatic arch and gives origin to the anterior fibers of the masseter muscle; the **maxillary** border, rough and concave, is connected by suture with the maxilla, and near the margin of the orbit gives origin to the infraorbital head of the quadratus labii superioris muscle.

Blood-supply.—The arteries of the zygomatic bone are derived from the infraorbital, lacrimal, transverse facial, and deep temporal arteries.

Articulations.—With the maxilla, frontal, temporal, and sphenoid bones.

Ossification.—The zygomatic is ossified in membrane from three centers which appear in the eighth week of intrauterine life. The three pieces, which have received the names of *premalar, postmalar,* and *hypomalar,* unite about the fifth month.

Variations.—The canals and foramina, which transmit branches of the zygomatic ramus of the maxillary nerve, are subject to frequent variation in number and position. Occasionally the primary nuclei fail to coalesce, and the bone is then represented in the adult by two or three portions separated by sutures. The bipartite zygomatic has been observed in skulls obtained from at least a dozen different races of mankind, but because of its greater frequency in the crania of the Japanese (seven per cent.), the name of *os Japonicum* has been given to it.

THE MANDIBLE

The mandible or lower jaw-bone (figs. 188–192) is the largest and strongest bone of the face. It supports the lower teeth, and by means of a pair of condyles, moves on the skull at the mandibular fossæ of the temporal bones. It consists

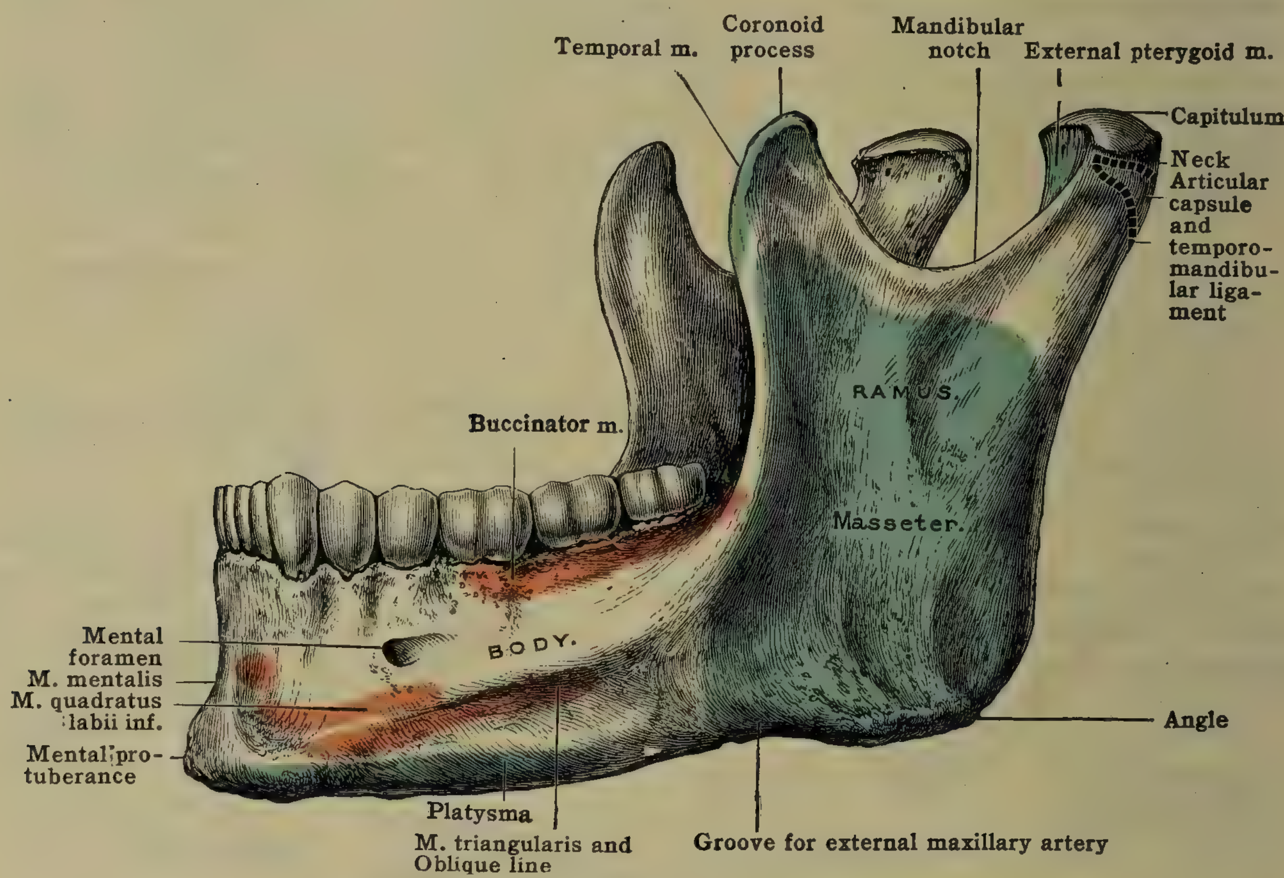


FIG. 188.—THE MANDIBLE. (Lateral view.)

of a horizontal portion—the **body**—strongly curved, so as to somewhat resemble in shape a horseshoe, from the ends of which two branches or **rami** ascend almost at right angles.

The **body of the mandible** is marked in the middle line in front by a faint groove which indicates the **symphysis** or place of union of the two originally separate halves of the bone. This ends below in the elevation of the chin known as the **mental protuberance,** the lowest part of which is slightly depressed in the center and raised on each side to form the **mental tubercle.** Each half of the body presents two surfaces and two borders. On the **external surface,** at the side of the symphysis, and below the incisor teeth, are **alveolar eminences** from which the mentalis and the incisivus labii inferioris muscles arise; and more laterally, opposite the second bicuspid tooth, and midway between the upper and lower margins, is the **mental foramen,** which transmits the mental nerve and vessels. Below the foramen is the **oblique line,** extending backward and upward from the mental tubercle to the anterior border of the ramus; it divides the body into an upper or **alveolar part** and a lower or **basilar part** and affords origin to the quadratus labii inferioris and the triangularis muscles.

The **internal surface** presents at the back of the symphysis four small projections, forming the **mental spine** (genial tubercles). These are usually arranged in two pairs, one above the other; the upper, comprising a pair of prominent

spines, gives origin to the genioglossi muscles, and the lower, represented in some bones by a median ridge or only a slight roughness, gives origin to the geniohyoid muscles. At the side of the symphysis near the inferior margin is an oval depression, the **digastric fossa,** for the attachment of the anterior belly of the digastric muscle. Commencing below the mental spine, and extending upward and backward to the ramus, is the **mylohyoid line,** which becomes more prominent as it approaches the alveolar border; it gives attachment along its whole length to the mylohyoid muscle, at its posterior fifth to the superior constrictor of the pharynx, and at the posterior extremity to the pterygomandibular raphe. Above this line at the side of the symphysis is a smooth depression the **sublingual pit** [fovea sublingualis] for the sublingual gland, and below it, farther back, is another depression for the submaxillary gland.

The **alveolar part** presents a superior border, hollowed out into eight sockets or **alveoli dentales.** These are conical in shape and form an exact counterpart of the roots of the teeth which they contain. From the lateral aspect of the alveolar part as far forward as the first molar tooth, the buccinator muscle takes origin.

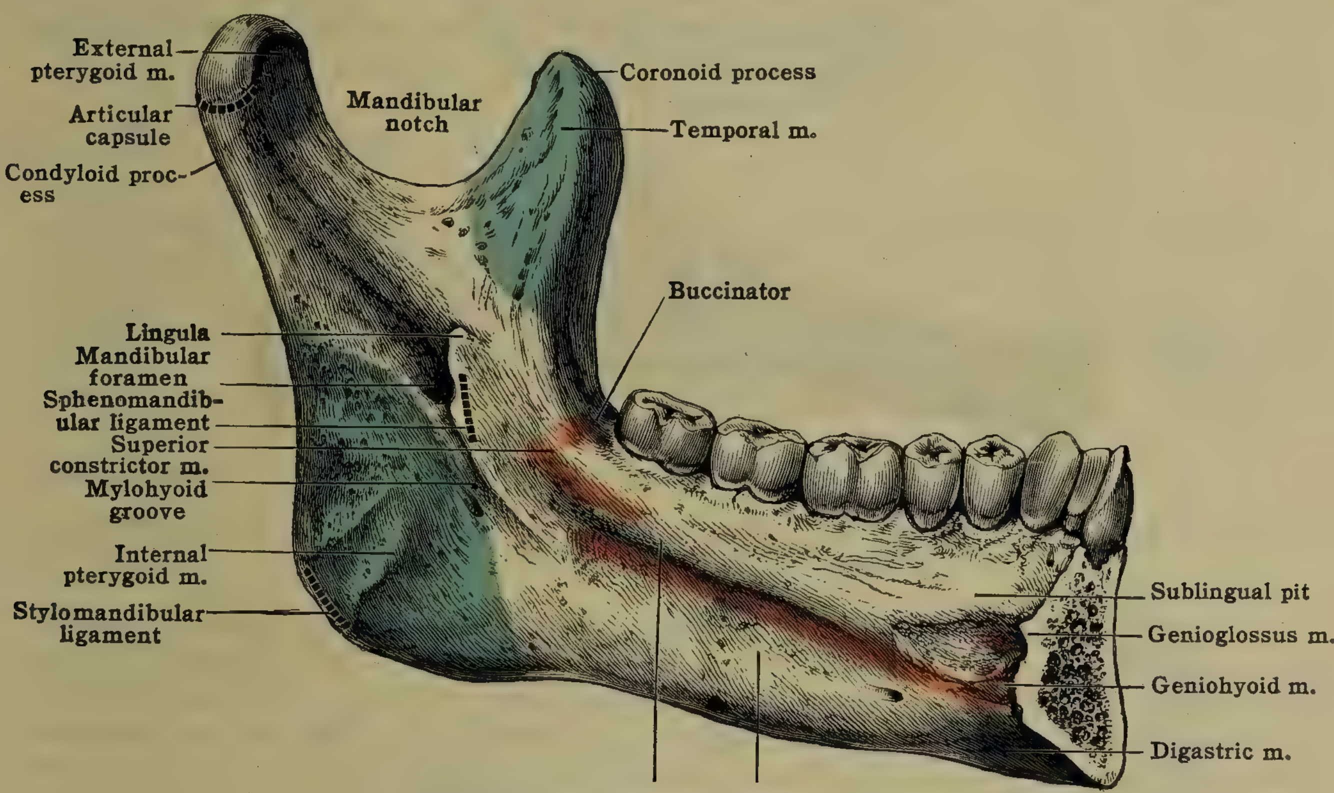


FIG. 189.—THE MANDIBLE. (Medial view.)

The **base of the mandible** or inferior border is thick and rounded. In the anterior part of its extent it gives attachment to the platysma, and near its junction with the ramus is a groove for the external maxillary artery which here turns upward into the face.

The **ramus of the mandible** is thinner than the body and quadrilateral in shape. The lateral surface is flat, gives insertion to the masseter muscle, and at the lower part is marked by several oblique ridges for the attachment of tendinous bundles in the substance of the muscle. The medial surface presents near the middle the **mandibular foramen,** leading into the **mandibular canal.**

The canal traverses the bone and terminates at the mental foramen on the external surface of the body. From the canal, which in its posterior two-thirds is nearer to the internal, and in its anterior third nearer to the external surface of the mandible, a series of small channels pass upward to the sockets of the posterior teeth and transmit branches of the inferior alveolar vessels and nerve; in front of the mental foramen a continuation of the canal extends forward and conveys the vessels and nerves to the canine and incisor teeth. The mandibular foramen is bounded medially by a sharp margin forming the **lingula mandibulæ,** which gives attachment to the sphenomandibular ligament. The posterior margin of the lingula is notched. This notch forms the commencement of a groove, the **mylohyoid groove** [sulcus mylohyoideus], which runs obliquely downward and forward and lodges the mylohyoid nerve and artery, and, in the embryo, Meckel's cartilage. Behind the spine is a rough area for the insertion of the internal pterygoid muscle.

The posterior border of the ramus is thick and rounded, and in meeting the inferior border of the ramus forms the **angle of the jaw,** which is rough, obtuse,

usually everted, and about 122° in the adult; the angle gives attachment to the stylomandibular ligament. The inferior border is thick, rounded, and continuous with the base. The anterior border is continuous with the oblique line of the external surface of the body and with a triangular surface medial to the third molar. Here a short ridge (crista buccinatoria) is often present, giving attachment to the buccinator muscle. The upper border presents two processes separated by a deep concavity, the **mandibular** (sigmoid) **notch.** Of the processes, the anterior is the **coronoid;** the posterior, the **condyloid process.**

The **condyloid process** consists of the **capitulum** and the narrowed portion by which it is supported, the **neck.** The **capitulum** is oval in shape, with its long axis transverse to the upper border of the ramus, but oblique with regard to the median axis of the skull, so that the lateral extremity, which presents the **condyloid tubercle** for the temporomandibular ligament of the mandibular articulation, is a little more forward than the medial extremity. The convex surface of the capitulum is covered with fibrocartilage in the recent state, and meets the articular disk which intervenes between the capitulum and the surface of the mandibular fossa; the **neck** [collum proc. condyloidei mandibulæ] is flattened from before backward, and presents, in front, the **pterygoid depression** [fovea pterygoidea] for the insertion of the external pterygoid muscle.

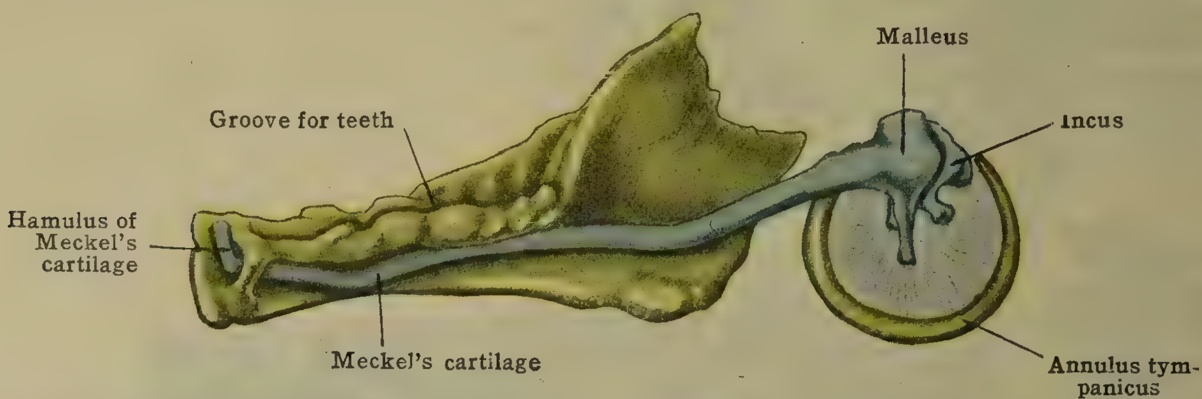


FIG. 190.—MANDIBLE SHOWING RELATIONS OF MECKEL'S CARTILAGE IN HUMAN FETUS OF 8 CM. CROWN-RUMP LENGTH. (After Kollmann.)

The **coronoid process,** flattened and triangular, is continued upward from the anterior part of the ramus, usually to a higher level than that reached by the capitulum. The lateral surface is smooth and gives insertion to the temporal and masseter muscles; the medial surface is marked by a ridge which descends from the tip and becomes continuous with the posterior part of the mylohyoid line. On the medial surface, as well as on the tip of the coronoid process, the temporal muscle is inserted. The **mandibular notch,** the deep semilunar excavation separating the coronoid from the condyloid process, is crossed by the masseteric nerve and vessels.

Blood-supply.—Compared with other bones, the superficial parts of the mandible are not so freely supplied with blood. The chief artery is the inferior alveolar which runs in the mandibular canal, and hence, as the bone is exposed to injury and sometimes actually laid bare in its alveolar portion, it often necroses, especially if the artery is involved at the same time.

Ossification.—The mandible is mainly formed by ossification in the fibrous tissue investing Meckel's cartilage, although a small portion of the cartilage itself is directly replaced by bone (fig. 190).

It is now generally admitted that the lower jaw is developed in membrane as a single skeletal element. The center of ossification appears in the sixth week of intrauterine life in the outer aspect of Meckel's cartilage and gives rise to the bony plate comparable to the *dentale* in lower animals. This plate extends forward right up to the midline in front, and from it a shelf grows upward for the support of the tooth-germs. Meckel's cartilage lies below and medial to the dentary plate, and the inferior alveolar nerve passes forward between the two structures. Meckel's cartilage itself takes some small part in the formation of the lower jaw. Ossification from the primary nucleus invades the cartilage at a point opposite the interval between the first and second tooth-germs, and the resulting bone contributes to the formation of the alveolar margin opposite these two teeth. Behind this point the cartilage atrophies except in so far as it helps to form the sphenomandibular ligament and the malleus. Behind the symphysis the anterior extremity of the cartilage does not enter into the formation of the jaw, but it usually persists throughout fetal life as one or two small, rounded, cartilaginous masses. Occasionally they become ossified and give rise to accessory ossicles in this situation. The lamella of bone situated on the medial side of Meckel's cartilage, corresponding to the distinct splenial element in some animals, arises in man as an extension from the dentary element.

In connection with the condyloid and coronoid processes, cartilaginous masses are developed. These do not, however, indicate separate elements, but are adaptations to the growth of the

lower jaw. They are ossified by an extension from the surrounding membrane bone.

The process of ossification of the lower jaw commences as early as the thirty-ninth day (Mall), and proceeds rapidly, so that by the fourth month the various parts are formed.

Age-changes.—At birth the mandible (fig. 191) presents two nearly horizontal troughs of bone, lodging unerupted teeth, and joined at the symphysis by fibrous tissue. The body is mainly alveolar, the basal part being but little developed; the capitulum and the upper edge of the symphysis are nearly on a level; the mental foramen is nearer the lower than the upper margin, and the angle is about 175°. The inferior alveolar nerve lies in a shallow groove between the splenial and dentary plates.

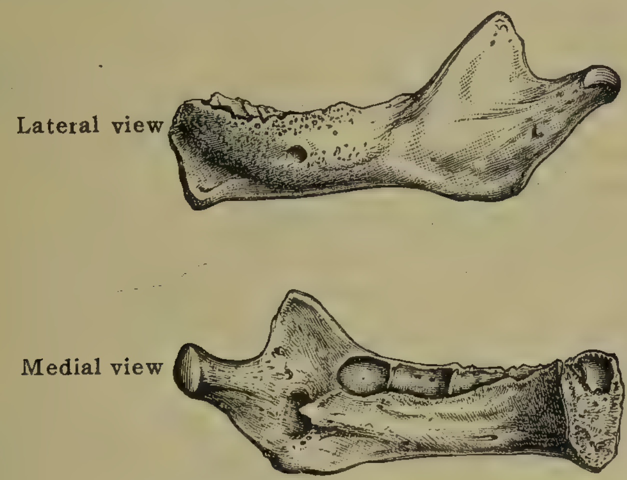


FIG. 191.—THE MANDIBLE AT BIRTH.

During the first year osseous union of the two halves takes place from below upward, but is not complete until the second year. After the first dentition, the ramus forms with the body of the mandible an angle of about 140°, and the mental foramen is situated midway between the upper an lower borders of the bone opposite the second deciduous molar. In the adult, the angle formed by the ramus and body is nearer to a right angle, and the mental foramen is opposite the second bicuspid, so that its relative position remains unaltered after the first dentition. In old age, after the fall of the teeth, the alveolar margin is absorbed, the angle formed by the

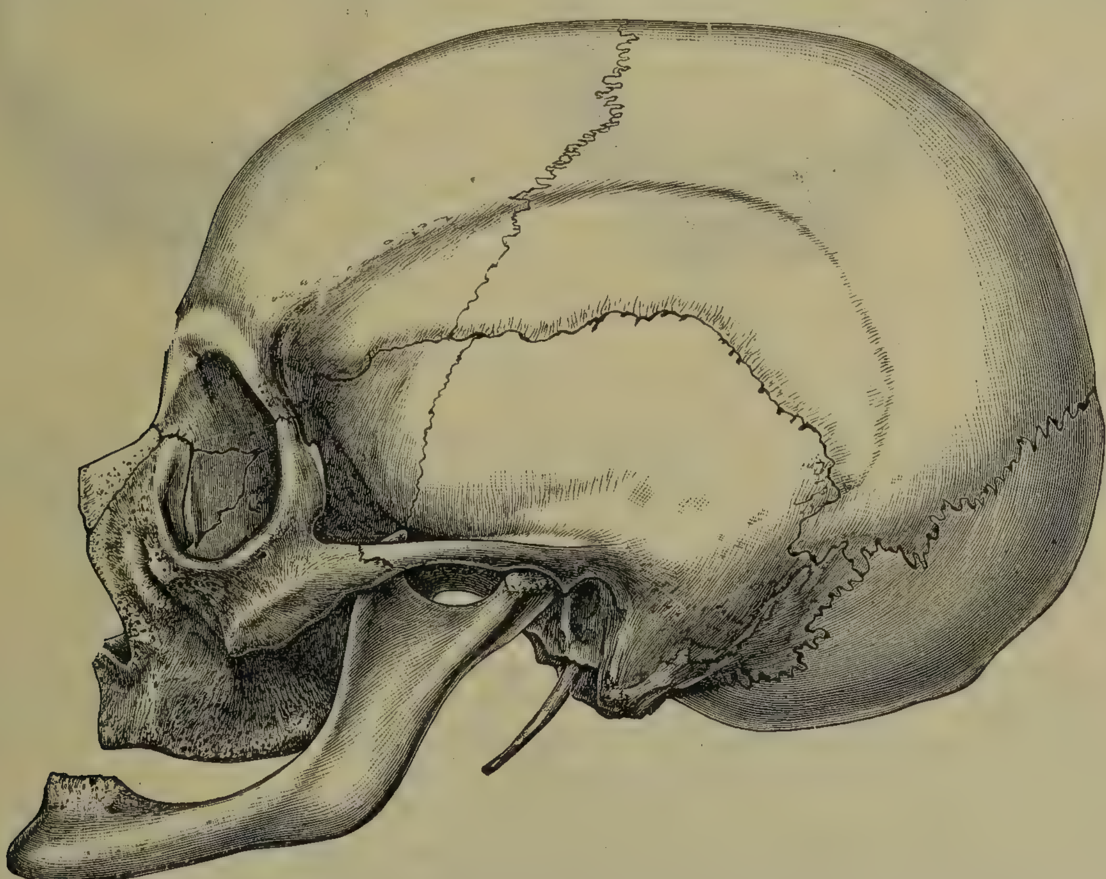


FIG. 192.—THE SKULL OF A WOMAN EIGHTY-THREE YEARS OLD, TO SHOW THE CHANGES IN THE MANDIBLE AND MAXILLA.

ramus and body is again increased, and the mental foramen approaches the alveolar margin. In a young and vigorous adult the mandible is, with the exception of the petrous portion of the temporal, the densest bone in the skeleton; in old age it becomes exceedingly porous, and often so soft that it may easily be broken. The appearance in old age is shown in fig. 192.

Variations.—Besides the extensive changes in weight and form to which the mandible is normally subjected in the life cycle many sorts of variation may occur. The chin may be protruding or receding. There may be but one eminence instead of a pair of mental tubercles. A median foramen is rarely present at the symphysis, comparable with an arterial canal normally present in certain apes. The coronoid and condyloid processes vary considerably in

form and size. They are rarely united with the rest of the ramus by sutures. A process of the inferior margin near the angle is often observed and has been compared with a similar spur in the jaws of carnivora.

In the commonest **fracture** of the mandible,—unilateral, near the mental foramen—the larger anterior fragment will be pulled downward and medially by the depressor muscles, the smaller posterior portion will be pulled upward and usually lateral to the other fragment.

THE HYOID BONE

The **hyoid bone** [os hyoideum] (os hyale NK) (fig. 193), situated in the anterior part of the neck between the chin and the thyroid cartilage, supports the tongue and gives attachment to numerous muscles. It is suspended from the lower extremities of the styloid processes of the temporal bones by two slender bands known as the **stylohyoid ligaments,** and is divisible into a **body** and two pairs of processes, the **greater** and **lesser cornua.**

The **body of the hyoid bone** [corpus ossis hyoidei], (os basihyale NK), constituting the central portion of the bone, is transversely placed and quadrilateral in form. It is compressed from before backward and lies obliquely so that the anterior surface looks upward and forward and the posterior surface in the opposite direction.

The **anterior surface** is convex and divided by a horizontal ridge into a superior and an inferior portion. Frequently it also presents a vertical ridge crossing the former at right angles, and just above the point of intersection is the **glossohyal** process, the vestige of a well-developed process, to be found in this situation in the hyoid bone of some of the lower animals. In this way four spaces or depressions for muscular attachments are marked off, two on either

Fig. 193.—The Hyoid Bone. A, Male; B, Female. (Natural size.)

side of the middle line. The **posterior surface** is deeply concave and separated from the epiglottis by the hyothyroid membrane, and by some loose areolar tissue. The membrane passes upward from the thyroid cartilage to be attached to the **superior border,** and interposed between it and the concavity on the back of the body is a small synovial bursa. The **inferior border,** thicker than the upper, gives insertion to muscles. The **lateral borders** are partly in relation with the great cornua, with which they are connected, up to middle life, by synchrondrosis, but after this period, usually by bone.

The **greater cornua** [cornua majora] (os ceratohyale NK) project upward and backward from the sides of the body. They are flattened from above downward, thicker near their origin, and terminate posteriorly in a rounded tubercle to which the hyothyroid ligament is attached.

The **lesser cornua** [cornua minora] (os chondrohyale NK) are small conical processes projecting upward and backward opposite the lines of junction between the body and the greater cornua, and by their apices give attachment to the stylohyoid ligaments; they are connected to the body by fibrous tissue. Professor Parsons has shown that a joint with a synovial cavity is common between the smaller and greater cornua. The lesser cornua are sometimes partly or completely cartilaginous in the adult.

The **muscles** attached to each half of the hyoid bone may be enumerated as follows:—

Body.............Geniohyoid, genioglossus, mylohyoid, sternohyoid, omohyoid, stylohyoid, thyrohyoid and hyoglossus.

Greater cornu......Thyrohyoid, middle constrictor, hyoglossus, and digastric.

Lesser cornu........Chondroglossus, and middle constrictor.

Ossification.—In the early months of intrauterine life the hyoid bone is composed of hyaline cartilage and is directly continuous with the styloid processes of the temporal bones. Ossification takes place from six centers, of which two appear in the central piece of cartilage, one on either side of the middle line, either just before or just after birth; soon after their appearance, however, they coalesce to form the body of the bone (basihyal). The center for each of the greater cornua (thyrohyals) appears just about the time of birth, and for each of the lesser cornua (ceratohyals) some years after birth, even as late as puberty. (F. G. Parsons.) The greater cornua and the body unite in middle life; the lesser cornua rarely ankylose with the body and only in advanced age. Parsons has shown, however, that the lesser cornua more frequently unite with the greater cornua.

THE MORPHOLOGY OF THE SKULL

In man the skull during development passes through three stages. At first the brain vesicles are enclosed in a delicate capsule of mesenchyma, the **membranous cranium.** This, in turn, is partly converted into the membrane or roof bones of the cranium, whilst the remainder is represented in the adult by the dura mater. At the sides and base of the membranous cranium, however, cartilage is deposited, **chondrocranium,** in which as well as in the membranous tracts, osseous tissue appears in due course. Eventually, an **osseous box** is formed, consisting of membrane bones and cartilage bones intricately related. For early stages and figure of the chondrocranium, see p. 31.

The skull in the chondral stage may be considered as consisting of two parts: (1) The skull proper and (2) the appendicular elements.

(1) The **skull proper** presents three regions:—

(*a*) The **notochordal** region, which ultimately gives rise to the chief parts of the occipital bone and a part of the sphenoid. It is named notochordal because the notochord runs in it as far as the anterior extremity, i.e., the level of the fossa hypophyseos.

(*b*) Anterior to the notochordal is the **trabecular region,** from which the remainder of the sphenoid is developed.

(*c*) The most anterior part of the prechordal portion of the base is the **ethmoidal region** including the **nasal capsules,** from which the cartilages of the nose and the nasal septum arise. These three parts continue forward the line of the vertebral axis, and constitute a cartilaginous trough, mostly open dorsally and with incomplete lateral walls. Finally, wedged in on each side, between the notochordal and trabecular regions, is the complicated **periotic** (auditory) capsule. In the chondral stage the sides and roof of the skull consist chiefly of membrane.

(2) The **appendicular elements** of the skull are a number of cartilaginous rods surrounding the visceral cavity—i. e., nose, mouth, and pharynx—which undergo a remarkable metamorphosis, and are represented in the adult by the *ear-bones*, the *styloid process*, and the *hyoid bone.* These rods of cartilage are named, from before backward, the **mandibular, hyoid,** and **thyroid** bars. They may with care be easily dissected in the fetus between the third and fourth months. For description of their metamorphosis, see p. 32.

While the chondrocranium is in its perfected state ossifications occur in its basal part and in the connective tissue external to it which give rise to the pterygoid (medial pterygoid process of the sphenoid), the palate, the maxillary, the zygomatic, and the incisive bones.

The Skull at Birth

The skull at birth presents, when compared with the adult skull, several peculiarly characteristic and interesting features. Its peculiarities may be considered under three headings:— The peculiarities of the fetal skull as a whole; the construction of the individual bones; the remnants of the chondrocranium.

(1) *The General Characters of the Fetal Skull* (Figs. 194–196)

The most striking features of the skull at birth are, its relatively large size in comparison with the body, and the predominance of the cranial over the facial portion of the skull (8 to 1).

The frontal and parietal eminences are large and conspicuous; the adjacent margins of the bones of the vault are separated by septa of fibrous tissue continuous with the dura mater internally and the pericranium externally; hence it is difficult to separate the roof bones from the underlying dura mater, each being lodged, as it were, in a dense membranous layer. The bones of the vault consist of a single layer without any diploë, and their cranial surfaces present no digital impressions. Six membranous spaces exist, named fontanelles: two are median, the **frontal fontanelle** [fonticulus frontalis; major] being anterior and the **occipital fontanelle** [fonticulus occipitalis; minor] posterior. Two exist on each side, termed **sphenoidal fontanelle** [fonticulus sphenoidalis] and **mastoid fontanelle** [fonticulus mastoideus]. Each angle of the parietal bones is in relation with a fontanelle. The frontal fontanelle is lozenge-shaped, the occipital triangular. The lateral fontanelles, sphenoidal and mastoid, are irregular in outline. The lateral fontanelles close soon after birth; the occipital fontanelle closes in the first year, and the frontal during the second year. For further details on the fontanelles, see p. 33.

Turning to the base of the skull, the most striking points are the absence of the mastoid processes, and the large angle which the pterygoid plates form with the skull-base, whereas in the adult it is almost a right angle. The base of the skull is relatively short, and the lower border of the mental symphysis is on a level with the occipital condyles.

The **facial skeleton** is relatively small in consequence of the small size of the nasal fossæ, the small size of the maxillary sinus, and the rudimentary condition of the alveolar parts of the maxillæ and mandible; the nasal fossæ are as wide as they are high, and are almost filled

with the conchæ. Growth takes place rapidly in the first seven years after birth. There is a second period of rapid growth at puberty, when the air-sinuses develop, and this affects especially the face and frontal portion of the cranium. For further details on the growth of the skull, see p. 33.

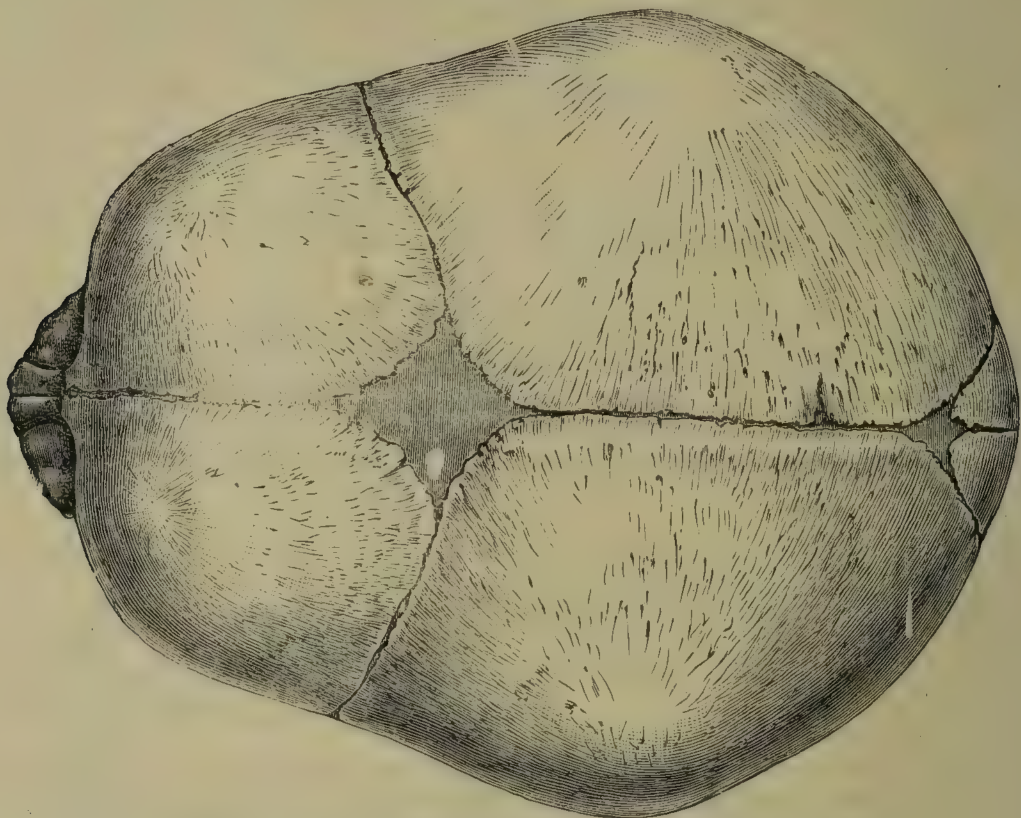


FIG. 194.—THE CRANIUM AT BIRTH. (Viewed from above.)

(2) *The Peculiarity of Individual Bones at Birth*

The **occipital bone** (fig. 144) consists of four distinct parts, which have already been described. Compared with the adult bone, the following are the most important points of distinction:—There is no **pharyngeal tubercle** or **jugular process,** the squamous portion presents two deep fissures separating the interparietal from the supraoccipital portion and extending

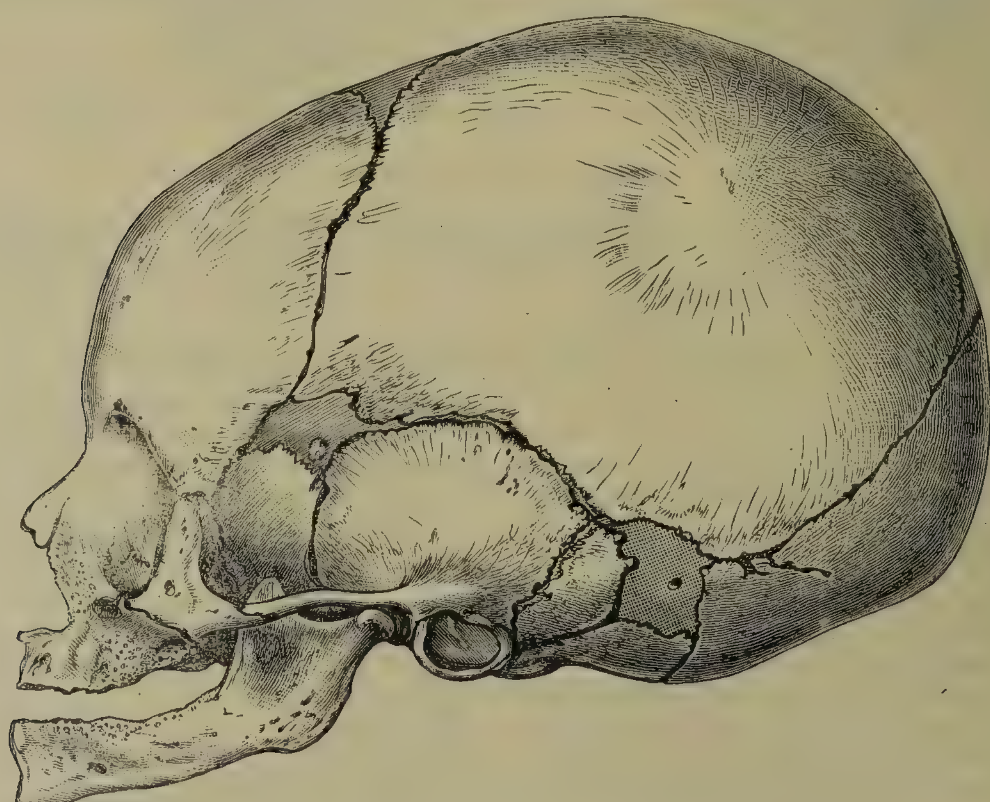


FIG. 195.—THE CRANIUM AT BIRTH. (Lateral view.)

medially as far as the occipital protuberance. The grooves for the transverse sinuses are absent.

The **sphenoid bone** (see fig. 155) in a macerated fetal skull falls into three pieces: (1) united pre- and post-sphenoids, **orbitosphenoids,** and **lingulæ,** and (2 and 3) the **alisphenoids.** The **presphenoid** is quite solid and connected with the ethmovomerine cartilage, and presents but

traces of the air-sinuses which occupy this part in the adult skull. The presphenoid by its upper surface forms part of the anterior cranial fossa, from which it is subsequently excluded by the growth of the orbitosphenoids. The optic foramina are large and triangular in shape. The **lingulæ** stand out from the basisphenoid as two lateral buttresses, and at the tuberculum sellæ is the **craniopharyngeal canal,** which in the recent bone is occupied by fibrous tissue. The **dorsum sellæ** is still cartilaginous. The **alisphenoids** with the pterygoid processes are separated from the rest of the bone by cartilage. The foramen rotundum is complete, but the future foramen ovale is merely a deep notch in the posterior border of the great wing, and there is no foramen spinosum. The pterygoid processes are short, and each medial pterygoid plate presents a broad surface for articulation with the lingula. The **pterygoid canal** is a groove between the medial pterygoid plate, the lingula, and great wing.

The **temporal bone** at birth (figs. 160, 161, 162) consists of three elements, the **petrosal, squamosal,** and **tympanic.** The **petrosal** presents a large and conspicuous floccular (subarcuate) fossa; the hiatus canalis facialis (Falloppii) is a shallow bay lodging the geniculate ganglion of the facial nerve. There is a relatively large mastoid antrum, but no mastoid process. The styloid process is unossified, but the **tympanohyal** may be detected as a minute rounded nodule of bone near the stylomastoid foramen.

The **squamosal** has a very shallow mandibular fossa and a relatively large postglenoid tubercle. The posterior part of the inferior border is prolonged downward into an uncinate process (*postauditory process*) which closes the mastoid antrum laterally.

The **tympanic** bone or annulus is a delicate, horseshoe-shaped ossicle, attached by its anterior and posterior extremities to the inferior border of the squamosal.

FIG. 196.—THE CRANIUM AT BIRTH IN SAGITTAL SECTION. (Sphenoidal concha indicated by *.)

The **ear-bones** are chiefly of interest from their size, for they are as large at birth as in the adult. The anterior (Folian) process of the malleus may be 2 cm. in length.

The **frontal bone** (fig. 150) consists of two bones separated by a median vertical (metopic) suture. The frontal eminence is very pronounced, but the superciliary arches and frontal sinuses are wanting. The frontal spine, which later becomes one of the most conspicuous features of this bone, is absent. There is no temporal line.

The **parietal bone** (figs. 194–195) is simply a quadrilateral lamina of bone, concave on its inner and convex on the outer surface. The parietal eminence, which indicates the point at which the ossification of the bone commenced, is large and prominent. The grooves for blood-sinuses, as in other cranial bones, are absent. Each angle of the parietal is in relation with a fontanelle. As in the adult, the anterior inferior angle of the bone is prolonged downward toward the alisphenoid.

The **ethmoid bone** consists of two lateral portions separated by the still cartilaginous ethmovomerine plate. The ethmoid cells are represented by shallow depressions, and the uncinate process is undeveloped.

The **sphenoidal conchæ** are two small triangular pieces of bone lying in the perichondrium on each side of the ethmovomerine plate near its junction with the presphenoid. (Indicated by the * in fig. 196.)

The **maxilla** (fig. 183) presents the following characters:—The incisive suture is visible on the palatine aspect of the bone. The alveolar border presents five sockets for teeth. The infraorbital foramen communicates with the floor of the orbit by a deep fissure; this **infraorbital fissure** sometimes persists in the adult. The sinus is a shallow depression.

The **mandible** at birth (figs. 190, 191, 196) consists of two halves united by fibrous tissue in the line of the future symphysis. Each half is a bony trough lodging teeth. The trough is divided by thin osseous partitions into five compartments: of these, the fifth is the largest, and is often subdivided by a ridge of bone. The floor is traversed by a furrow as far forward as the fourth socket (that for the first deciduous molar), where it turns outward at the mental

foramen. This furrow lodges the inferior alveolar nerve and artery, which enter by the large mandibular foramen. The capitulum is on a level with the upper border of the anterior extremity of the bone.

The **palate bones** differ mainly from those in the adult in that the vertical and horizontal plates are of the same length; thus the nasal fossæ in the fetus are as wide as they are high, whereas in the adult the height of each nasal fossa greatly exceeds the width.

Concerning the remaining bones little need be said. The **vomer** (fig. 196) is a delicate trough of bone for the reception of the inferior border of the ethmovomerine plate; its inferior border, which rests upon the hard palate, is broad, and the bone presents quite a different appearance from that in the adult. The **nasal bones** are short and broad; the **zygomatics** and **inferior conchæ** are relatively very large; and the **lacrimals** are thin, frail, and delicate lamellæ.

The **hyoid** consists of five parts. There is a median nucleus for the basihyal, and one on each side for the greater cornua (thyrohyals). The lesser cornua are cartilaginous.

(3) *Remnants of the Chondrocranium*

It has already been pointed out that at an early date the base of the skull and the face are represented by hyaline cartilage, which for the most part is replaced by bone before birth. Even at birth remnants of this primitive chondral skull are abundant. In the cranium, cartilaginous tracts exist between the various portions of the occipital bone, as well as at the line of junction of the occipital with the petrosal and sphenoid. The dorsum sellæ is entirely cartilaginous at birth, and the last portion of this cartilage disappears with the ankylosis of the basioccipital and basisphenoid about the twentieth year. A strip of cartilage unites the alisphenoids with the lingulæ, and for at least a year after birth this cartilage is continuous with that which throughout life occupies the foramen lacerum. A strip of cartilage exists along the posterior border of the orbitosphenoid, and not infrequently extends lateralward to the pterion. In the adult skull it is replaced by fibrous tissue.

The ethmoidal skeleton is entirely cartilaginous, and near the end of the nose it supports the lateral nasal cartilages, remnants of the nasal capsules. The fate of the ethmoidal skeleton is instructive. The upper part of the cartilaginous septum is ossified to form the perpendicular plate of the ethmoid; the lower part atrophies: the anterior end remains as the septal cartilage. The lateral snout-like extremities of the chondral ethmoidal skeleton persist as the lateral cartilages of the nose. Among the appendicular elements of the skull, the styloid process and a large portion of the hyoid are cartilaginous at birth.

The Nerve-foramina of the Skull

The various foramina and canals in the skull which give passage to nerves may be arranged in two groups, **primary** and **secondary. Primary foramina** indicate the places where the nerves leave the general cavity of the dura mater, and as this membrane indicates the limit of the primitive cranium, a cerebral nerve, in a morphological sense, becomes extracranial at the point where it pierces this membrane. The primary foramina are the foramen magnum, the hypoglossal, jugular, auditory, ethmoidal and optic foramina. In consequence of the complicated and extraordinary modifications the vertebrate skull has undergone many nerves traverse, in the adult skull, bony tunnels and canals which are not represented in the less complex skulls of low vertebrates, such as sharks and rays. To such foramina and canals the terms **secondary** or **adventitious** may be applied. These include the superior orbital fissure, foramen rotundum, foramen ovale, ethmoidal canals, infraorbital canal, zygomaticotemporal foramen, zygomaticofacial canals, sphenopalatine foramen, incisive foramen, pharyngeal canal, pterygoid (Vidian) canal, pterygopalatine canal, mandibular canal, facial canal, stylomastoid foramen, iter chordæ posterius, iter chordæ anterius, petrotympanic fissure, and inferior orbital fissure.

Craniometry

Among normal human individuals of all races the **capacity of the cranial cavity,** which has been used in calculating the size of the brain, is between 1000 and 1800 c.c. with an average of 1400 c.c. Crania having a capacity below 1350 are *microcephalic;* those exceeding 1450, *megacephalic;* ranging between these figures, *mesocephalic.* The capacity may be found by carefully filling the cranial cavity with seed (millet, mustard) and then measuring the volume of the latter under suitable methods of control.

The greatest **length of the cranium** (fig. 197) is between the glabella and the point in the midline of the occiput furthest removed—the opisthocranion. The **breadth of the cranium** is the greatest transverse diameter above the level of the supramastoid ridges. The **cephalic index** is obtained by finding the proportion of the maximum breadth to the length: $\frac{100 \times \text{breadth}}{\text{length}}$. Skulls having a cephalic index between 75 and 80 are *mesaticephalic;* above 80, *brachycephalic;* below 75, *dolichocephalic.*

The horizontal **circumference of the cranium** is measured by passing a tape around the skull through the glabella and the maximum occipital point.

The *basibregmatic height* (from basion to bregma) is used in determinations of the **index of height:** $\frac{100 \times \text{height}}{\text{length}}$ = *index of height:* 70–75, *orthocephalic;* below 70, *chamæcephalic;* above 75, *hypsicephalic.*

The degree of facial prominence is indicated by the **facial angle,** made with the Frankfort horizontal plane (which passes through the highest points of the two external acoustic meatuses and the lowest points of the orbital margins), by a line from nasion to prosthion. When the angle is below 80° the skull is *prognathous;* above 85° *orthognathous;* between 80° and 85° *mesognathous.*

The **form of the face** (fig. 198), is determined by comparing the length and breadth (nasion-gnathion length and bizygomatic breadth); the face is *leptoprosopic* when the index is 90 or above; *euryprosopic* below 85; *mesoprocopic*, 85–90.

The **orbital index** (fig. 198) is obtained by comparing the vertical height of the aditus orbitæ to its transverse breadth. Index between 76–85 is *mesoconch;* below 76 *chamæconch;* above 85 *hypsiconch.*

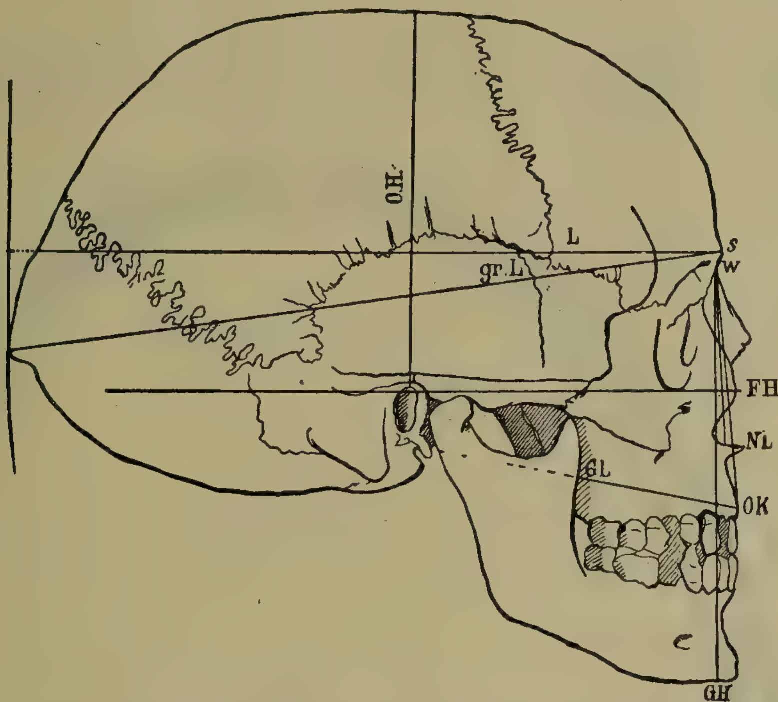


FIG. 197.—DOLICHOCEPHALIC SKULL, LATERAL VIEW. (After J. Kollmann and E. Schmidt, from Rauber-Kopsch, Lehrbuch der Anatomie.)

gr.L, maximum cranial length; GH, total facial length; NL, nasal length; OH, vertical auricular height of cranium; s, glabella; w, nasion; FH, Frankfort horizontal.

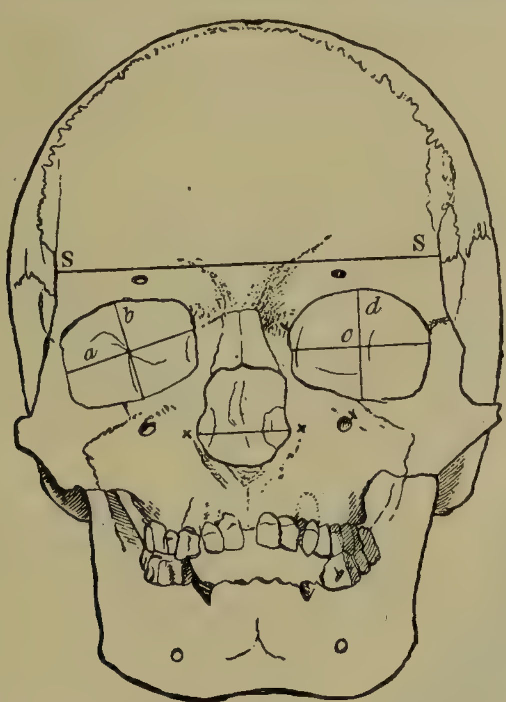


FIG. 198.—MESOCEPHALIC SKULL, ANTERIOR VIEW. (After J. Kollmann and E. Schmidt from Rauber-Kopsch, Lehrbuch der Anatomie.)

a, maximum breadth of orbital aditus; *b*, height of same at right angles to *a*; *c*, horizontal orbital breadth; *d*, vertical height; xx, maximum breadth of piriform aperture; SS, minimum frontal breadth.

The **nasal index** is derived by comparing the length of the nose (nasion to nasospinale) with the maximum width of the piriform aperture. A skull having a nasal index under 47 is *leptorrhine;* above 51 *chamœrrhine;* between 47 and 51, *mesorrhine.*

Size of teeth varies considerably among the races, with tendency to be larger in savage peoples. The **dental index** of Flower is: dental length (distance between anterior surface of the first premolar and posterior surface of the third molar), compared with the basinasal length. Teeth are *mesodont* when the index is between 42 and 44; *microdont* below 42; *megadont*, above 44.

C. THE THORAX

The **thorax** is a bony cage (figs. 212, 213) formed by the thoracic vertebræ already described, the ribs with their costal cartilages, and the sternum. It

serves to protect and support the thoracic viscera and in connection with the musculature of the ribs performs important respiratory functions. The red marrow of the spongy tissue of the ribs and sternum is one of the chief sites of red blood-corpuscle formation.

THE RIBS

The **ribs** [costæ] (figs. 199–202) twelve in number on each side, constitute a series of narrow, flattened bones, extending from the sides of the thoracic

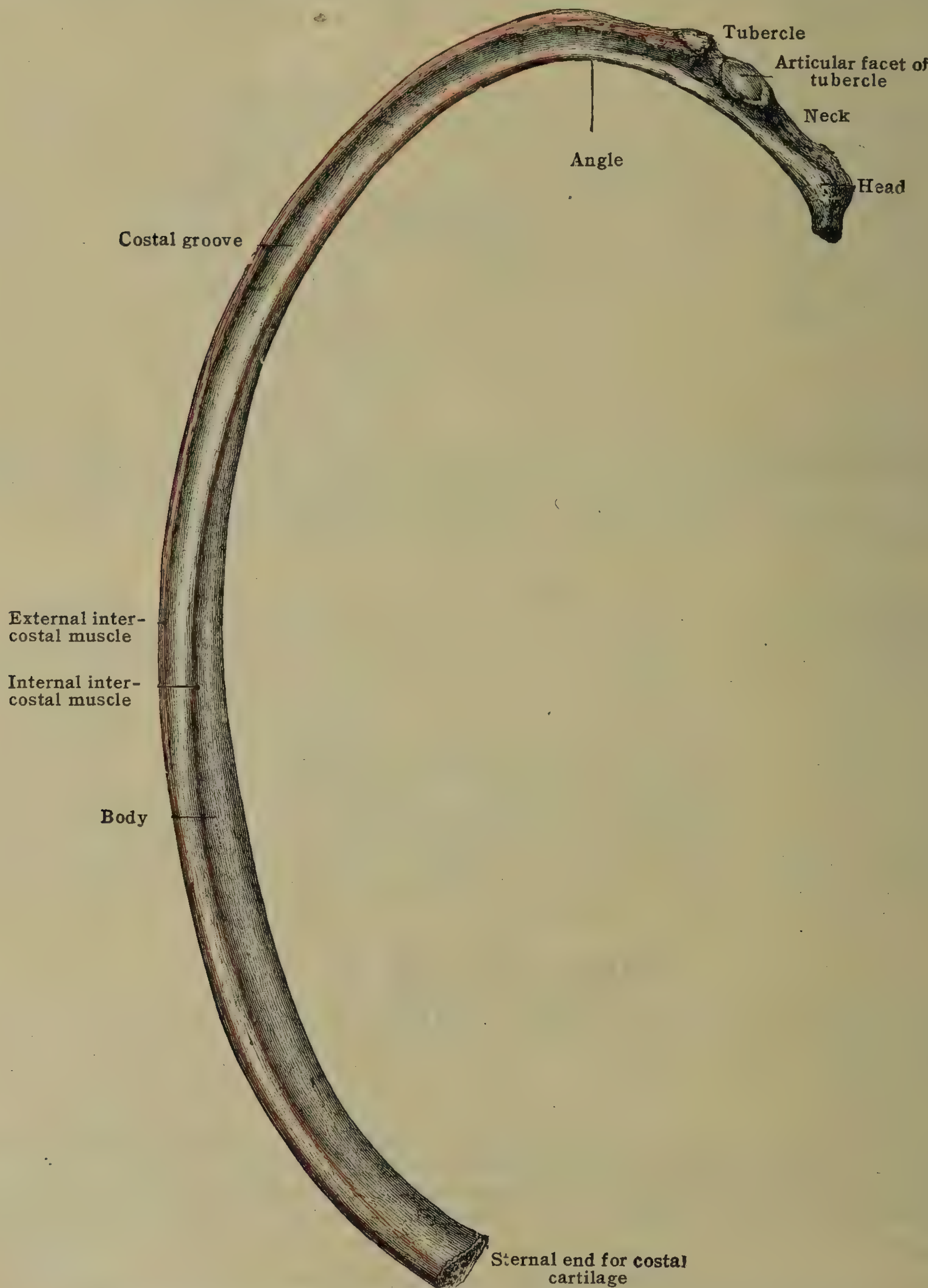


Fig. 199.—The Seventh Rib of the Left Side. (Seen from below.)

vertebræ toward the median line on the anterior aspect of the trunk. The anterior ends of the first seven pairs are connected, by means of their costal cartilages, with the sides of the sternum, and on this account the first seven ribs on each side are termed **true ribs** [costæ veræ] (costæ sternales NK). The remaining five pairs, known as **false ribs,** [costæ spuriæ] may be arranged in two sets:—one, including the eighth, ninth, and tenth ribs, in which the cartilages of the anterior extremities are connected together, and the other, including the

eleventh and twelfth, in which the anterior extremities, tipped with cartilage, are free. Thus, the first seven are **vertebrosternal**; the eighth, ninth, and tenth, **vertebrochondral**; the eleventh and twelfth, **vertebral** ribs.

The ribs increase in length from the first to the seventh, and decrease from the seventh to the twelfth. They also vary in their direction, the upper ones being less oblique than the lower. The obliquity is greatest at the ninth rib and gradually decreases from the ninth to the twelfth.

Typical characters of a rib (fig. 199).—The seventh is regarded as the most typical rib. It presents a vertebral extremity or **head**; a narrow portion or **neck**; a **sternal** extremity; and an intermediate portion, the **body** or **shaft.**

The **head** [capitulum costæ] presents an **articular surface** [facies articularis capituli costæ] made up of two flattened articular facets separated by a horizontal **crest** [crista capituli].

The crest is connected by an interarticular ligament with an intervertebral disk, and the facets articulate with the costal pits on the sides of the bodies of two vertebræ (sixth and seventh). As a rule, the lower facet is the larger, and articulates with the thoracic vertebra, to which the rib corresponds in number. This is the primary facet, and is the one represented in those ribs which possess only a single facet on the rib-head.

The **neck** [collum costæ] is that portion of the rib extending from the head to the **tubercle.** It is flattened from before backward and is in relation posteriorly with the transverse process of the lower of the two vertebræ with which the head articulates. It forms the anterior boundary of the **costotransverse foramen.**

It is rough where the neck ligament is attached. The anterior surface is flat and smooth and gives attachment near the head of the rib to the radiate ligament. The superior border of the neck, continuous with the corresponding border of the shaft, presents a rough **crest** [crista colli costæ] for the anterior costotransverse ligament. The inferior border of the neck is rounded and continuous with the ridge of the **costal groove.**

The **tubercle** [tuberculum costæ] situated behind at the junction of the neck with the shaft, consists of an upper and lateral part, rough for the attachment of the posterior costotransverse ligament, and a lower and medial part, bearing a **convex oval facet** [facies articularis tuberculi costæ] for articulation with the pit near the tip of the transverse process of a vertebra. The tubercle projects below the lower edge of the rib to form a crest, marking the beginning of the costal groove.

The **body** [corpus costæ] is strongly curved and presents two surfaces and two borders. At first the curve is in the same plane as the neck, but it quickly turns forward at a point on the posterior surface of the shaft known as the **angle** [angulus costæ], where it gives attachment to the iliocostalis muscle and some of its subdivisions. The rib has also a second or upward curve, beginning at the angle. These curves are expressed by describing the main curve as disposed around a vertical, and the second or upward curve around a second transverse axis.

Besides the two curves now described, the rib is slightly twisted on itself, so that the surfaces which look medially and laterally behind are placed obliquely in front and look downward as well as medially, and upward as well as laterally.

The **external surface** of the rib is convex, and gives attachment to muscles. Near its anterior extremity it forms a somewhat abrupt curve, indicated by a ridge on the bone, which gives attachment to the serratus anterior muscle, and is sometimes called the **anterior angle.**

The **internal surface** is concave and presents near its inferior border the **costal groove** [sulcus costæ]. The groove is best marked near the angle, and gradually becomes shallower toward the anterior extremity of the rib, where it is finally lost; it lodges the intercostal vessels and nerve. The ridge limiting the groove above is continuous with the inferior border of the neck of the rib, and gives attachment to the internal intercostal muscle.

The **superior border** is rounded, and affords attachment to the internal and external intercostal muscles. The **inferior border** commences abruptly near the angle, and gives attachment to the external intercostal muscle.

The **sternal** end of the shaft is cupped for the reception of the costal cartilage.

Blood-supply.—The ribs are very vascular and derive numerous branches from the intercostal arteries. The branches in the shaft run toward the vertebral end, whilst those in the head and neck run, as a rule, toward the shaft. In the neighborhood of the tuberosity the vessels do not seem to have any constant arrangement.

Peculiar ribs (figs. 200, 201).—Several ribs present certain peculiarities and differ in many particulars from the general description given above. These are the first, second, tenth, eleventh and twelfth.

The **first rib** (fig. 200) is the broadest, shortest, and most curved of all the series. It is not twisted, and is so placed that its superior surface looks forward as well as upward, and its inferior surface backward as well as downward. The head is small, and as a rule is furnished with only one articular facet. The neck, longer than that of most of the ribs, is slender and rounded. The tubercle is large and prominent. The shaft lies for its whole extent nearly in one plane, has no angle, and is curved in one direction only, i. e., around a vertical axis. The superior surface presents two shallow grooves, separated near the inner border by the rough **scalene tubercle** [tuberculum scaleni, Lisfranci] for the scalenus anterior muscle. The groove in front of the tubercle is for the subclavian vein and the groove behind it is for the subclavian artery [sulcus subclaviæ] and the lowest cord of the brachial plexus. Between the groove for the artery and the tubercle is a rough surface for the insertion of the scalenus medius, and between the groove and the outer margin is an area for the origin of the serratus anterior. The inferior surface is uniformly flat and lacks a subcostal groove. By the lateral portion, which is rough, it gives attachment to the internal intercostal muscle; the remainder of the inferior surface is in relation to pleura and lung. The lateral border is thick and rounded, and gives attachment to the external intercostal muscle, whilst the medial border, thin, sharp, and concave, receives the attachment of the fascia (Sibson's) covering the dome of the pleura. The anterior extremity is thick and broad, and its upper margin, as well as the cartilage to which it is joined, afford attachment to the costoclavicular ligament and the subclavius muscle. The

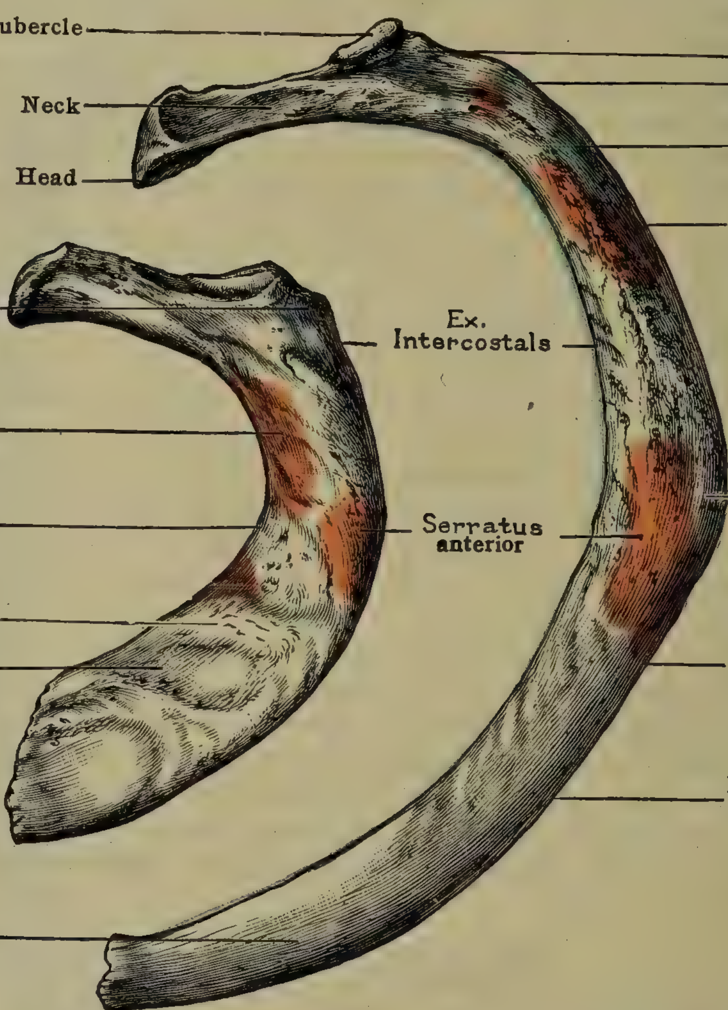


Fig. 200.—First and Second Ribs. (Viewed from above.)

costal cartilage of this rib is directly united to the manubrium sterni, and occasionally the cartilage and the adjoining part of the anterior extremity of the rib are replaced by fibrous tissue. The rib derives its nutrition mainly from the superior intercostal branch of the subclavian artery.

The **second rib** (fig. 200) is much longer than the first, and although like it in being strongly curved round a vertical axis, in its form and general character there is a closer resemblance to the ribs lower down in the series. The head is round and presents two facets, the costal groove is present, though faintly marked, and an angle is situated near the tubercle. The specially distinguishing feature of the rib, however, is a well-marked **tuberosity** [tuberositas costæ II] on its outer surface somewhat near the middle, for the origin of a part of the first digitation, and the whole of the second digitation of the serratus anterior muscle. Between the tuberosity and the tubercle the outer surface is smooth and rounded and gives attachment to the scalenus posterior the serratus posterior superior, the iliocostalis cervicis, and the iliocostalis dorsi. The internal surface is smooth and in relation to the pleura. The borders give attachment to the intercostal muscles, the upper, to those of the first space, the lower, to those of the second. The shaft of the second rib is not twisted on its own axis, so that both ends can lie flat on the table. The second rib receives vessels from the superior intercostal branch of the subclavian artery and the first aortic intercostal.

The **tenth rib** (fig. 201) is distinguished by a single facet on the head for articulation with the body of the tenth thoracic vertebra. Occasionally there are two facets, in which case the

rib articulates also with the ninth thoracic vertebra. The tenth rib, like the ribs immediately above, is long, curved, presents a deep costal groove, a well-marked tuberosity and an angle. It may be noted, however, that the distance between the tubercle and the angle in this rib is greater than in the ribs above. Speaking generally, the distance between these points increases from above downward.

The **eleventh rib** is peculiar in that it has a single facet on the head, a feebly marked angle some distance from the head, a shallow costal groove, no tubercle, and no neck. The tubercle is sometimes represented by a slight elevation or roughness without any articular facet. The anterior extremity is pointed.

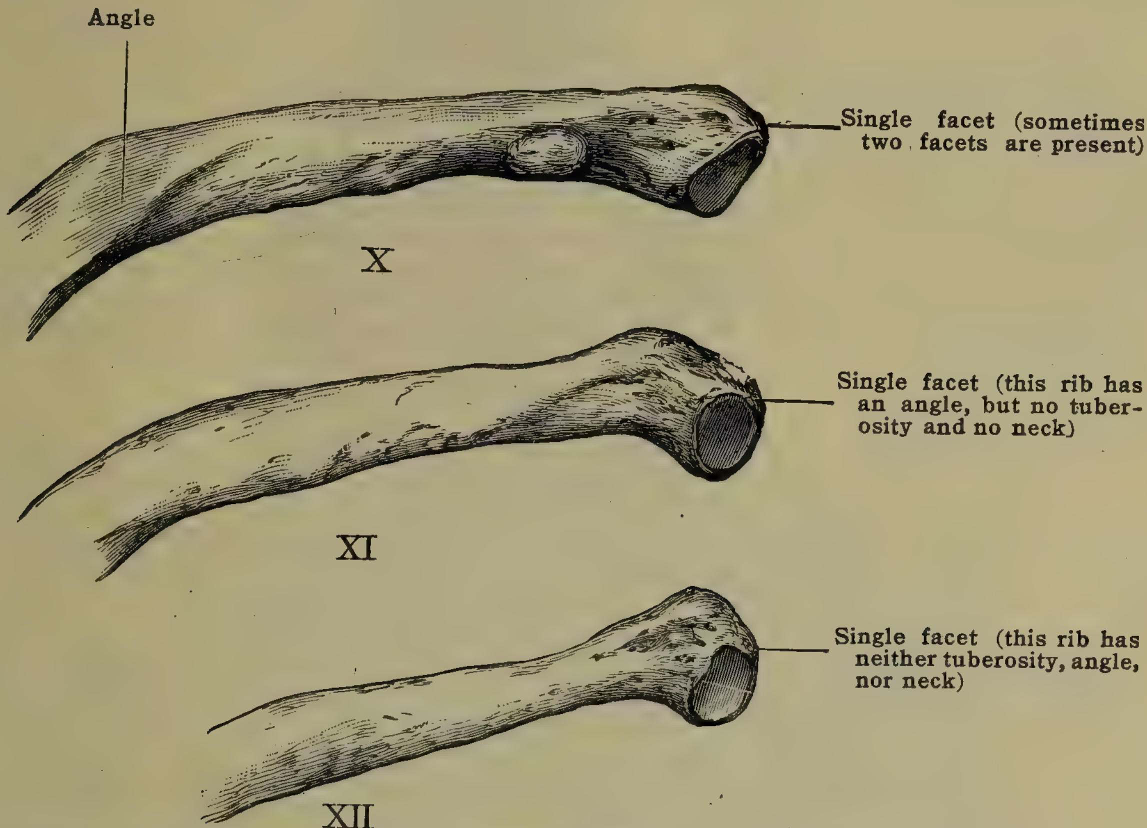


Fig. 201.—The Vertebral Ends of Tenth, Eleventh, and Twelfth Ribs.

The **twelfth rib** has a large head furnished with one facet for articulation with the root of the twelfth thoracic vertebra. The shaft is narrow and extremely variable in length (3 to 20 cm.). It is usually somewhat longer than the first rib, but it may be shorter. There is no tubercle, no angle, no neck, no costal groove. The anterior extremity is pointed. Posteriorly, the upper border is smooth and rounded; the lower border is sharp and rough.

The **costal cartilages** [cartilagines costales] are bars of hyaline cartilage attached to the anterior extremities of the ribs. Like the shaft of a rib, each cartilage has an outer and inner surface. The outer surfaces give origin and insertion to large muscles, and the inner surfaces, from the second to the sixth inclusive, are in relation with the transversus thoracis muscle. The upper and lower borders serve for the attachment of the internal intercostal muscles. The

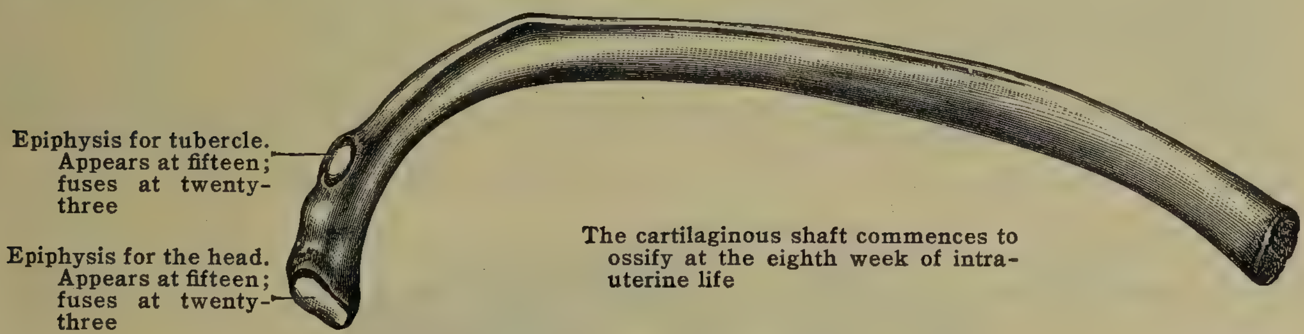


Fig. 202.—Rib at Puberty.

upper seven cartilages, and occasionally the eighth, are connected with the sternum. Of these, the first fuses with the manubrium sterni and the remaining six are received into small articular concavities, and retained by means of ligaments. The cartilages of the vertebrochondral ribs are united to one another and to the seventh costal cartilage by ligaments (sometimes by short vertical bars of cartilage), while those of the vertebral ribs form no such attachment, but lie between the abdominal muscles. The inner surfaces of the lower six costal cartilages afford attachment to the diaphragm and the transversalis muscle.

The second costal cartilage articulates with the side of the sternum at a point corresponding to the junction of the manubrium and body. The articulation of the seventh corresponds to the line of junction of the body and xiphoid process; and the eighth, when it reaches the sternum, articulates with the xiphoid process (fig. 203).

Blood-supply.—The costal cartilages derive their blood-supply from the terminal twigs of the aortic intercostals and from the internal mammary arteries. They are distributed to the perichondrium. (Blood-supply of ribs noted above.)

Ossification.—At the eighth week of intrauterine life the ribs are cartilaginous. About this time a nucleus appears near the angle of each rib, and spreads with great rapidity along the shaft, and by the fourth month reaches as far as the definitive costal cartilage. At this date the length of rib-shaft bears the same proportion to that of the costal cartilage as in adult life.

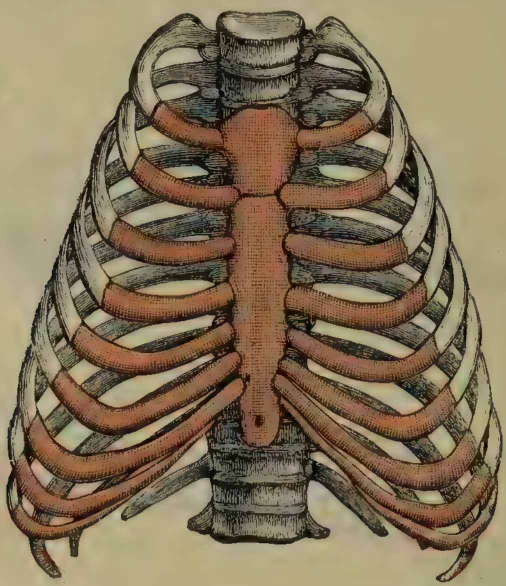


FIG. 203.—THE THORAX AT THE EIGHTH FETAL MONTH.
(On the left side eight cartilages reach the sternum.)

Whilst the ribs are in a cartilaginous condition, the first eight reach to the side of the sternum, and even after ossification has taken place, the costal cartilage of the eighth rib, in many instances, retains its articulation with the sternum up to as late as the eighth month (fig. 203). This relationship may persist through life, but usually the cartilage retrogresses, and is replaced by ligamentous tissue. About the fifteenth year a secondary center appears for the head of each rib, and a little later one makes its appearance for the tubercle, except in the eleventh and

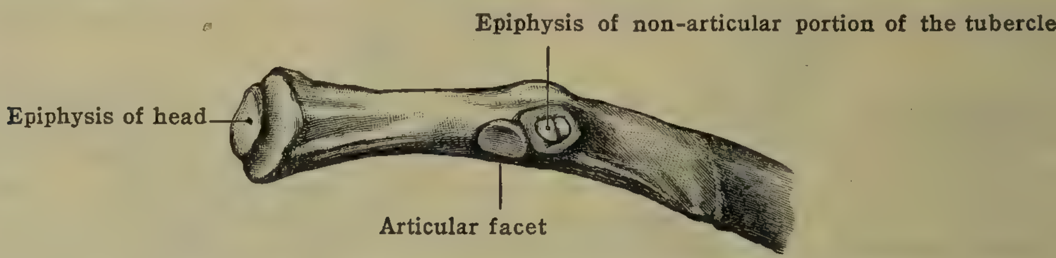


FIG. 204.—POSTERIOR PORTION OF THE SIXTH RIB IN THE FIFTEENTH YEAR.
(After Toldt.)

twelfth ribs. Frequently epiphyses are developed on both parts of the tubercle (see figs. 204 and 205). The epiphyses fuse with the ribs about the twenty-third year. The rib-shaft increases in length mainly at its line of junction with the costal cartilage.

Clinical relations.—The *nipple* in the male usually lies between the fourth and fifth ribs. In *counting the ribs,* the position of the second is denoted by the subcutaneous transverse ridge (sternal angle) at the junction of the manubrium and body of the sternum. It is best to count the ribs from this point, and never from below, as the twelfth rib varies in size and may be

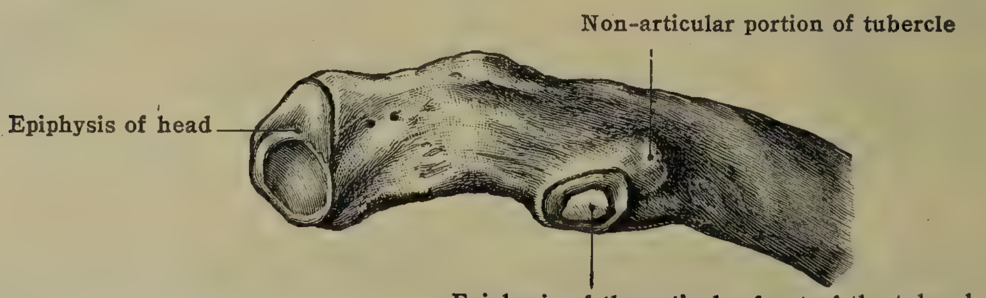


FIG. 205.—POSTERIOR PORTION OF THE SIXTH RIB IN THE EIGHTEENTH YEAR.
(After Toldt.)

obscured by the sacrospinalis muscles. Owing to the obliquity of the ribs, their sternal ends are at a much lower level than their vertebral extremities.

"Thus the first rib in front corresponds to the fourth rib behind, the second to the sixth, the third to the seventh, the fourth to the eighth, the fifth to the ninth, the sixth to the tenth, and the seventh to the eleventh. If a horizontal line be drawn round the body from before

backward at the level of the inferior angle of the scapula, while the arms are at the sides, the line would cut the sternum in front between the fourth and fifth ribs, the fifth rib at the nipple line, and the ninth rib at the vertebral column." (Treves.) The most frequently broken are the sixth, seventh, and eighth. The upper four and the two lowest ribs are best covered by soft parts, and, in the case of the former, the shoulder and arm take off some of the violence that would otherwise reach them. The way in which the ribs are embedded in the soft parts, and the fact that the fragments are often held in place by the periosteum, account for the difficulty which is often met with in detecting crepitus. The intercostal spaces are wider in front than behind. The three upper are the widest of all.

Variations.—The ribs may be increased in number by addition either at the cervical or lumbar end of the series, but it is extremely rare to find an additional rib or pair of ribs in both the cervical and lumbar regions in the same subject.

Cervical ribs (fig. 206) are fairly common, occurring in 3 of 260 subjects (1.16 per cent.) examined by T. W. Todd. As a rule, they are of small size and rarely extend more than a few mm. beyond the extremity of the transverse process. Occasionally they exceed such insignificant proportions and reach as far as the sternum; between these two extremes many varieties occur. The anterior extremity of a cervical rib may, according to the degree of its development (1) lie free among the scalene muscles; (2) be connected with the sternum by a ligamentous prolongation; (3) articulate with the upper surface of the first thoracic rib at about its center by a synchrondrosis, or (4) form a complete rib, articulating by a costal cartilage with the sternum.

The lowest trunk of the brachial plexus formed by the eighth cervical and first thoracic roots, the subclavian artery and less commonly the subclavian vein, curve over the upper surface of these ribs or over a ligament stretched from the first rib to the tip of the cervical rib.

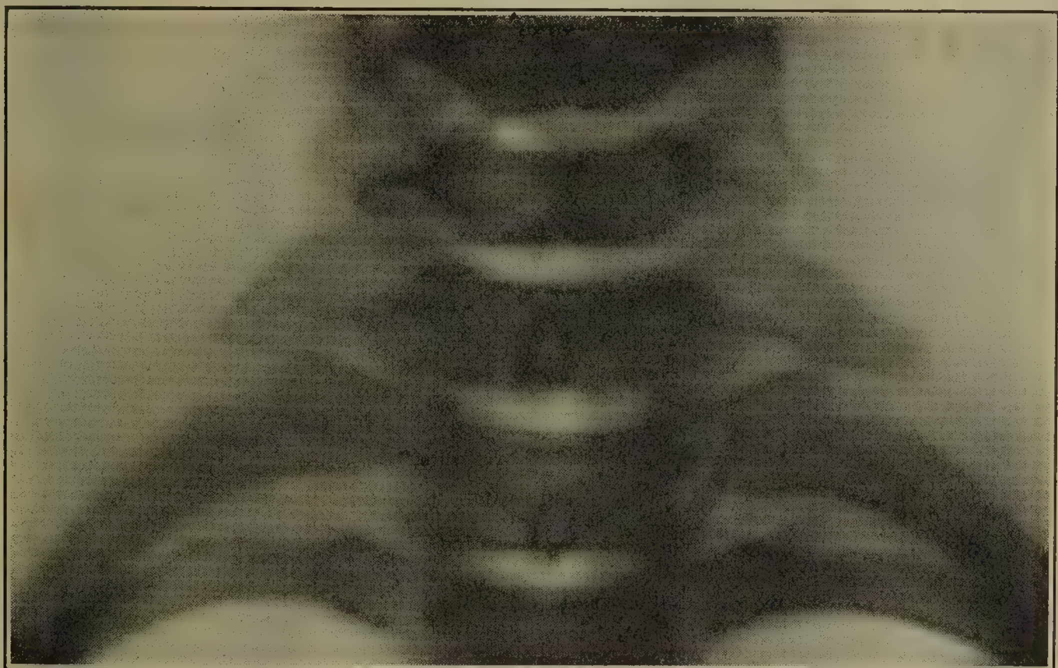


FIG. 206.—RADIOGRAM SHOWING A PAIR OF SMALL CERVICAL RIBS.

The abnormality owes its clinical importance to the pressure effects produced on the nerves (especially the ulnar) in a small proportion of the cases. This pressure is manifested by (1) pain, going on to anesthesia down the medial side of arm, forearm and hand; (2) paralysis of the intrinsic muscles of the hand, producing the *main en griffe*, and to a less extent of the muscles of the forearm; (3) vascular effects (anemia, gangrene, etc.), manifested chiefly in the hand. Todd has shown that these vascular effects are not due to mechanical pressure on the subclavian artery by the cervical rib as was formerly supposed, but are trophic lesions of the sympathetic (vasomotor) nerves. The vasomotor nerves to the arm mainly come from the second thoracic root by the communication it gives to the lowest cord of the brachial plexus, and so are exposed to pressure from the rib.

The symptoms associated with cervical ribs usually develop about the 18th year. Todd has shown that similar symptoms may be produced occasionally by a first thoracic rib in cases where the brachial plexus has migrated caudad. In the living patient, unless a radiogram be taken showing all the vertebræ up to the base of the skull, it is not possible with precision to ascertain with which vertebra the highest rib present articulates.

For a discussion of the subject of cervical ribs see Todd, Jour. Anat. & Phys., vols. 46 and 47.

The first rib occasionally shows reduction in extent, being short and slender, its costal cartilage likewise reduced or replaced in part by fibrous tissue, connected with the second costal cartilage. Ossification of the first costal cartilage affecting the surface and resulting in a bony enveloping mantle is frequently encountered.

Lumbar ribs are of less significance than cervical ribs and rarely attain a great length. Their presence is accounted for as the differentiated costal elements of the transverse processes. They are never so complete as the cervical ribs, and articulate only with the transverse processes; the head never reaches as far as the body of the vertebra, and there is no neck or tubercle. An extra levator costæ muscle is associated with a lumbar rib.

An interesting variation is that known as the **bicipital rib.** This condition is seen exclusively in connection with the first thoracic rib. The vertebral end consists of two limbs which lie in

different transverse planes. These bicipital ribs have been especially studied in whales and in man. This abnormality is the result of the fusion of two ribs, either of a cervical rib with the shaft of the first thoracic, or the more common form, the fusion of the first and second true ribs. Among unusual variations of ribs should be mentioned the replacement of the costal cartilage and a portion of the rib-shaft by fibrous tissue, a process which occurs normally in the case of the eighth rib during its development. Sometimes the shafts of two or more ribs may become united by small quadrilateral plates of bone extending across the intercostal spaces.

THE STERNUM

The **sternum** (figs. 207–209) is a flat, oblong plate of bone, situated in the anterior wall of the thorax, and divisible into three parts—(1) the **manubrium**

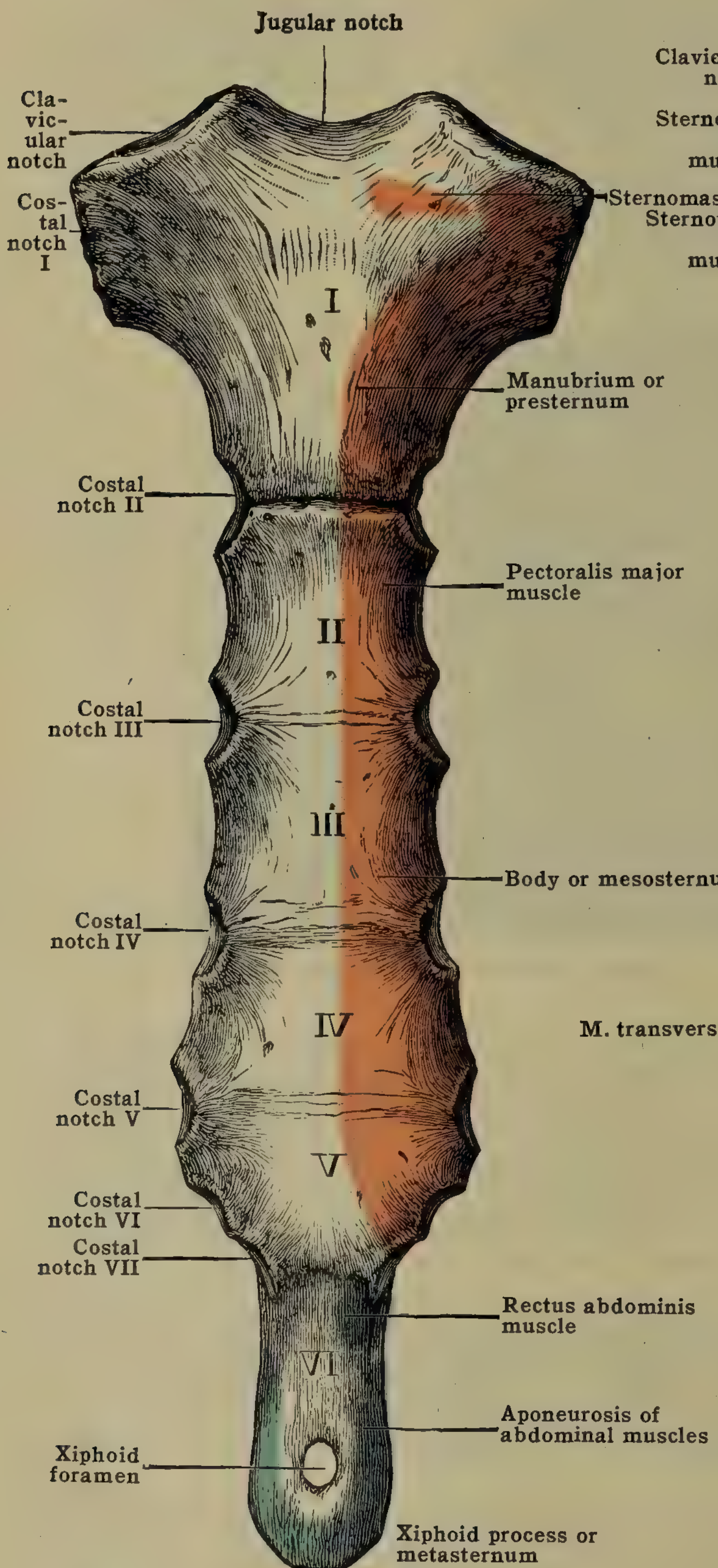


FIG. 207.—THE STERNUM. (Anterior view.)

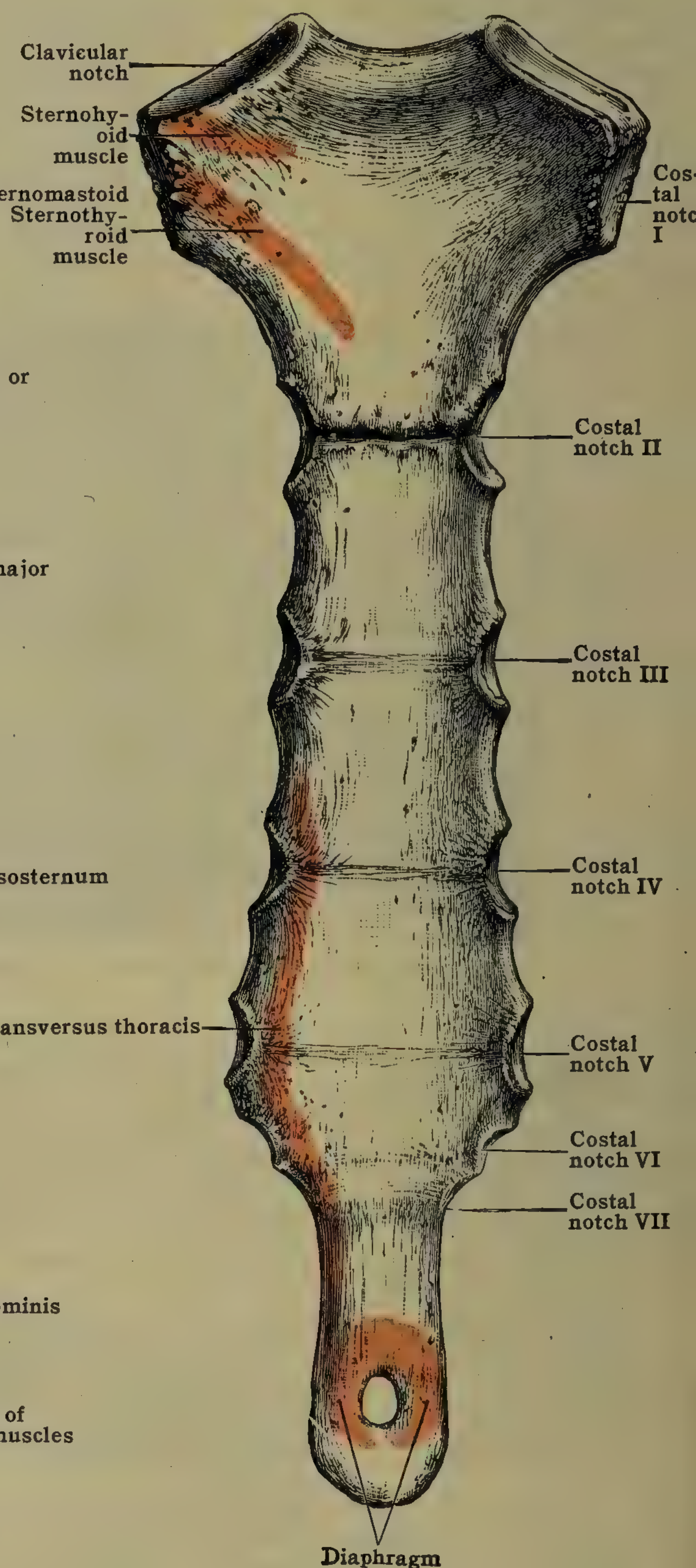


FIG. 208.—THE STERNUM. (Posterior view.)

sterni (presternum), (2) the **corpus sterni** (mesosternum), constituting the **body** of the bone, and (3) the **xiphoid** (or ensiform) **process** (metasternum). In the young subject it consists of six segments (sternebræ). Of these, the first remains separate throughout life and forms the manubrium; the succeeding four segments

fuse together, forming the body; while the lowest segment, also distinct until middle life, is represented by the xiphoid process.

In its natural position the sternum is inclined obliquely from above downward and forward and corresponds in length to the vertebral column from the third to the ninth thoracic vertebra. It is not of equal width throughout, being broader above at the manubrium and narrow at the junction of this piece with the body. Toward the lower part of the body, the sternum again widens, and suddenly then contracts at its junction with the xiphoid process which constitutes the narrowest part.

The **manubrium** or first piece of the sternum forms the broadest and thickest part of the bone, and is of a somewhat triangular form with the base directed upward and the apex downward. It presents two surfaces and four borders. The **anterior surface** is largely subcutaneous. It is slightly convex and directed obliquely upward and forward, is smooth and gives origin on each side to the sternal head of the sternomastoid and the pectoralis major muscles. The **posterior surface,** almost flat, and directed downward and backward, affords origin near the lateral margins on each side, to the sternohyoid muscle above and the sternothyroid muscle below. Of the four borders, the **superior** is the longest and much the thickest. In the middle is a curved, non-articular depression, called the **jugular notch** [incisura jugularis], to which the fibers of the interclavicular ligament are attached, and at either end is an oval articular surface, the **clavicular**

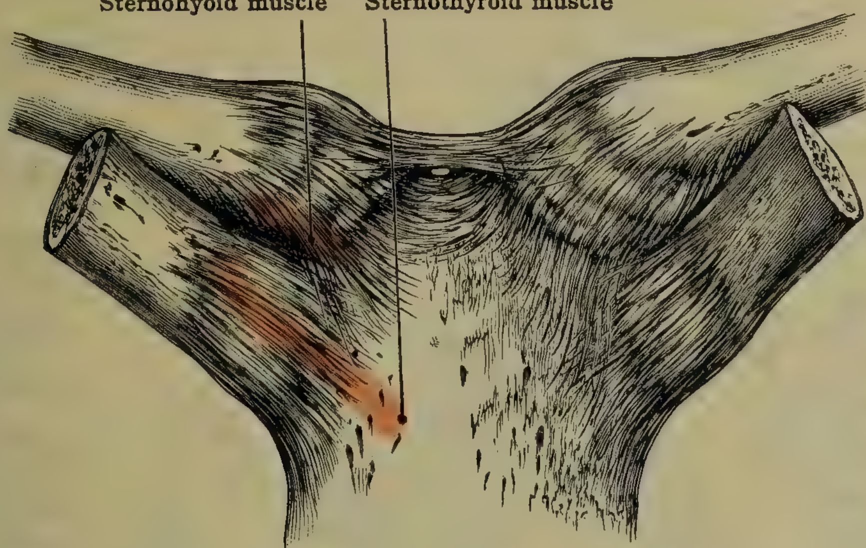


FIG. 209.—POSTERIOR SURFACE OF THE MANUBRIUM, WITH STERNAL ENDS OF CLAVICLES AND THE FIRST COSTAL CARTILAGES.

notch [incisura clavicularis], somewhat saddle-shaped and directed upward, backward, and laterally for the reception of the medial end of the clavicle. The circumference of the clavicular notch gives attachment to the sternoclavicular ligaments.

The **lateral borders** of the manubrium slope from above downward and medially and each presents superiorly an irregular **costal notch** [incisura costalis], for the first costal cartilage and a small facet below, which, with an adjoining facet on the body of the sternum, forms a notch for the second costal cartilage. The two articular surfaces are separated by a narrow curved edge in relation with the internal intercostal muscle of the first space. The **lower border** is thick and short and presents an oval rough surface which articulates with the upper border of the body, forming the superior sternal synchondrosis. The two opposed surfaces are separated by a fibrocartilaginous disk, which may, however, become partially ossified in advanced age, and at the position of the joint there is usually an angle—the **sternal angle** [angulus sterni] (angulus Ludovici)—which can be felt as a transverse ridge beneath the skin. This is useful in locating the second rib in the living subject.

The **body of the sternum** [corpus sterni] or second piece of the sternum is longer, narrower, and thinner than the manubrium. It is widest opposite the notches for the fifth costal cartilages and becomes narrower above and below. The **anterior surface** [planum sternale] is flat, directed upward and forward, and marked by three transverse elevations which indicate the lines of junction of its four component parts. It gives attachment on each side to fibers of the pectoralis major muscle and is subcutaneous in the midline; it occasionally presents a foramen—the **sternal foramen**—situated at the junction of the third and fourth

pieces of the bone. The **posterior surface** is slightly concave, marked by transverse lines corresponding to those on the anterior surface, and below gives attachment on each side to fibers of the transversus thoracis muscle.

The **lateral borders** of the body present four whole costal notches and two half-notches on each side, which articulate with the costal cartilages of the second to the seventh ribs inclusive; the two half-notches are completed by corresponding notches on the manubrium and the xiphoid process. Between the articular depressions the lateral border is curved and in relation to the internal intercostal muscles.

The **superior border** of the sternal body presents an oval face for articulation (synchondrosis) with the manubrium. The **inferior border** is short and articulated with the xiphoid process, the two opposed surfaces being separated by a layer of cartilage so long as they are not united by bone.

The **xiphoid process** [processus xiphoideus] (proc. ensiformis NK) is the thin, elongated process projecting downward between the cartilages of the seventh ribs. It is the least developed part of the sternum and is subject to many variations in form, being sometimes pointed, broad and thin, occasionally bifid or perforated by a foramen, and sometimes bent forward, or deflected to one side. It usually retires from the surface, corresponding to the depression of the epigastric angle, or pit of the stomach. In structure it is cartilaginous in early life, partially ossified in the adult, but in old age it tends to become ossified throughout and to fuse with the body.

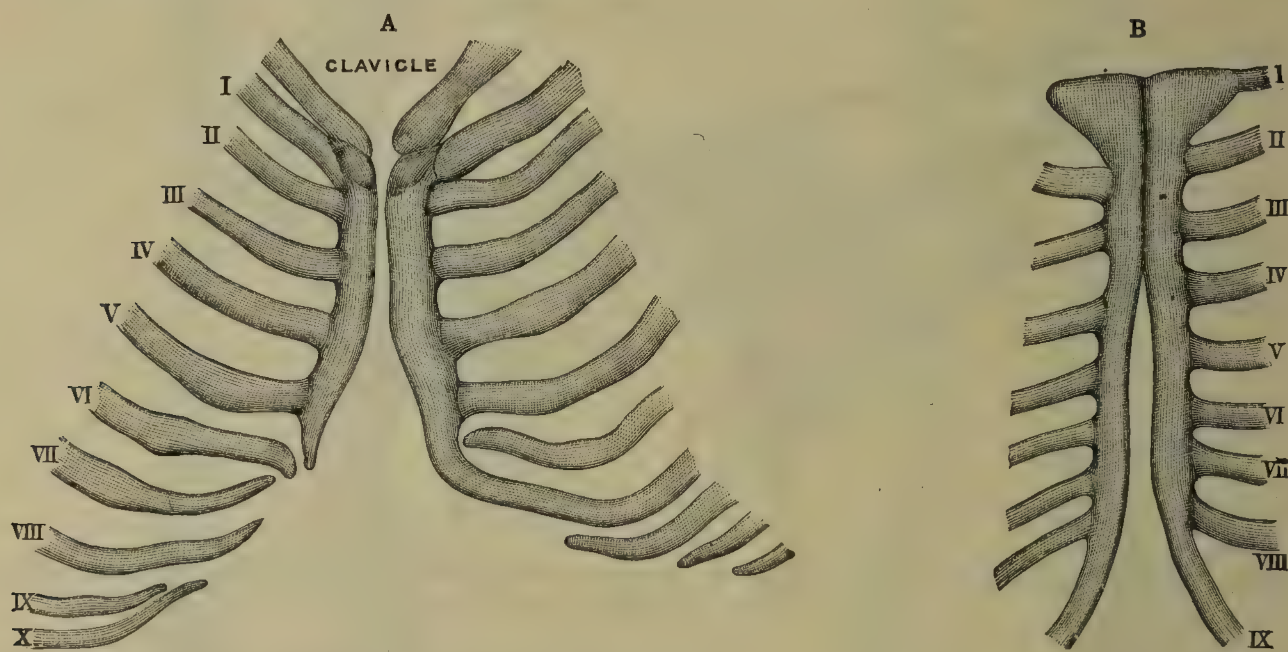


FIG. 210.—TWO STAGES IN THE FORMATION OF THE CARTILAGINOUS STERNUM. (After Ruge.)

The **anterior surface** of the xiphoid process gives attachment to a few fibers of the rectus abdominis muscle and the costoxiphoid ligament; the **posterior surface** to the sternal fibers of the diaphragm, and the lowest fibers of the transversus thoracis, while the lateral margins receive the aponeuroses of the abdominal muscles. Its tip is directly continuous with the linea alba.

Differences according to sex.—The sternum differs somewhat in the two sexes. The female sternum is relatively shorter, the diminution being confined almost to the body. In the male the body is more than twice as long as the manubrium, whereas in the female it is usually less than twice the length of the first piece.

Structurally the sternum is composed of spongy tissue covered with an outer layer of compact tissue. Its **arterial supply** is derived mainly from the sternal and perforating branches of the internal mammary.

Ossification.—The earlier stages in the development of the sternum are described on p. 34. The ossification of the sternum is slow and irregular. The process begins in the manubrium by a single center about the sixth month of intrauterine life, though occasionally other accessory centers are superadded.

The body usually ossifies from seven centers. The upper segment ossifies from a single median nucleus about the eighth month, and below this, three pairs of ossific nuclei appear, which may remain for a long time separate. Of these, two pairs for the second and third segments are visible at birth, and those for the lower segment make their appearance toward the end of the first year. The various lateral centers unite in pairs, so that at the sixth year the sternum consists of six pieces, the lowest (xiphoid) being cartilaginous. Very often, however, there are only four centers of ossification in the body, as shown in fig. 211. Gradually the four pieces representing the body fuse with one another, and at twenty-five they form a single piece, but exhibit, even in advanced life, traces of their original separation. A sternal foramen is usually the result of non-union across the middle line or of a defect of ossification.

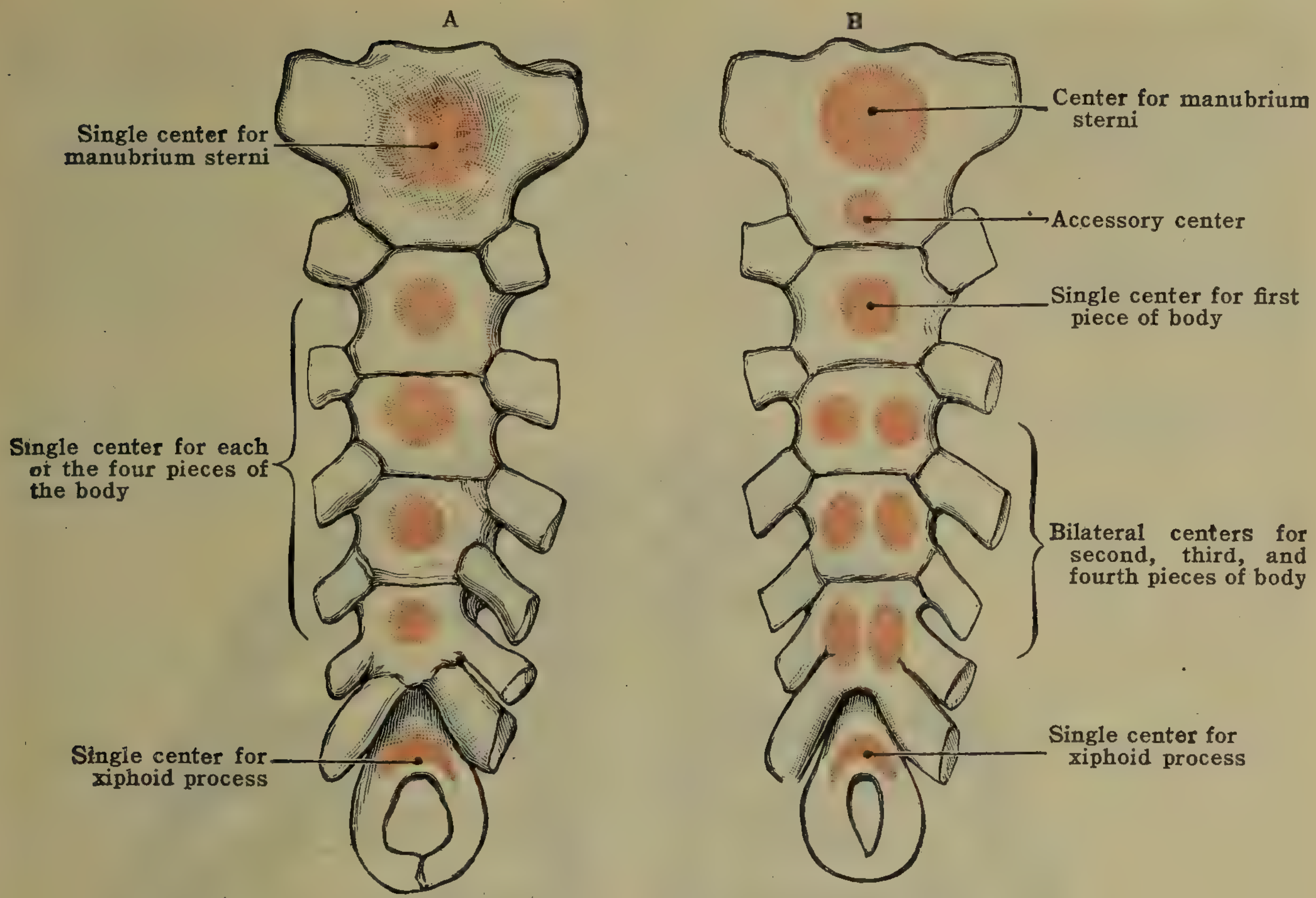


Fig. 211.—Ossification of the Sternum.

A, common arrangement of the ossific centers. B, showing accessory center in the manubrium sterni, and bilateral centers in the second, third, and fourth pieces of the body.

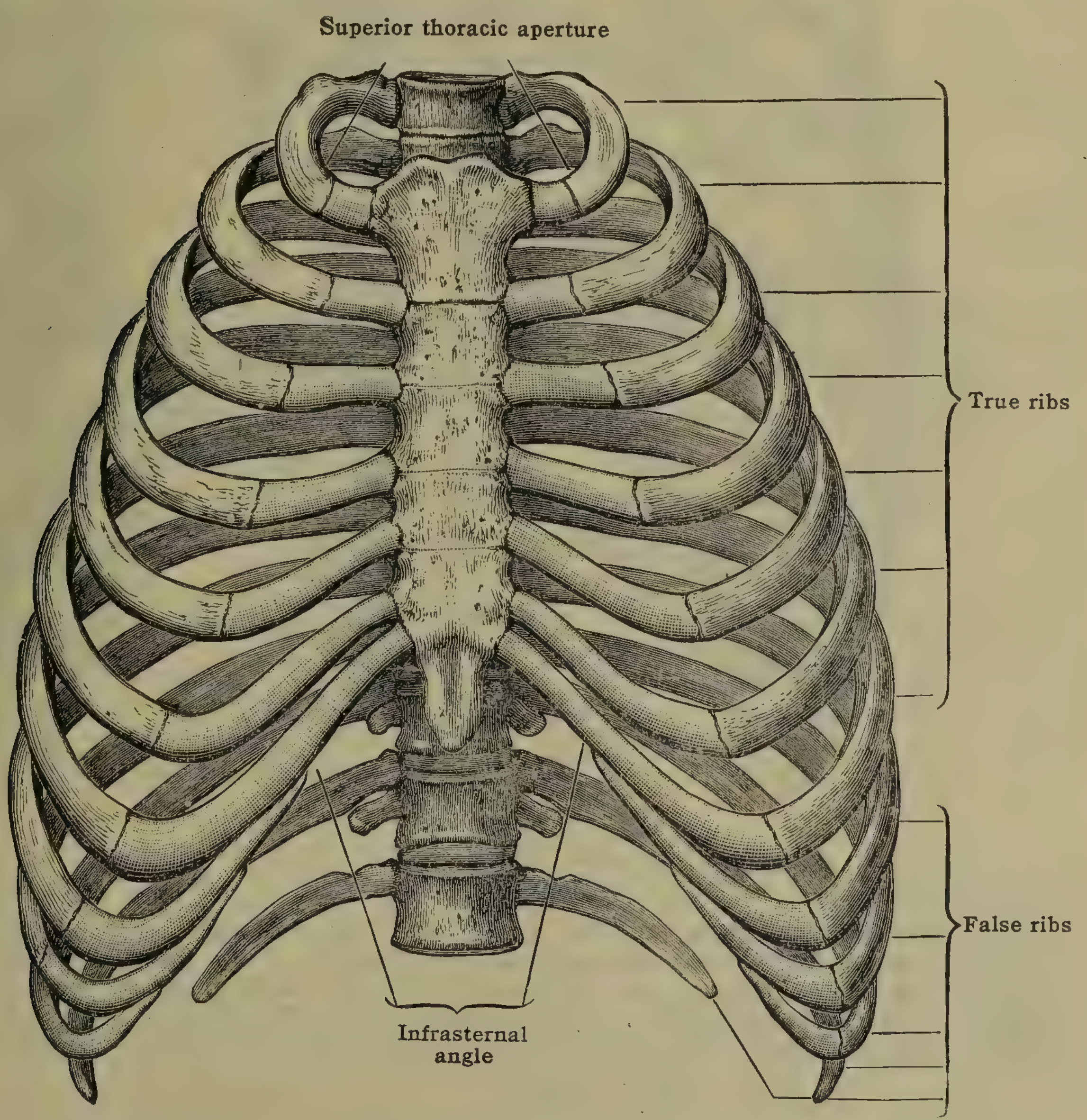


Fig. 212.—The Thorax. (Anterior view.)

The xiphoid is always imperfectly ossified, and does not join with the body till after middle life. The manubrium and body rarely fuse. The dates given above for the appearance of the various nuclei, and for the union of the various segments, are merely approximate, hence the sternum affords very uncertain data as to age.

Variations.—The mode of development of the sternum (figs. 210, 211) will explain some deviations to which it is occasionally subject. In rare instances the two lateral halves fail to unite, giving rise to the anomaly of a completely cleft sternum (fissura sterni). The union of the two halves may occur in the region of the manubrium and fail below, while in other cases the upper and lower parts have fused but the middle remains separate. The clefts are in many instances so small as not to be of any moment, and are not even recognized until the skeleton is prepared. In a few individuals, however, they have been so extensive as to allow the pulsation of the heart

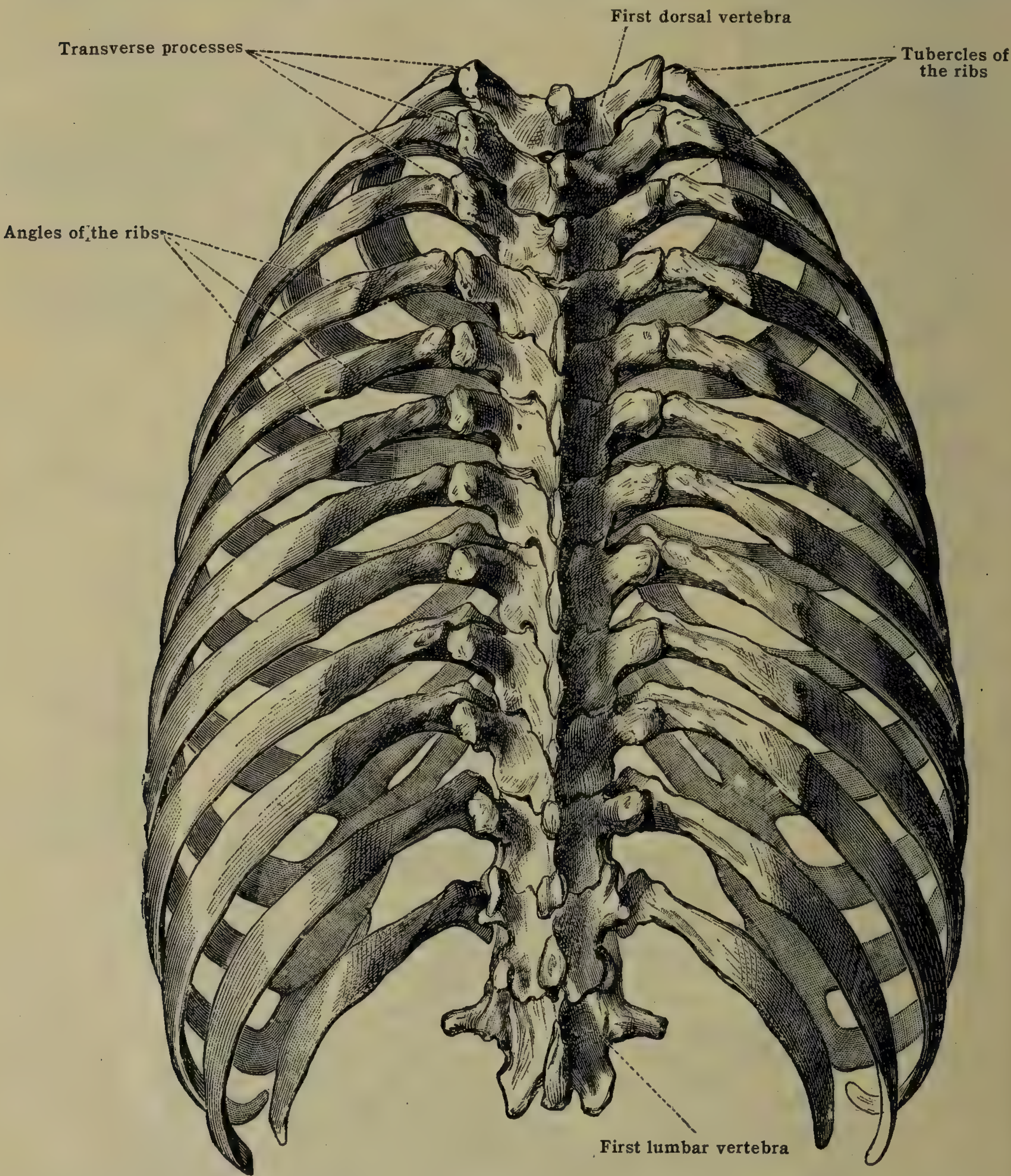


FIG. 213.—THE THORAX. (Posterior view.) (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

to be perceptible to the hand, and even to the eye, through the skin covering the defect in the bone. A common variation in the sternum is asymmetry of the costal cartilages. Instead of corresponding, the cartilages may articulate with the sternum in an alternating manner. Rarely a pair of cartilaginous nodules or ossicles [ossa suprasternalia] occur at the superior margin of the manubrium; these have been interpreted as vestiges of an *episternum*.

THE THORAX AS A WHOLE

The bony thorax (figs. 212, 213) is somewhat conical in shape, deeper behind than in front and compressed anteroposteriorly, so that in the adult it measures less in the sagittal than in

the transverse axis. The long **posterior** wall, formed by the thoracic vertebræ and the ribs as far lateralward as their angles, is convex from above downward, and the backward curve of the ribs produces on each side of the vertebræ externally, a deep furrow, the **costovertebral groove**, in which the sacrospinalis muscle and its subdivisions are lodged. The backward curve of the ribs produces also on each side a deep, broad groove or hollow, the **pulmonary sulcus** [sulcus pulmonalis], in which the posterior bulky margin of the lung is contained. The short **anterior** wall is formed by the sternum and costal cartilages. It is slightly convex and inclined forward in its lower part, forming an angle of about 20° with the vertical plane. The **lateral** walls are formed by the ribs from the angles to the costal cartilages. The top of the thorax presents an elliptical aperture, the **superior thoracic aperture** [apertura thoracis superior], which measures on an average 12.5 cm. (5 inches) transversely and 6.2 cm. (2½ inches) in its sagittal axis. It is bounded by the first thoracic vertebra behind, the upper margin of the manubrium sterni in front, and the first rib on each side. As the upper margin of the manubrium sterni is oftenest on a level with the disk between the second and third thoracic vertebræ, it follows that the plane of the opening is directed obliquely upward and forward. The sternal angle is usually opposite the body of the fifth thoracic vertebra and the junction between the body and xiphoid process corresponds to the disk between the ninth and tenth thoracic vertebræ. The **lower aperture of the thorax** [apertura thoracis inferior] is very irregular, and is formed by the twelfth thoracic vertebra and the twelfth ribs behind, and the curving free edge presented by the cartilages of the remaining false ribs, and the cartilage of the seventh rib meeting the sternum, at the sides and in front. The two borders form the **costal arch** [arcus costarum], which in the median line below the sternum forms the **infrasternal angle** (angulus arcus costarum NK). From this angle the xiphoid process projects downward. The intervals between the ribs are the **intercostal spaces** [spatia intercostalia], and are eleven in number on each side.

The ratio of the sagittal and the transverse diameter of the thorax forms the **thoracic index**, which is higher in the female and in children, in whom the thorax is more rounded. In the embryo (p. 19), the index is very much higher, the sagittal diameter being greater than the transverse. In the early embryo, the index is nearly 200; at birth it is about 90. In adults it varies from 70 to 75, averaging 2 or 3 per cent. lower in the male than in the female. It is also lower in the negro than in the white race. (Rodes, Zeitschr. f. Morph. u. Anthrop., Bd. 9.) The lower thoracic index in man (as compared with quadrupedal mammals) is partly an effect of gravity upon the anterior thoracic wall in the upright posture. Jackson, however, concludes that other factors are predominant.

II. THE APPENDICULAR SKELETON

A. BONES OF THE UPPER EXTREMITY

The skeleton of the upper limb [ossa extremitatis superioris] is adapted chiefly to the function of prehension which in man is perfected to a high degree. The

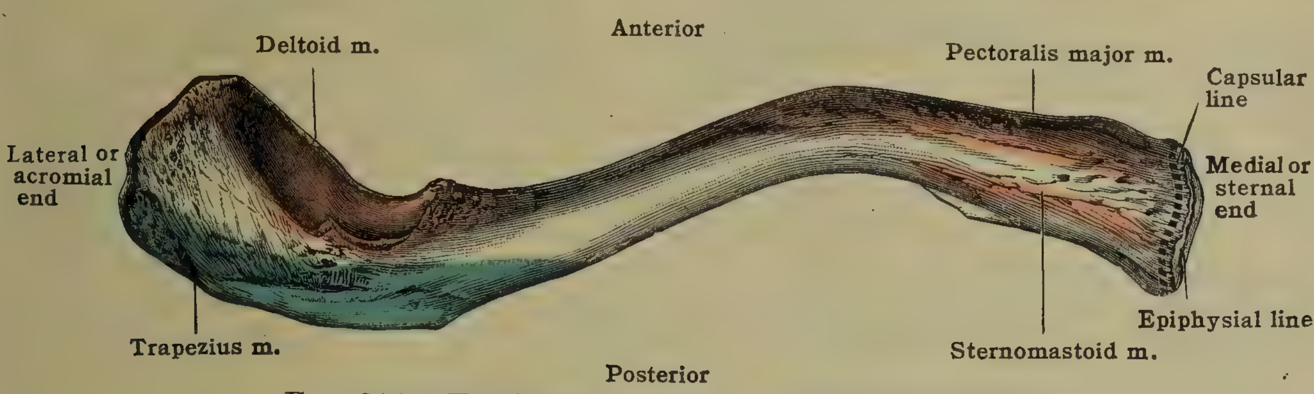


Fig. 214.—The Left Clavicle. (Superior surface.)

bones of the upper extremity may be arranged in four groups corresponding to the division of the limb into four segments. In the *shoulder* are the **clavicle** and the **scapula**, which together constitute the **girdle of the upper extremity** [cingulum extremitatis superioris] or pectoral girdle: in the *arm* is the **humerus**; in the *forearm* are the **radius** and **ulna**; and in the *hand* the **carpus**, the **metacarpus**, and the **phalanges**.

THE CLAVICLE

The **clavicle** [clavicula] or collar bone (figs. 214, 215) is situated immediately above the first rib and extends from the upper border of the manubrium sterni, laterally and backward to the acromion of the scapula. It connects the upper limb with the trunk, and is so situated that while the medial end is securely but flexibly united with the sternum and first costal cartilage, the lateral end is joined with the scapula, supporting it firmly in its various positions and associated with it in all its movements. The clavicle functions chiefly as a prop to the shoulder, putting it away from the side of the body and so establishing conditions for free action of the arm. The clavicle is a long bone, and when viewed

from above presents a double curvature, so that it somewhat resembles in shape the italic letter *f*, with a medial prismatic portion, convex forward, and a lateral flattened portion, concave forward.

Prismatic portion.—The medial two-thirds of the bone, extending from the sternal extremity to a point opposite the coracoid process of the scapula, has the form of a triangular prism. This portion, however, is subject to considerable variations of form, being more cylindrical in ill-developed specimens and becoming almost quadrangular when associated with great muscular development. In a typical specimen it is marked by three borders separating three surfaces. Of these, the **anterior surface** is convex and divided near the sternal end by a prominent ridge into two parts, a lower, giving origin to the clavicular portion of the pectoralis major; an upper, for the clavicular portion of the sternocleidomastoid muscle. Near the middle of the shaft the ridge disappears, the surface is smooth, and is covered only by the integument, and the platysma. The **posterior surface** is concave, forming an arch over the brachial plexus and the subclavian artery, broadest medially and smooth in its whole extent. It gives origin near the sternal extremity to a part of the sternohyoid and occasionally to a few fibers of the sternothyroid muscle. Somewhere near the middle of this surface is a small **nutrient foramen,** directed laterally, for the chief nutrient artery of the bone,

FIG. 215.—THE LEFT CLAVICLE. (Inferior surface.)

derived from the transverse scapular (suprascapular) artery. Sometimes the foramen is situated on the inferior surface of the bone, in the subclavian groove. On the **inferior surface** near the sternal end is a rough area, the **costal tuberosity** [tuberositas costalis], about twenty mm. in length, for the attachment of the costoclavicular ligament by which the clavicle is fixed to the cartilage of the first rib. More laterally is a longitudinal groove for the subclavius muscle bordered by two lips, to which the sheath of the muscle is attached. To the posterior of the two lips the layer of deep cervical fascia which binds down the posterior belly of the omohyoid to the clavicle is also attached.

Of the three **borders,** the **superior** separates the anterior and posterior surfaces. Beginning at the sternal end, it is well-marked, becomes rounded and indistinct in the middle, whilst laterally it is continuous with the posterior border of the outer third. The **posterior border** separates the inferior and posterior surfaces and forms the posterior lip of the subclavian groove. It begins at the costal tuberosity and can be traced laterally as far as the coracoid tubercle, an eminence on the under aspect of the bone near the junction of the prismatic and flattened portions. The **anterior border** is continuous with the anterior border of the flattened portion and separates the anterior and inferior surfaces. Medially, it forms the lower boundary of the elliptical area for the origin of the pectoralis major muscle, and approaches the posterior border. Near the middle of the bone it coincides with the anterior lip of the subclavian groove.

Flattened portion.—The lateral third of the bone is flattened from above downward and presents two surfaces and two borders. The **superior surface** is rough and looks directly upward and gives attachment to the trapezius muscle behind and the deltoid in front; between the two areas the surface is subcutaneous. On the **inferior surface** is a rough elevation, the **coracoid tuberosity** [tuberositas coracoidea]; it overhangs the coracoid process and gives attachment to the coracoclavicular ligament which binds the clavicle down to the coracoid process.

The coracoid tuberosity presents medially and posteriorly the projection named **conoid tubercle** and laterally the obliquely placed **trapezoid line;** giving attachments to the conoid and trapezoid subdivisions of the coracoclavicular ligament.

The **sternal extremity** [extremitas sternalis] of the clavicle presents a triangular **articular surface** [facies articularis sternalis], directed medially, downward, and a little forward, slightly concave from before backward and convex from above downward (saddle-shaped), which articulates with the clavicular notch on the upper border of the manubrium sterni through an interposed interarticular disk.

Of the three angles, one is above and two below. The *posteroinferior angle* is prolonged backward, and so renders this surface considerably larger than that with which it articulates; the *superior angle* receives the attachment of the upper part of the disk. The lower part of the surface is continuous with a facet on the under aspect of the bone, medial to the costal tuberosity, for the first costal cartilage. The circumference of the extremity is rough, and gives attachment to the articular capsule and sternoclavicular ligament, and to the interclavicular ligament above.

The **acromial extremity** [extremitas acromialis] presents a smooth, oval, articular facet, flattened or convex (form and size very variable), directed laterally and slightly downward for the articular surface of the acromion; its border is rough, for the attachment of the capsule of the acromioclavicular joint.

Structure.—The clavicle consists externally of a compact layer of bone, much thicker in the middle and thinning out gradually toward the two extremities. There is no true medullary cavity, for the interior is occupied from end to end by spongy tissue, the amount in the various parts of the bone being in inverse proportion to the thickness of the outer compact shell.

The left clavicle is straighter and probably longer than the right; the male clavicle thicker relatively than the female.

Ossification.—From observations made by F. P. Mall, D. C. L. Fitzwilliams, and E. Fawcett it seems almost certain that there are two centers of ossification of the shaft of the clavicle, at the juncture of the middle and lateral thirds. They appear very early (first ossific center in the body), about the fifth week of embryonic life, and rapidly fuse. The ossific process extends medially and laterally along the shaft toward the medial and lateral extremities, respectively. About the eighteenth year a secondary center appears at the sternal end and forms a small epiphysis which joins the shaft about the twenty-fifth year. According to observations of Todd and D'Errico, Jr., an epiphyseal center appears at the acromial extremity in the twentieth year and unites within the same year (Am. Jour. Anat., 1928, 41: 25).

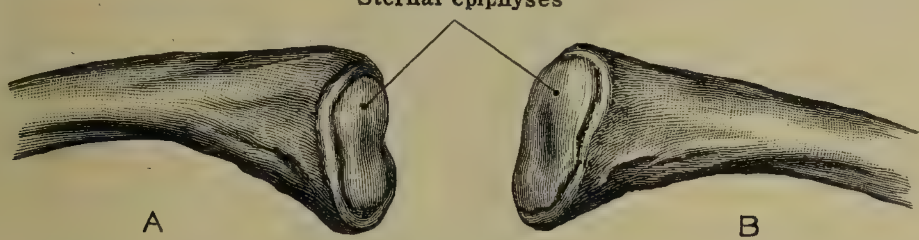


FIG. 216.—THE STERNAL ENDS OF TWO CLAVICLES WITH EPIPHYSES.
A, right clavicle from below and behind. B, left clavicle from below and behind.
(From Royal College of Surgeons Museum.)

Variations.—Not infrequently the shaft of the clavicle is perforated by a small canal transmitting one of the cutaneous nerves of the cervical plexus (in 6.6. per cent. Santos Fol. Anat. Univ. Coim., 1927, 2: 21). The most important deviation from the type is a true variation, with a hereditary tendency, namely partial or total (very rare) absence of one or both clavicles. This rare condition is the more remarkable because of its constant association with certain defects of the cranium. It has been named *dysostosis cleidocranialis*. For further details, see Hultkranz, Zeitschr. f. Morph. u. Anthropol., 1908, 11: 385; Huc, Ann. Anat. Pathol., 1927, 4: 267.

THE SCAPULA

The **scapula** (figs. 217, 218, 219) is a large flat bone, triangular in shape, situated on the dorsal aspect of the thorax, between the levels of the second and seventh ribs. It is attached to the trunk by means of the clavicle, with which it is articulated, and by various muscles through which a variety of movements are permitted; it articulates with the humerus at the shoulder-joint. The greater part of the scapula consists of a triangular plate known as the **body**, from which two processes are prolonged: one anterior in position, is the **coracoid**; the other, posterior in position, is the **spine**, which is continued laterally into the **acromion.**

The body presents two surfaces, three borders, and three angles. The **costal** (anterior) **surface** [facies costalis], looks considerably medialward, is deeply concave, forming the **subscapular fossa** [fossa subscapularis].

The fossa is marked by several oblique **muscular lines** [lineæ musculares] which commence at the posterior border and pass obliquely upward and laterally; these lines or ridges divide

the surface into several shallow grooves, from which the subscapularis muscle takes origin, while the ridges give attachment to the tendinous intersections of that muscle. The lateral third of the surface is smooth and overlapped by the subscapularis, while medially are two small flat areas in front of the upper and lower angles respectively, but excluded from the subscapular fossa by fairly definite lines and joined by a ridge which runs close to the vertebral border. The ridge and its terminal areas serve for the insertion of the serratus anterior muscle.

The **dorsal** (posterior) **surface** [facies dorsalis] is generally convex and divided by a prominent plate of bone—the **spine**—into two unequal parts. The hollow above the spine is the **supraspinous fossa** [fossa supraspinata] and lodges the supraspinatus muscle. The part below the spine is the **infraspinous fossa** [fossa infraspinata]; it is three times as large as the supraspinous fossa, is alternately concave and convex, and gives origin to the infraspinatus. The muscle is

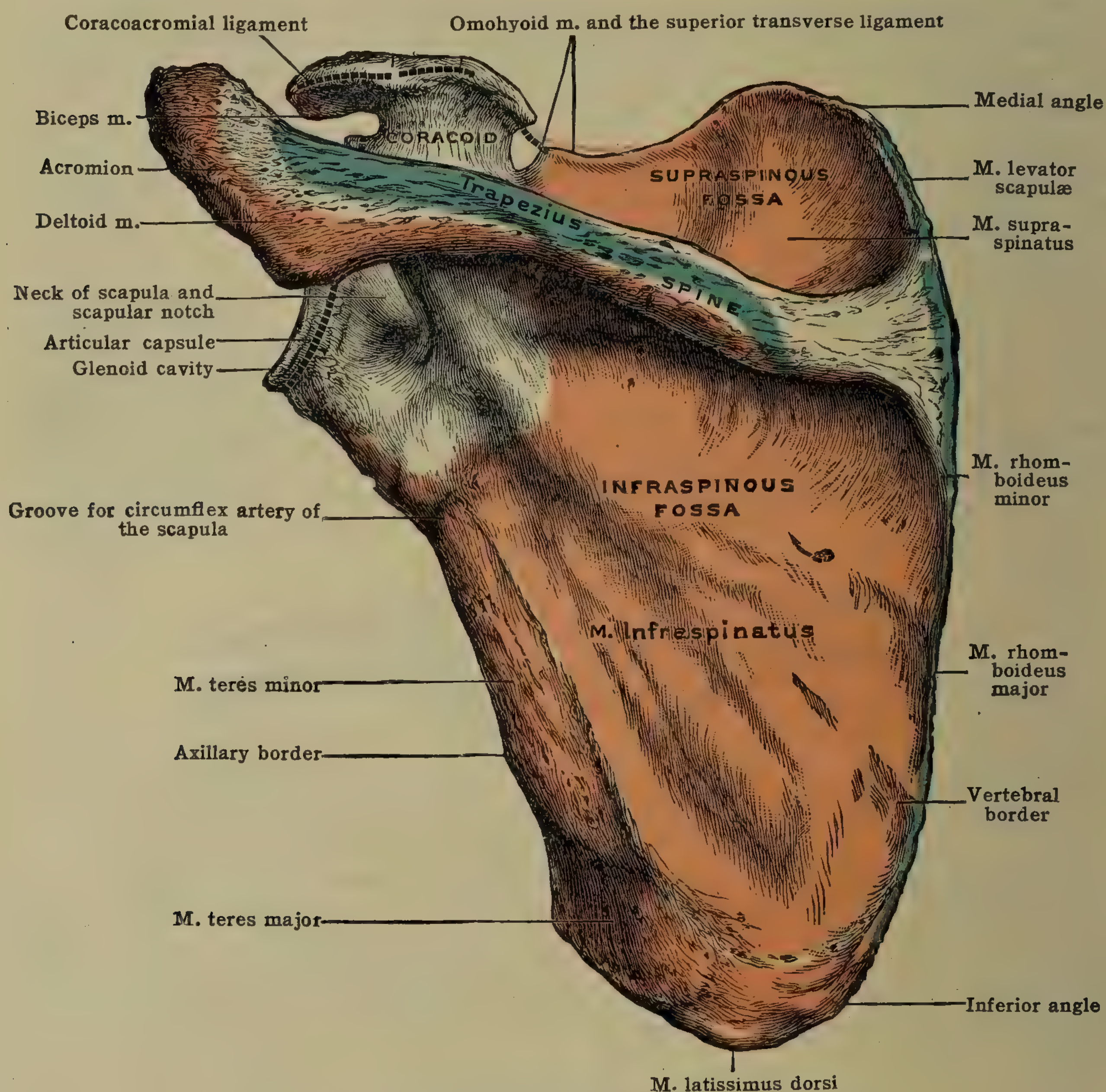


FIG. 217.—THE LEFT SCAPULA. (Dorsal surface.)

attached to its medial three-fourths and covers the lateral fourth, without taking origin from it.

The infraspinous fossa does not extend as far as the axillary border, but is limited laterally by a ridge—**the oblique line**—which runs from the glenoid cavity—the large articular surface for the head of the humerus—downward and backward to join the posterior border a short distance above the inferior angle. This line, which gives attachment to a stout aponeurosis, cuts off an elongated surface, narrow above for the origin of the teres minor muscle, and crossed near its middle by a groove for the circumflex (dorsal) artery of the scapula; below, the surface is broader for the origin of the teres major muscle and occasionally a few fibers of the latissimus dorsi muscle. The two areas are separated by a line which gives attachment to an aponeurotic septum situated between the two teres muscles.

The supra- and infraspinous fossæ communicate through the **great scapular notch** at the lateral border of the spine, and through the notch the suprascapular nerve and transverse scapular artery are transmitted from one fossa to the other.

Borders.—The three borders of the scapula are named superior, vertebral, and axillary. The **superior** [margo superior] (margo cervicalis NK) is short and thin and extends from the medial angle to the coracoid process. Laterally it presents a deep depression, the **scapular notch** [incisura scapulæ] to the extremities of which the superior transverse ligament is attached.

The notch or foramen transmits the suprascapular nerve, while the transverse scapular artery usually passes over the ligament. From the adjacent margins of the notch and from the ligament the posterior belly of the omohyoid muscle takes origin.

The **vertebral border** [margo vertebralis] (sometimes called the base) is the longest, and extends from the medial to the lower angle of the bone.

It is divisible into three parts, to each of which a muscle is attached: an upper portion extending from the medial angle to the spine, for the insertion of the levator scapulæ; a middle portion, opposite the smooth triangular area at the commencement of the spine, for the rhomboideus minor muscle; and the lowest and longest portion, extending below this as far as the inferior angle, for the rhomboideus major muscle, the attachment of which takes place through the medium of a fibrous arch. This portion of the vertebral margin may be convex, straight or concave.

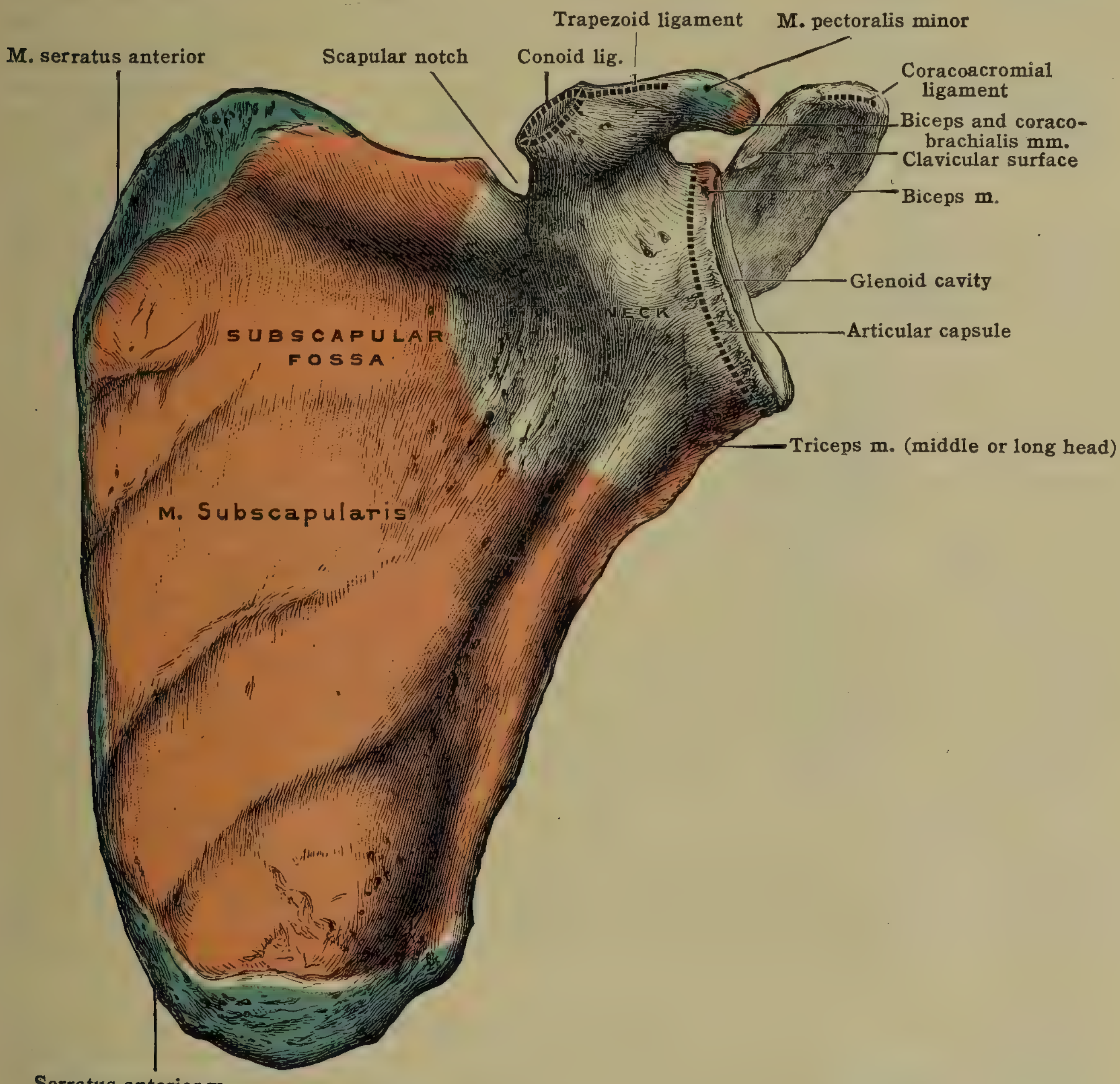


FIG. 218.—THE LEFT SCAPULA. (Costal surface.)

The **axillary border** [margo axillaris] is the thickest, and extends from the lower margin of the glenoid cavity to the inferior angle of the bone. Near its junction with the glenoid cavity there is a rough surface, about 2.5 cm. (1 in.) in length, the **infraglenoid tuberosity** [tuberositas infraglenoidalis], from which the long head of the triceps muscle arises, and below the tuberosity is the groove for the circumflex (dorsal) artery of the scapula. The upper two-thirds of the

border is deeply grooved on the ventral aspect and gives origin to a considerable part of the subscapularis muscle.

Angles.—The three angles are named medial, inferior, and lateral.

The **medial** (or superior) **angle** [angulus medialis] (angulus cranialis NK) forming the highest part of the body, is thin, smooth, and either rounded or approximating a right angle. It is formed by the junction of the superior and vertebral borders and gives insertion to a few fibers of the levator scapulæ muscle. The **inferior angle,** constituting the lowest part of the body, is thick, rounded, and rough. It is formed by the junction of axillary and vertebral borders, gives origin to the teres major muscle, and is crossed horizontally by the upper part of the latissimus dorsi muscle, the latter occasionally receiving from it a small slip of fleshy fibers.

The **lateral angle** [angulus lateralis] (angulus articularis NK) forms the expanded portion of the bone known as the **head,** bearing the **glenoid cavity,** and supported by a somewhat constricted **neck.** The glenoid cavity [cavitas glenoidalis] (fossa articularis NK) is a wide, shallow, pyriform, articular surface for the head of the humerus, directed forward and laterally, with the apex above and the broad end below. Its margin is raised, and affords attachment to the glenoid lip, which deepens its concavity. The margin is not, however, of equal prominence throughout, being somewhat defective where it is overarched by the acromion, notched anteriorly, and elevated above to form a small eminence, the **supraglenoid tuberosity** [tuberositas supraglenoidalis], for the origin of the long head of the biceps muscle of the arm.

The circumference and adjoining part of the neck give attachment to the articular capsule of the shoulder-joint, and the anterior border to the three accessory ligaments of the capsule, known as the superior, middle, and inferior glenohumeral folds. In the recent state the glenoid cavity is covered with hyaline cartilage. The **neck** is more prominent behind than before and below than above, where it supports the coracoid process. It is not separated by any definite boundary from the body of the scapula.

Processes.—The **spine of the scapula** [spina scapulæ] is a strong, triangular plate of bone attached obliquely to the dorsum of the scapula and directed backward and upward. Its apex is situated at the vertebral border; the base, corresponding to the middle of the neck, is free, concave, and gives attachment to the inferior transverse ligament, which arches over the transverse scapular (suprascapular) vessels and suprascapular nerve. Of the two borders, the anterior is joined to the body of the scapula, while the posterior is free, forming a prominent subcutaneous **crest.** The latter commences at the vertebral border, in a smooth triangular area, over which the tendon of the trapezius muscle glides, usually without the intervention of a bursa, as it passes to its insertion into a small tubercle on the crest beyond. Further laterally, this border is rough, and presents two lips—a superior for the insertion of the trapezius and an inferior for the origin of the deltoid muscle. Laterally the crest is continued into the **acromion.**

The **spine** has two surfaces, the superior, which also looks medialward and forward, is concave, contributes to the formation of the supraspinous fossa, and gives origin to the supraspinatus muscle; the inferior surface, also slightly concave, is directed lateralward and backward, forms part of the infraspinous fossa, and affords origin to the infraspinatus muscle. On both surfaces are one or more conspicuous vascular foramina.

The **acromion,** a process overhanging the glenoid cavity, springs from the angle formed by the junction of the crest with the base of the spine. Somewhat crescentic in shape, it forms the summit of the shoulder and is compressed from above downward so as to present two surfaces, two borders, and two extremities.

The posterior part sometimes terminates laterally in a prominent **acromial angle** (metacromion) and the process then assumes a more or less triangular form. Of the two extremities, the posterior is continuous with the spine, while the anterior forms the free tip. The upper surface, directed upward, backward, and slightly lateralward, is rough and convex, and affords origin at its lateral part to a portion of the deltoid muscle; the remaining part of this surface is subcutaneous. The lower surface, directed downward, forward, and slightly medialward, is concave and smooth. The medial border, continuous with the upper lip of the crest, presents, from behind forward, an area for the insertion of the trapezius muscle; a small, oval, concave (but variable) **articular surface** [facies articularis acromii] for the acromial articular surface of the clavicle, the edges of which are rough for the acromioclavicular ligaments; and, beyond this, the anterior extremity or tip, to which is attached the coracoacromial ligament. The lateral border, continuous with the inferior lip of the crest, is thick, convex, and presents three or four tubercles with intervening depressions; from the tubercles the tendinous septa in the

acromial part of the deltoid muscle arise, and from the depressions, some fleshy fibers of the same muscle.

Projecting upward from the neck of the scapula is the **coracoid process** [processus coracoideus], bent finger-like, pointing forward and laterally. It consists of two parts, ascending and horizontal, placed at almost a right angle to each other.

The *ascending part* arises by a wide root, extends upward and medially for a short distance, and is compressed from before backward; it is continuous above with the horizontal part and below with the neck of the scapula; the lateral border lies above the glenoid cavity and gives attachment to the coracohumeral ligament; the medial border, which forms the lateral boundary of the scapular notch, gives attachment to the conoid ligament above and the superior transverse ligament below. Its anterior and posterior surfaces are in relation with the subscapularis and supraspinatus muscles respectively. The *horizontal part* of the process runs forward and lateralward; it is compressed from above downward so as to present two borders, two surfaces, and a free extremity. The medial border gives insertion along its anterior half to the pectoralis minor muscle and nearer the base to the coracoclavicular fascia (costocoracoid membrane); the lateral border is rough for the coracoacromial and coracohumeral ligaments; the upper surface is irregular and gives insertion in front to the pectoralis minor, and behind to the

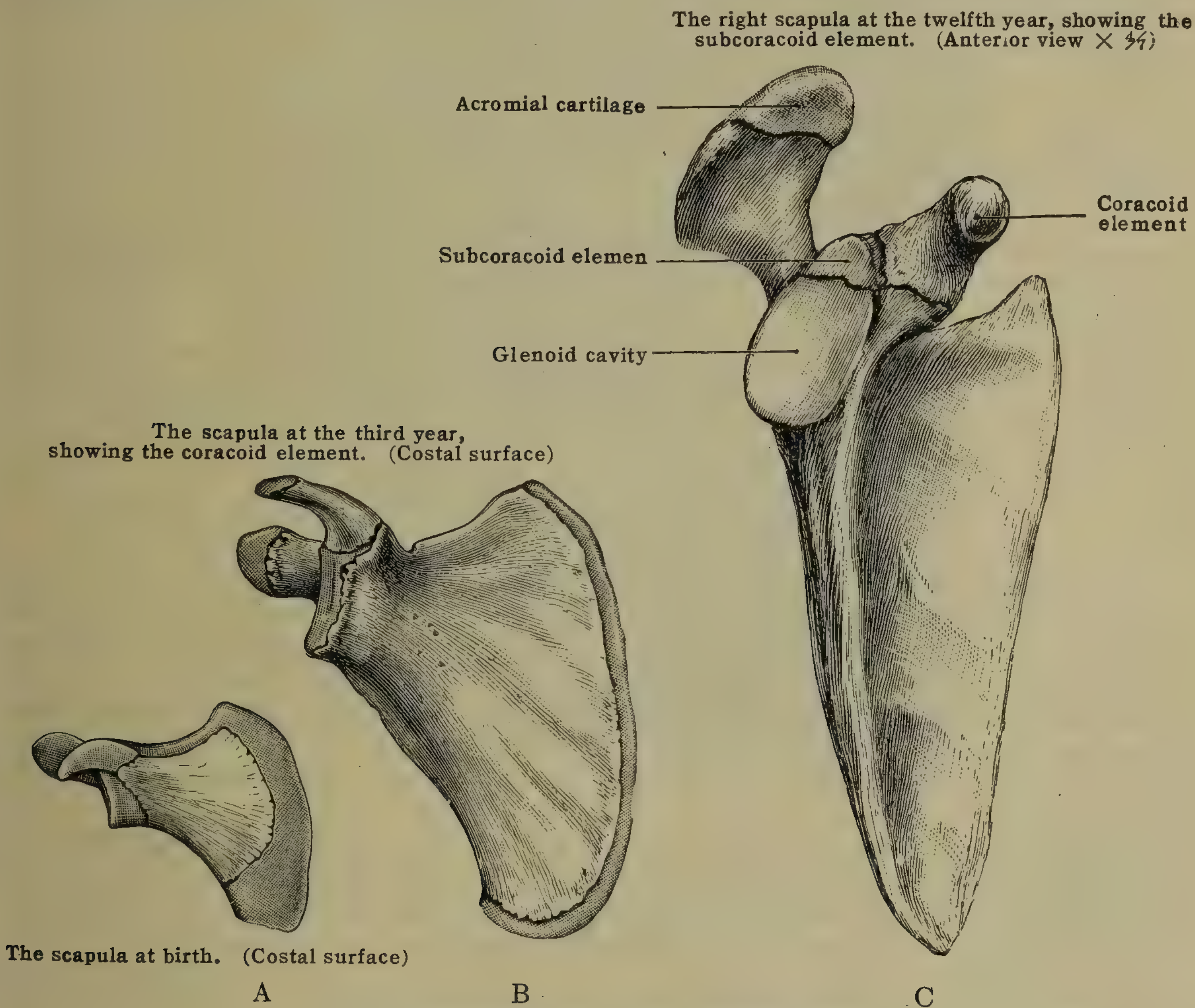


Fig. 219.—Ossification of the Scapula.

trapezoid ligament; the inferior surface is smooth and directed toward the glenoid cavity, which it overhangs; the free extremity or apex gives origin to the conjoined coracobrachialis and short head of the biceps muscles.

Structure and vessels.—The greater part of the body of the scapula and the central part of the spinous process are thin and transparent. The coracoid and acromion processes, the crest of the spine and inferior angle, the head, neck, and axillary border, are thick and opaque. The young bone consists of two layers of compact tissue with an intervening spongy layer, but in the transparent parts of the adult bone the middle layer has disappeared. The vascular foramina on the costal surface transmit twigs from the subscapular and transverse scapular (suprascapular) arteries; those in the infraspinous fossa, twigs from the circumflex and transverse scapular arteries, the latter also giving off vessels which enter the foramina in the supraspinous fossa. The acromion is supplied by branches from the thoracoacromial artery.

The line of attachment of the spinous process to the dorsum of the scapula is known as the **morphological axis,** and the obtuse angle in the subscapular fossa opposite the spine as the *subscapular angle.* From the axis three plates of bone radiate as from a center, the **prescapula** forward, the **mesoscapula** laterally, and the **postscapula** backward, being named in accordance with the long axis of the body in the horizontal position. In the human subject the postscapula

is greatly developed, and this is associated with the freedom and versatility of movement possessed by the upper limb.

The **scapular index**, $\frac{\text{morphological length} \times 100}{\text{morphological breadth}}$, is the ratio between the breadth and length of the bone. The index is higher in negroes than in Europeans; it is also higher in women than in men.

Ossification.—The scapula is ossified from nine centers. Of these, two (for the body of the scapula and the coracoid) may be considered as **primary**, and the remainder as **secondary.** The center for the body appears in a plate of cartilage near the neck of the scapula about the eighth week of intrauterine life, and quickly forms a triangular plate of bone, from which the spine appears as a slight ridge about the middle of the third month. At birth the glenoid cavity and part of the scapular neck, the acromion and coracoid process, the vertebral border and inferior angle, are cartilaginous. During the first year a nucleus appears for the coracoid, and at the tenth year a second center appears for the base of the coracoid and the upper part of the glenoid cavity (subcoracoid, fig. 219). The coracoid center has recently been reported present at birth and in the fetus (Sydney Smith, Jour. Anat., 1925, 59: 387).

During the fifteenth year the coracoid unites with the scapula, and about this time the other secondary centers appear. Two nuclei are deposited in the acromial cartilage, and fuse to form the acromion, which joins the spine at the twentieth year. The union of spine and acromion may be fibrous, hence the latter is sometimes found separate in macerated specimens. The cartilage along the vertebral border ossifies from two centers, one in the middle, and another at the inferior angle. A thin lamina is added along the upper surface of the coracoid process and occasionally another at the margin of the glenoid cavity. These epiphyses join by the twenty-fifth year.

The occurrence of a special primary center for the coracoid process is of morphological importance in that the process is the representative of what in the lower vertebrates is a distinct *coracoid bone.* This primarily takes part in the formation of the glenoid cavity and extends medially to articulate with the sternum. In man and all the higher mammals only the lateral portions of the bone persists.

Variations.—The scapular notch is sometimes found bridged over by bone converting it into a foramen (normal in some animals). The whole acromion process may fail to unite or a part of it, representing one of the two or three component centers may be separate. Scapulæ with concave vertebral margins (scaphoid type) have been described by Dr. W. W. Graves as of frequent occurrence in the earlier decades of life, generally poorly ossified and with low scapular index. Abnormally high position of the scapulæ (Sprengel's deformity) has been explained by arrest in the shifting of the pectoral girdle downward from its primitive position in the embryo. A plate of bone extending from the vertebral margin of the scapula to the vertebral column is rarely encountered.

Clinical Relations of the Shoulder Region

Landmarks of the shoulder.—The following surface marks, of the greatest importance in determining the nature of shoulder injuries, should receive careful consideration:—The **clavicle** in its whole extent, the **acromion,** the **greater tubercle,** and **upper part of the shaft of the humerus.** Much less distinctly, the position of the **coracoid process** in the infraclavicular fossa and the **head of the humerus** through the axilla can be made out. The anterior margin of the **clavicle,** convex medially and concave laterally, can be followed in its whole extent, the bone, if traced laterally, being found not to be horizontal, but rising somewhat to its junction with the acromion. The most important relations of this bone are, passing from the medial end laterally, the subclavian vein, the subclavian artery, and the cords of the brachial plexus as they lie on the first rib (cf. fig. 598). The **sterno-** and **acromioclavicular joints** are referred to on p. 308.

The *frequency of fracture of the clavicle* is explained chiefly by its exposure to shocks of varied kinds from the upper extremity, inseparable from the out-rigger-like action of the bone and its early ossification. On the other hand, the main safeguards are the elasticity and curves of the bone, the way in which it is embedded in muscles which will damp vibrations, and the buffer-bond articular disks at either extremity. The looseness and toughness of the overlying skin explain the rarity of compound fracture here. The junction of the two curves is the weakest spot and the usual site of fracture. The weight of the limb acting through the coracoclavicular ligaments and overcoming the trapezius is the chief factor in the downward displacement; the pectoralis minor and serratus anterior acting on the scapula draw the acromial fragment forward. The tip of the *acromion,* when the arm hangs by the side with hand supinated, is in the same line as the lateral epicondyle of the humerus and the styloid process of the radius. On the medial side, the head and medial epicondyle of the humerus and the styloid process of the ulna are in the same line. Thus the *greater tubercle* looks laterally, the *head* medially, and the *lesser tubercle* somewhat forward. Between the two tubercles runs the *intertubercular (biciptal) groove,* which, with the arm in the above position, looks directly forward. In thin subjects its lower part can be defined. Its position can be marked with sufficient accuracy by a line running downward from the acromion in the long axis of the humerus. Besides containing the long tendon of the biceps and its synovial sheath and the insertion of the latissimus dorsi, the ascending branch of the anterior circumflex artery runs in the groove. When the fingers are placed on the acromion and the thumb in the axilla, the lower edge of the glenoid

cavity can be felt; and if the humerus be rotated (the elbow-joint being flexed), the head of the humerus can be felt also.

The **characteristic roundness of the shoulder** is due to the greater tubercle of the humerus lying under the deltoid (cf. fig. 220). In dislocation the loss of this roundness is due to the displacement of the head and tubercle and consequent projection of the acromion.

This normal projection of the deltoid renders it impossible to place a flat straight body in contact with both the acromion and the lateral epicondyle at the same time (Hamilton's dislocation test). Below the junction of the lateral and middle thirds of the clavicle, between the contiguous origins of the pectoralis major and deltoid, is the infraclavicular fossa, in which lie the cephalic vein, the deltoid branch of the thoracoacromial artery, and a lymphatic node which may be involved in obstinate tuberculosis of the cervical groups. On pressing deeply here, the coracoid process can be made out if the muscles are relaxed, and the axillary artery compressed against the second rib.

Fig. 220.—Adult Shoulder-joint, as Shown by the Röntgen-rays. (Cf. fig. 226.)

Scapula.—Concerning the landmarks in the back, the student should be careful to trace the angles and borders of the scapula as far as these are accessible. The upper border is the one most thickly covered. With the hands hanging down, the upper (medial) angle corresponds to the upper border of the second rib; the lower angle to the seventh intercostal space; and the root of the spine of the scapula to the interval between the third and fourth thoracic spines.

The axillary border of the scapula, covered by the latissimus dorsi and teres major, may best be palpated with the arm hanging to the side. The vertebral border is brought into prominence by placing the hand on the opposite shoulder. This border is held in apposition with the thorax by the serratus anterior; consequently in paralysis of that muscle, supplied by the thoracodorsal nerve (5, 6, and 7 C.), it becomes unduly prominent, giving rise to 'winged scapula.'

THE HUMERUS

The **humerus** (figs. 221–225) is the longest and largest bone of the upper limb, and extends from the shoulder above, where it articulates with the scapula, to the elbow below, where it articulates with the two bones of the forearm. It is divisible into a **shaft** and two extremities; the *upper* extremity includes the **head, neck,** and two **tubercles**—great and small; the *lower* extremity includes the **articular surfaces for the ulna and radius** with the surmounting **fossæ** in front and behind, and the two **epicondyles.**

Upper extremity.—The **head of the humerus** [caput humeri] forms a nearly hemispherical articular surface, cartilage-clad in the recent state and directed

upward, medially, and backward toward the glenoid cavity. Below the head the bone is rough and somewhat constricted, constituting the **anatomical neck** [collum anatomicum], best marked superiorly, where it forms a groove separating the articular surface from the two tubercles. The circumference of the neck gives attachment to the articular capsule of the shoulder-joint. The lowest part of the capsule descends upon the humerus some distance from the articular margin. Laterally and in front of the head are the two tubercles, separated by a deep furrow. The **greater tubercle** [tuberculum majus], lateral in position and

FIG. 221.—THE LEFT HUMERUS. (Anterior view.)

reaching higher than the **lesser tubercle** [tuberculum minus], is marked by three impressions for the insertion of muscles: an upper one for the supraspinatus, a middle for the infraspinatus, and a lower for the teres minor. The **lesser tubercle** is situated in front of the head and is the more prominent of the two; it receives the insertion of the subscapularis muscle. The furrow between the tubercles lodges the long tendon of the biceps and forms the commencement of the **intertubercular groove** [sulcus intertubercularis], which extends downward along the shaft of the humerus. Between the tubercles the transverse humeral ligament

converts the upper end of the groove into a canal. In addition to the long tendon of the biceps and its tube of synovial membrane, the groove transmits a branch of the anterior circumflex artery. Immediately below the two tuberosities the bone becomes contracted and forms the **surgical neck** [collum chirurgicum].

The **shaft** or **body** [corpus humeri] is somewhat cylindrical above, flattened and prismatic below. Three borders and three surfaces may be recognised.

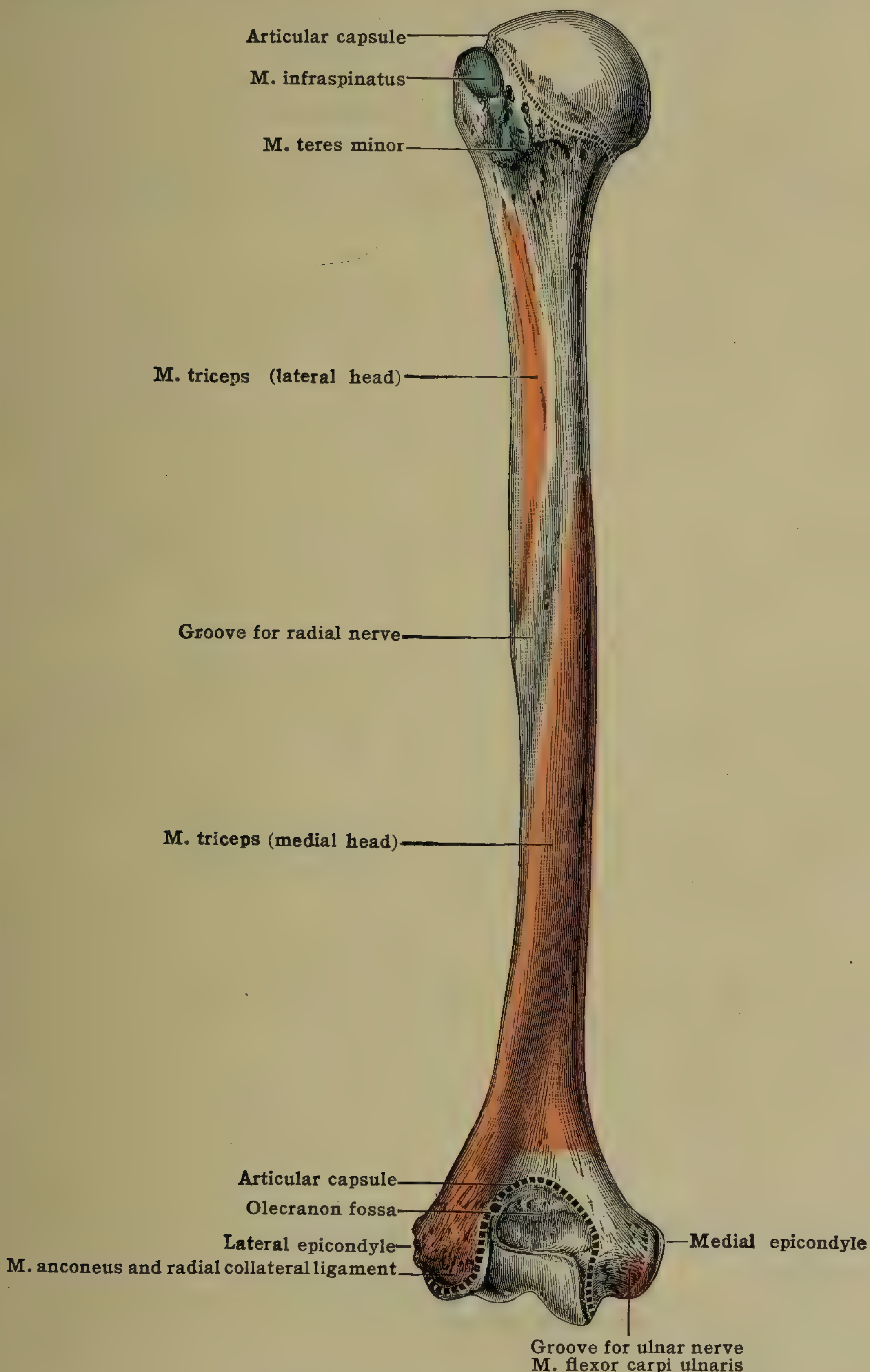


Fig. 222.—The Left Humerus. (Posterior view.)

Borders.—The **anterior border** commences above at the greater tubercle, and its upper part, forming the **crest of the greater tubercle** [crista tuberculi majoris] receives the pectoralis major muscle. In the middle of the shaft it is rough and prominent and gives insertion to the deltoid; below it is smooth and rounded, giving origin to the brachialis muscle, and finally it passes along lateral to the coronoid fossa to become continuous with the ridge separating the capitulum and trochlea. It separates the anteromedial from the anterolateral surface. The **lateral border** [margo lateralis] (margo radialis NK) extends from the lower

and posterior part of the greater tubercle to the lateral epicondyle. Smooth and indistinct above, it gives attachment to the teres minor muscle and the lateral head of the triceps; it is interrupted in the middle by the **groove for the radial nerve** (musculospiral groove) [sulcus n. radialis], and the lower third becomes prominent and curved laterally to form the **lateral supracondylar ridge,** which affords origin in front to the brachioradialis and the extensor carpi radialis longus muscles; behind to the medial head of the triceps, and between these

Fig. 223.—The Left Humerus with a Supracondyloid Process and Some Irregular Muscle Attachments. (Anterior view.)

muscles in front and behind to the lateral intermuscular septum. It separates the anterolateral from the posterior surface. The **medial border** [margo medialis] (margo ulnaris NK) commences at the lesser tubercle, forming the **crest of the lesser tubercle** [crista tuberculi minoris] which receives the insertion of the teres major, and continuing downward to the medial epicondyle. Near the middle of the shaft it forms a ridge for the insertion of the coracobrachialis muscle and presents a **nutrient foramen** [foramen nutricium] for the nutrient artery, leading to the **nutrient canal** [canalis nutricius] directed downward toward the elbow-

joint. Below it forms a distinct **medial supracondylar ridge**, curved medially, which gives origin to the brachialis muscle in front, the medial head of the triceps behind, and the medial intermuscular septum in the interval between the muscles. This border separates the anteromedial from the posterior surface.

Surfaces.—The **anterolateral surface** [facies anterior lateralis] is smooth above, rough in the middle, presenting a large impression for the insertion of the deltoid, below which is the termination of the groove for the radial nerve. The lower part of the surface gives origin to the lateral part of the brachialis. The **anteromedial surface** [facies anterior medialis] is narrow above, where it forms the floor of the intertubercular groove, and receives the insertion of the latissimus dorsi muscle. Near the junction of the upper and middle thirds of the bone the groove, gradually becoming shallower, widens out and, with the exception of a rough impression near the middle of the shaft for the coracobrachialis, the remaining part of the anteromedial surface is flat and smooth, and gives origin to the brachialis.

Occasionally, a bony spine of variable size, the **supracondyloid process** (fig. 223), projects downward from the anteromedial surface about 5 cm. (2 in.) above the medial epicondyle, to which it is joined by a band of fibrous tissue. It occurs in from 1 per cent. (Testut) to 2.7 per cent. (Gruber) of cases; and was found in 7 of 1000 living subjects (Terry). Its occurrence in the colored races so far examined is rare. Through the ring formed by the process, band and humeral shaft, which corresponds to the supracondyloid foramen in many of the lower animals, the median nerve and brachial artery, or a large branch of it, are transmitted, though in some cases it is occupied by the nerve alone. The process gives origin to a part of the pronator teres muscle, and may afford insertion to a persistent lower part of the coracobrachialis.

The **posterior surface** [facies posterior] is obliquely divided by the broad shallow **radial groove** [sulcus n. radialis], which runs in a spiral direction from behind downward and forward and transmits the radial (musculospiral) nerve and the profunda brachii artery. The lateral part of the surface above the groove gives attachment to the lateral head, and the part below the groove, to the medial head of the triceps muscle.

The **lower extremity** of the humerus is flattened from before backward, and terminates below in a sloping articular surface, subdivided by a low ridge into the **trochlea** and the **capitulum.** The **trochlea** [trochlea humeri] is the pulley-like surface which extends over the end of the bone from front to back for articulation with the semilunar notch (great sigmoid cavity) of the ulna. It is constricted in the center and expanded laterally to form two prominent edges, the medial of which is thicker, descends lower, and forms a marked projection; the lateral edge is narrow and corresponds to the interval between the ulna and radius. The contour of the trochlea suggests an hourglass shape, the groove, however, does not follow the path of a circle but of a spiral. Above the trochlea are two fossæ: on the anterior surface is the **coronoid fossa** [fossa coronoidea], an oval pit which receives the coronoid process of the ulna when the forearm is flexed; on the posterior aspect is the **olecranon fossa** [fossa olecrani], a deep hollow for the reception of the anterior extremity of the olecranon in extension of the forearm. These fossæ are usually separated by a thin, translucent plate of bone, sometimes merely by fibrous tissue, so that in macerated specimens a perforation, the **supratrochlear foramen,** exists. The **capitulum** [capitulum humeri], or radial head, is much smaller than the trochlea, somewhat globular in shape, and limited to the anterior and inferior aspects of the humerus. It articulates with the concavity on the summit of the head of the radius. The **radial fossa** [fossa radialis] is a slight depression on the front of the bone, immediately above the capitulum, which receives the anterior edge of the head of the radius in complete flexion of the forearm, whilst between the capitulum and the trochlea is a shallow groove occupied by the medial margin of the head of the radius.

In the recent state the inferior articular surface is covered with cartilage, the fossæ are lined by synovial membrane, and their margins give attachment to the capsule of the elbow-joint. Projecting on either side from the lower end of the humerus are the two **epicondyles.** Both epicondyles project beneath the skin and are easily felt in palpating the elbow. The **medial epicondyle** [epicondylus medialis] is large and by far the more prominent of the two, rough in front and below, smooth behind, where there is a shallow **groove for the ulnar nerve** [sulcus n. ulnaris]. The rough area serves for origin of the pronator teres above, the common tendon of origin of the flexor carpi radialis, palmaris longus, flexor digitorum sublimis and flexor carpi ulnaris muscles in the middle, and the ulnar collateral ligament below. The lateral epicondyle is flat and irregular. Above, it gives attachment to a common tendon of origin of the extensor carpi radialis brevis, extensor digitorum communis, extensor digiti quinti proprius, extensor

Fig. 224.—A Diagram Showing Pressure and Tension Curves in the Head of the Humerus. (After Wagstaffe.)

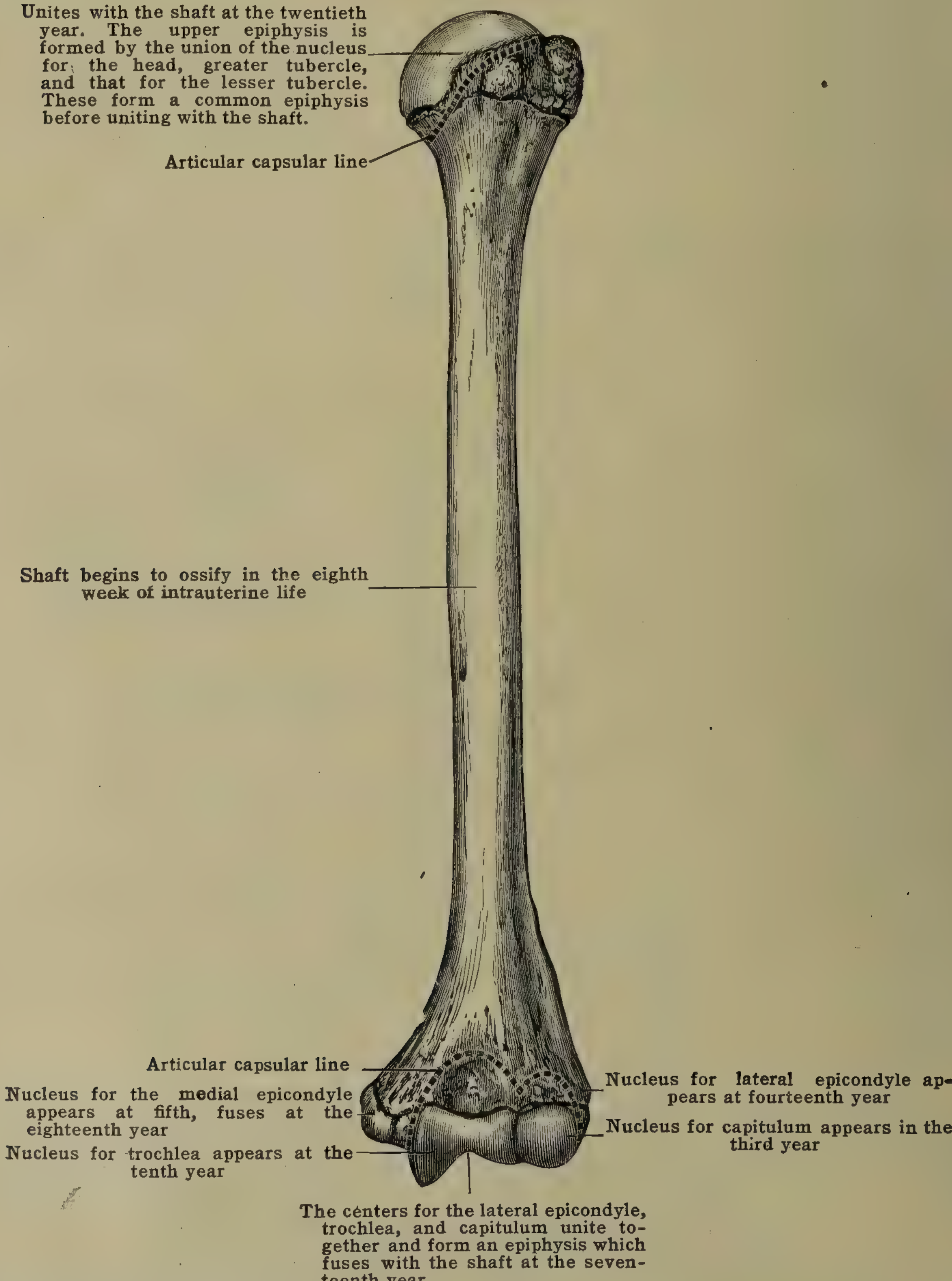


Fig. 225.—Ossification of the Humerus; the Figure also Shows the Relations of the Epiphysial and Capsular Lines.

carpi ulnaris, and supinator muscles; to a depression near the outer margin of the capitulum, the radial collateral ligament is attached, and from an area below and behind, the anconeus muscle takes origin.

The *length* of the humerus is somewhat less than one-fifth the stature of the individual. The principal axes of the upper and lower extremities of the bone lie in planes that cross each other at an angle that varies in size between 12° and 20° in Europeans and is greater in non-Europeans. This *torsion angle* diminishes during the period of embryonic to adult life, beginning at 90°.

The term **neck** is applied to three parts of the humerus. The *anatomical* neck is the constriction to which the articular capsule is mainly attached. The upper extremity of the humeral shaft, before its union with the epiphysis, terminates in a low three-sided pyramid, the surfaces of which are separated from one another by ridges. The medial of these three surfaces underlies the head of the bone, and the two lateral surfaces underlie the tubercles. The part supporting the head constitutes the *morphological* neck of the humerus. The *surgical* neck is the indefinite region below the tubercles where the bone is liable to fracture.

Architecture.—The interior of the shaft of the humerus is hollowed out by a large medullary canal, whereas the extremities are composed of spongy tissue invested by a dense compact layer. The arrangement of the spongy tissue at the upper end of the humerus is shown in fig.

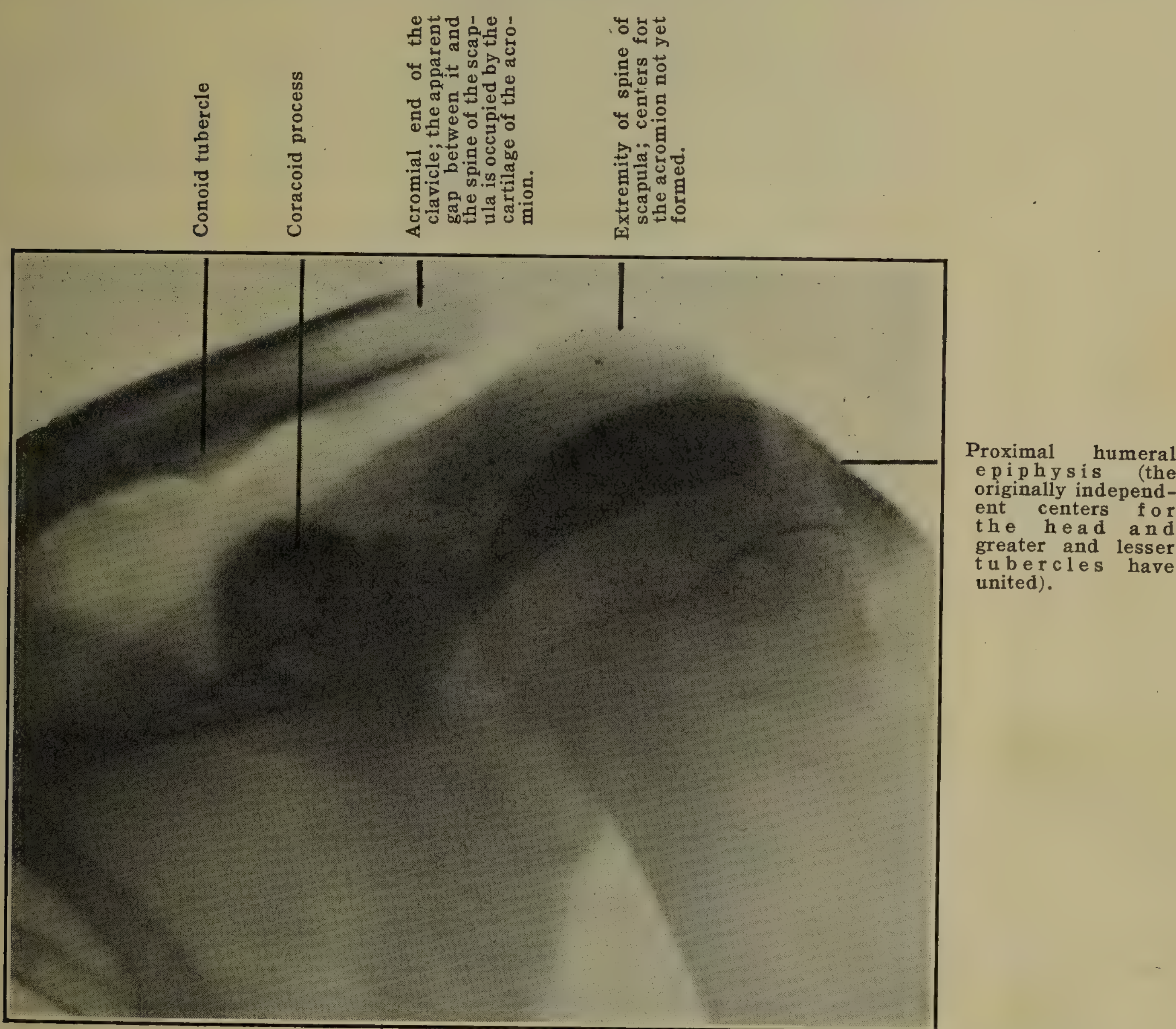


FIG. 226.—SHOULDER OF A BOY OF SIXTEEN YEARS. From an *X*-ray plate by Dr. Sherwood Moore, Washington University. (Cf. adult, fig. 220.)

224. The lamellæ converge to the axis of the bone and form a series of superimposed arches which reach upward as far as the epiphysial line. In the epiphyses the spongy tissue forms a fine network, the lamellæ being directed at right angles to the articular surface of the head and to the greater tubercle.

Blood-supply.—The foramina which cluster round the circumference of the head and tubercles transmit branches from the transverse scapular (suprascapular) and anterior and posterior circumflex arteries. At the top of the intertubercular groove is a large nutrient foramen for a branch of the anterior circumflex artery which supplies the head. The nutrient artery of the shaft is derived from the brachial, and in many cases, an additional branch, derived from the profunda brachii artery, enters a foramen in the groove for the radial nerve (musculospiral groove). The lower extremity is nourished by branches derived from the profunda brachii, the superior and inferior ulnar collateral, and the recurrent branches of the radial, ulnar, and interosseous arteries.

Ossification.—The humerus ossifies from one primary center (diaphysial) and six secondary centers (epiphysial). The center for the shaft appears about the seventh week (forty-second day, according to Mall) of intrauterine life and grows very rapidly. At birth only the two extremities are cartilaginous, and these ossify in the following manner: single centers appear for the head in the first year, for the greater tubercle in the third year, and for the lesser tubercle in the fifth year, though sometimes the latter ossifies by an extension from the greater tubercle. These three nuclei coalesce at six years to form a single epiphysis, which joins the shaft about the twentieth year.

The inferior extremity ossifies from four centers: one for the capitulum appears in the third year, a second for the medial epicondyle in the fifth year, a third for the trochlea in the tenth year, and a fourth for the lateral epicondyle in the fourteenth year. The nuclei for the capitulum, trochlea, and lateral epicondyle coalesce to form a single epiphysis which joins the shaft in the seventeenth year (figs. 225, 234). The nucleus of the medial epicondyle joins the shaft independently at the age of eighteen years.

Fig. 227.—The Elbow-joint, as Shown by the Röntgen-rays. (Epiphyses visible.)

Clinical aspects.—Injury to the epiphysis of the medial epicondyle may damage the ulnar nerve and open the elbow-joint. Thus, at and after puberty, there are two chief epiphyses to remember here:—(*a*) the larger, consisting of capitular, trochlear, and lateral epicondyle centers. This is almost entirely intra-articular; (*b*) the smaller, that for the medial epicondyle; the extent to which this is intra-articular varies. The structures that would be divided in **an amputation at the center of the arm** are shown in fig. 424B. The chief points needing attention are:—(1) To leave as much of the lever of the humerus as possible; (2) clean section of the large nerves, the radial (musculo-spiral) in its groove being especially liable to be frayed by the saw; (3) the difference between the amount of retraction of the free biceps in front, and the triceps behind, fixed to the bone and intermuscular septa.

The strength of such muscles as the deltoid, and their intimate connection with the periosteum of the humerus, account for **fracture** of this bone by muscular action being more common than elsewhere. The presence of muscular tissue between the fragments, together with deficient immobilization, explains the fact that ununited fractures are also most common in the humerus. **The best incisions for exploring the humerus**, e. g., in acute necrosis, etc., are (*a*)

for *the upper portion*, to be extended along the anterior and posterior borders of the deltoid. In the latter case the presence of the radial (musculospiral) nerve in the deeper part of the wound must be remembered; (*b*) for *the lower end* one parallel with the lateral intermuscular septum, deepened between the brachialis and brachioradialis.

THE RADIUS

The **radius** (figs. 228–231) is the lateral and shorter of the two bones of the forearm. Above, it articulates with the humerus; below, with the carpus; and on the medial side with the ulna. It presents a shaft and two extremities.

The **upper extremity,** smaller than the lower, includes the head, neck, and tuberosity. The **head of the radius** [capitulum radii], covered with cartilage in the recent state, is a disk forming the expanded, articular end of the bone.

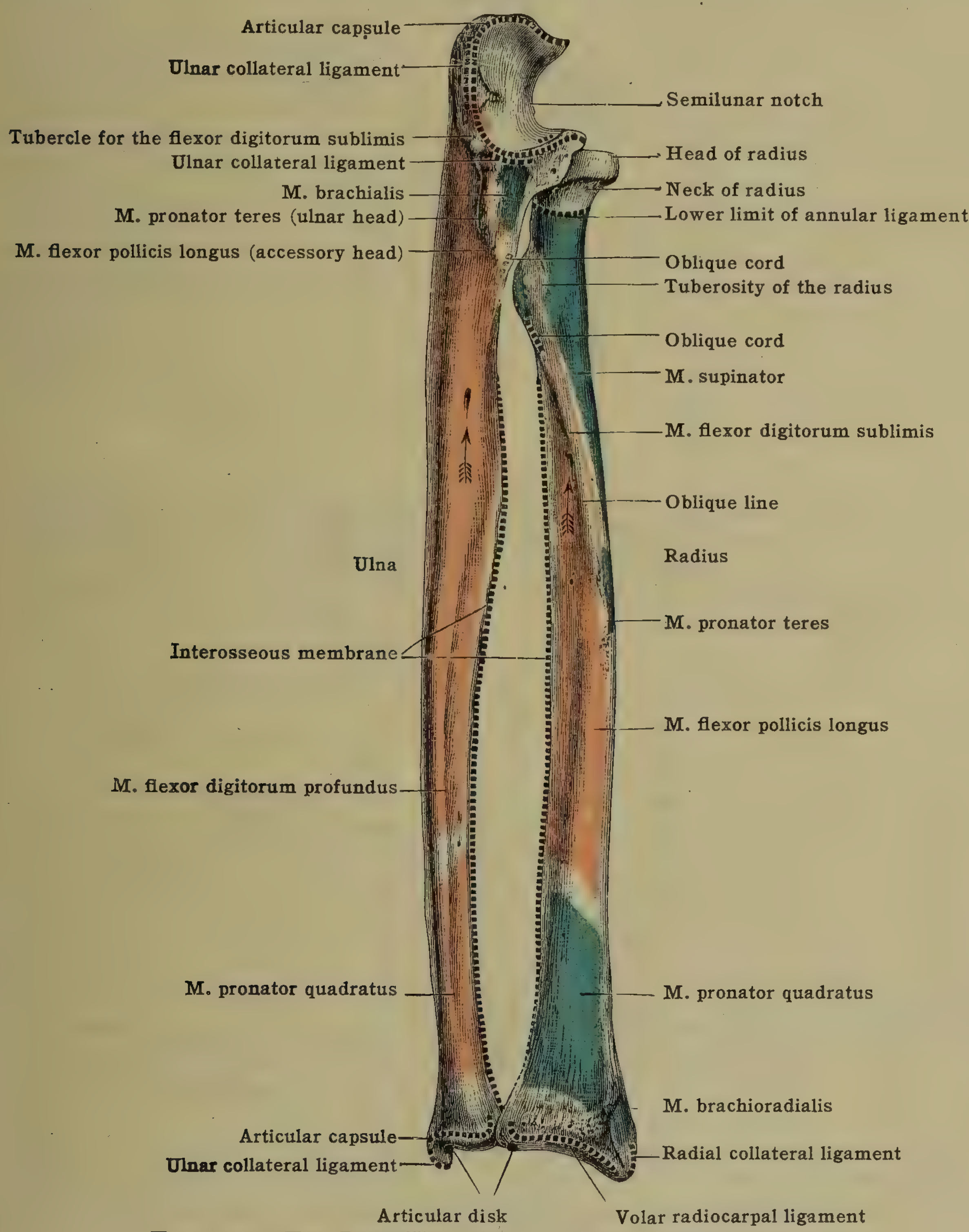


FIG. 228.—THE LEFT ULNA AND RADIUS. (Anteromedial view.)

Superiorly it presents the **capitular depression** [fovea capituli radii] for the reception of the capitulum of the humerus; its **articular circumference** [circumferentia articularis], deeper on the medial aspect, articulates with the radial notch (lesser sigmoid cavity) of the ulna, and is narrow elsewhere for the annular ligament by which it is embraced. Below the head is a short cylindrical portion of bone, somewhat constricted, and known as the **neck of the radius** [collum radii]. The upper part is surrounded by the ligament which embraces the head, and below this it gives insertion anterolaterally to the supinator muscle. Below the neck,

at the anteromedial aspect of the bone, is an oval eminence, the **radial tuberosity** [tuberositas radii], divisible into two parts: a rough posterior portion for the insertion of the tendon of the biceps, and a smooth anterior surface in relation with a bursa which is situated between the tendon and the tuberosity.

The **body** [corpus radii] or **shaft** is somewhat prismatic in form, gradually increasing in size from the upper to the lower end, and slightly curved so as to be concave toward the ulna. Three borders and three surfaces may be recognized. Of the borders, the medial or **interosseous crest** [crista interossea] is best marked.

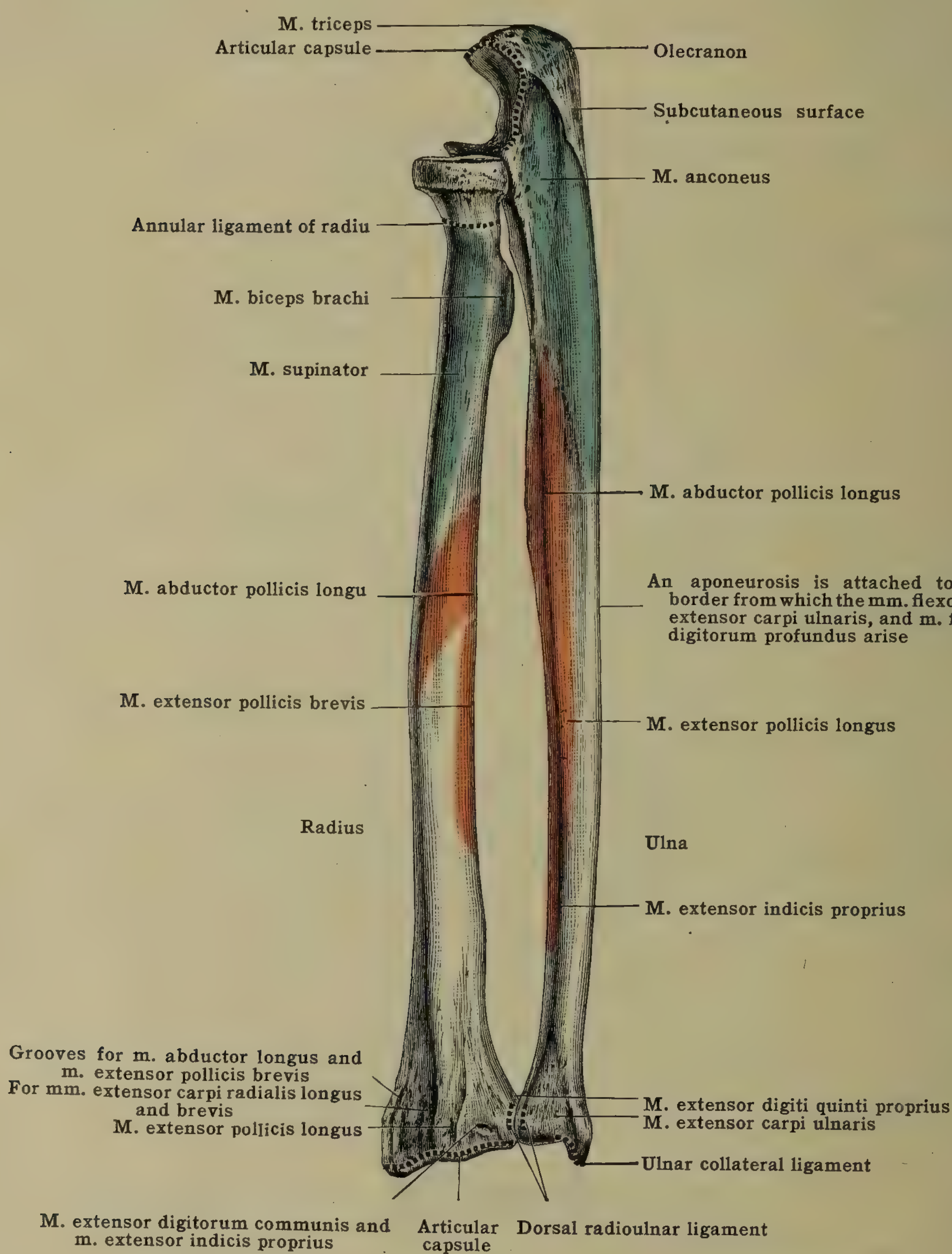


Fig. 229.—The Left Ulna and Radius. (Posterolateral view.)

Commencing at the posterior edge of the tuberosity, its first part is rounded and indistinct, and receives the attachment of the oblique cord of the radius; it is continued as a sharp ridge which divides near the lower extremity to become continuous with the anterior and posterior margins of the ulnar notch (sigmoid cavity). The prominent ridge and the posterior of the two lower lines give attachment to the interosseous membrane, whilst the triangular surface above the ulnar notch receives a part of the pronator quadratus muscle. The interosseous crest separates the volar from the dorsal surface.

The **volar border** [margo volaris] runs from the tuberosity obliquely downward to the lateral side of the bone and then descends vertically to the anterior border of the styloid process. The upper third, constituting the **oblique line** of the radius, gives origin to the radial head of the flexor digitorum sublimis, limits the insertion of the supinator above, and the origin of the flexor pollicis longus muscle below. The volar border separates the volar from the lateral surface. The **dorsal border** [margo dorsalis] extends from the back of the tuberosity to the prominent middle tubercle on the posterior aspect of the lower extremity. Separating the lateral from the dorsal surface, it is well marked in the middle third, but becomes indistinct above and below.

Surfaces.—The **volar** (or anterior) **surface** [facies volaris] is narrow and concave above; broad, flat, and smooth below. The upper two-thirds is occupied chiefly by the flexor pollicis longus and a little less than the lower third by the pronator quadratus muscle. Near the junction of the upper and middle thirds of the volar surface is the **nutrient foramen,** directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **lateral surface** [facies lateralis] is convex, rounded above and affords insertion to the supinator muscle; marked near the middle by a rough, low, vertical ridge (tuberositas pronatoria NK) for the pronator teres; smooth below, where the tendons of the extensor carpi radialis longus and brevis muscles lie upon it, and where it is crossed by the abductor pollicis longus and extensor pollicis brevis muscles. The **dorsal** (or posterior) **surface** [facies dorsalis], smooth and rounded above, is covered by the supinator; grooved longitudinally in the middle third for the abductor pollicis longus and the extensor pollicis brevis muscles; the lower third is broad, rounded, and covered by tendons. The line which forms the upper limit of the impression for the abductor pollicis longus muscle is known as the **posterior oblique line.**

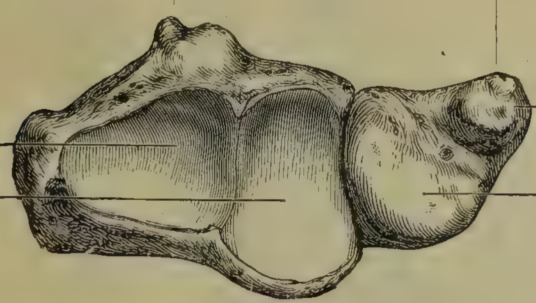


FIG. 230.—ARTICULAR FACETS ON THE LOWER END OF LEFT RADIUS AND ULNA.

The **lower extremity** of the radius is quadrilateral; its **carpal articular surface** [facies articularis carpea] is concave both transversely and anteroposteriorly and divided by a ridge into a medial quadrilateral portion, concave for articulation with the lunate bone; and a lateral triangular portion, extending on to the styloid process for articulation with the navicular bone. The medial surface, also articular, presents the cylindrically curved **ulnar notch** [incisura ulnaris], the articular surface, for the reception of the rounded margin of the head of the ulna. To the border separating the ulnar and carpal articular surfaces the base of the articular disk is attached, and to the anterior and posterior borders, the volar and dorsal radioulnar ligaments respectively. The **volar** (anterior) **surface** [facies volaris] is raised into a prominent area for the volar ligament of the wrist-joint. The **lateral surface** [facies lateralis] is represented by the **styloid process,** a blunt pyramidal eminence, easily palpated beneath the skin; to its base the brachioradialis is inserted, whilst the tip serves for the attachment of the radial (external) collateral ligament of the wrist. Its lateral surface is marked by two shallow furrows for the tendons of the abductor pollicis longus and extensor pollicis brevis muscles. The **dorsal surface** [facies dorsalis] is convex, and marked by three prominent ridges separating three furrows. The dorsal carpal ligament is attached to these ridges, thus forming with the bone a series of tunnels for the passage of tendons (fig. 231).

The most lateral groove is broad, shallow, and frequently subdivided by a low ridge. The lateral subdivision is for the extensor carpi radialis longus, the medial for the extensor carpi radialis brevis muscle. The middle groove is narrow and deep for the tendon of the extensor pollicis longus muscle. The sharp tubercle which limits this groove laterally can be distinguished by palpation. The most medial is shallow and transmits the extensor indicis proprius,

the extensor digitorum communis muscles, the dorsal branch of the interosseous artery, and the dorsal interosseous nerve. When the radius and ulna are articulated, an additional groove is formed for the tendon of the extensor digiti quinti proprius.

Ossification.—The radius is ossified from a center which appears in the middle of the shaft in the eighth week of intrauterine life and from two epiphysial centers which appear after birth. The nucleus for the lower end appears in the second year, and that for the upper end, which forms simply the disk-shaped head, from the fifth year to the tenth year. According to Pryor the distal epiphysis appears in female children at the eighth month; in males at fifteen months. The head unites with the shaft at the seventeenth year whilst the inferior epiphysis and the shaft join about the twentieth year. (See figs. 233, 234.)

Variations.—Congenital absence of the radius has frequently been observed; absence of the thumb has been noted in association with this variation in a number of cases. A sesamoid develops rarely in the tendon of the biceps over the tuberosity of the radius.

THE ULNA

The **ulna** (figs. 228, 229, 231, 232) is a long, prismatic bone, thicker above than below, on the medial side of the forearm and parallel with the radius, which it exceeds in length by the extent of the olecranon process. It articulates at the upper end with the humerus, on the lateral side with the radius, and at the lower end is connected indirectly with the carpus. It is divisible into a shaft and two extremities.

The **upper extremity** is of irregular shape and forms the thickest and strongest part of the bone. The superior articular surface is concave from above downward, divided by a longitudinal 'guiding ridge' into medial and lateral parts, and transversely constricted near the middle. It belongs partly to the **olecranon**,

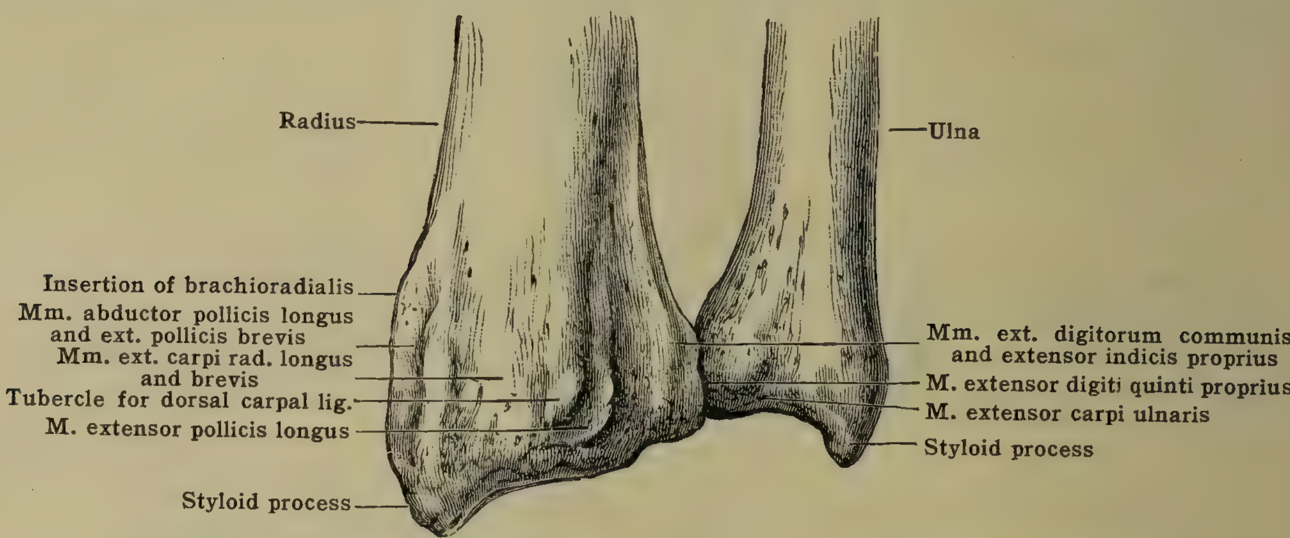


Fig. 231.—Dorsal View of the Lower End of the Radius and Ulna.

the thick upward projection from the shaft, and partly to the **coronoid process**, which projects horizontally forward from the front of the ulna. This extensive excavation forms the **semilunar notch** [incisura semilunaris] and articulates with the trochlea of the humerus, the guiding ridge fitting the trochlear groove. The **olecranon** is the large curved eminence forming the highest part of the bone.

The superior surface of the olecranon, uneven and somewhat quadrilateral in shape, receives behind, where there is a rough impression, the insertion of the triceps, and along the anterior margin, the articular capsule of the elbow-joint. The posterior surface, smooth and triangular in outline, is separated from the skin by a bursa and can be readily palpated. The anterior surface, covered with cartilage in the recent state, is directed downward and forward, and its margins give attachment to the articular capsule of the elbow-joint. This surface, as already noticed, forms the upper and back part of the semilunar notch. On the medial surface of the olecranon is a tubercle for the origin of the ulnar head of the flexor carpi ulnaris muscle, and in front of this a fasciculus of the ulnar collateral ligament of the elbow-joint is attached to the bone; the lateral surface is rough, concave, and gives insertion to a part of the anconeus muscle. The extremity of the olecranon lies during extension of the elbow in the olecranon fossa of the humerus.

The **coronoid process** [processus coronoideus], forming the lower and anterior part of the semilunar notch has a superior articular surface continuous with the anterior surface of the olecranon, and, like it, covered with cartilage. The inferior aspect is rough and concave, and gives insertion to the brachialis muscle.

It is continuous with the volar surface of the shaft, and near the junction of the two is a rough eminence named the **tuberosity of the ulna** [tuberositas ulnæ], which receives the attachment of the oblique cord of the radius and the insertion of the brachialis muscle. The

medial side presents above a smooth tubercle for the origin of the ulnar portion of the flexor digitorum sublimis, and a ridge below for the lesser head of the pronator teres and the rounded accessory bundle of the flexor pollicis longus muscle, whilst immediately behind the sublimis tubercle there is a triangular depressed surface for the upper fibers of the flexor digitorum profundus.

On the lateral surface is the **radial notch** [incisura radialis], a concave cylindrical articular surface which articulates with the circumference of the head of the radius, and the anterior and posterior margins afford attachment to the annular ligament and the radial collateral ligament of the elbow-joint. In flexion of the elbow the tip of the process is received into the coronoid fossa of the humerus.

The **body of the ulna** [corpus ulnæ] or **shaft** throughout the greater part of its extent is three-sided, but tapers toward the lower extremity, where it becomes smooth and rounded. It has three borders and three surfaces. Of the three borders, the **lateral,** the **interosseous crest** [crista interossea], is best marked. In the middle three-fifths of the shaft it is sharp and prominent, but becomes

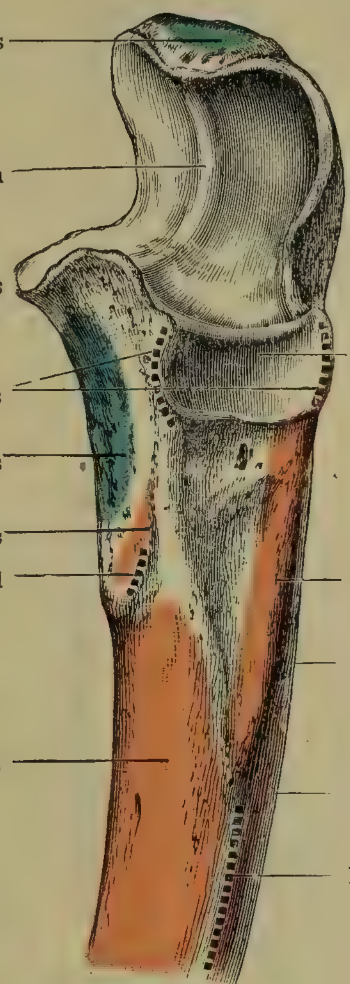


FIG. 232.—UPPER END OF LEFT ULNA. (Lateral view.)

indistinct below; above it is continued by two lines which pass to the anterior and posterior extremities of the radial notch and enclose a depressed triangular area (bicipital hollow), the fore part of which lodges the tuberosity of the radius with the insertion of the biceps tendon during pronation of the hand. From the posterior part of the bicipital hollow and from the posterior limiting line [crista m. supinatoris] the supinator muscle takes origin. The interosseous crest separates the volar from the dorsal surface and gives attachment by the lower four-fifths of its extent to the interosseous membrane. The **volar border** [margo volaris] is directly continuous with the medial edge of the rough surface for the brachialis muscle and terminates inferiorly in front of the styloid process. Throughout the greater part of its extent it is smooth and rounded, and affords origin to the flexor digitorum profundus and the pronator quadratus muscles. It separates the volar from the medial surface. The **dorsal border** [margo dorsalis] commences above at the apex of the triangular subcutaneous area on the back of the olecranon, and takes a sinuous course to the back part of the styloid process. The upper three-fourths gives attachment to an aponeurosis common to three muscles, viz., the flexor and extensor carpi ulnaris and the flexor digitorum

profundus. This border separates the medial from the dorsal surface, and is easily palpated throughout.

Surfaces.—The **volar** (or anterior) **surface** [facies volaris] is grooved in the upper three-fourths of its extent for the origin of the flexor digitorum profundus, narrow and convex below, for the origin of the pronator quadratus. The upper limit of the area for the latter muscle is sometimes indicated by an oblique line—the **pronator ridge.** Near the junction of the upper and middle thirds of the anterior surface is the **nutrient foramen,** directed upward toward the proximal end of the bone. It transmits a branch of the volar interosseous artery. The **medial surface** [facies medialis], smooth and rounded, gives attachment, on the upper two-thirds, to the flexor digitorum profundus, whereas the lower third is subcutaneous. The **dorsal** (or posterior) **surface** [facies dorsalis], directed laterally as well as backward, presents at its upper part the **oblique line** of the ulna running from the posterior extremity of the radial notch to the dorsal border.

FIG. 233.—OSSIFICATION OF THE RADIUS AND ULNA; EPIPHYSIAL AND CAPSULAR LINES.

The oblique line gives attachment to a few fibers of the supinator muscle and marks off the posterior surface into two unequal parts. That above the line, much the smaller of the two, receives the insertion of the anconeus muscle. The more extensive part below is subdivided by a vertical ridge into a medial portion, smooth, and covered by the extensor carpi ulnaris, and a lateral portion which gives origin to three muscles, viz., the abductor pollicis longus, the extensor pollicis longus and the extensor indicis proprius, from above downward.

The **lower extremity** of the ulna is of small size and consists of two parts, the **head of the ulna** [capitulum ulnæ] and the **styloid process,** separated from each other on the inferior surface by a groove into which the apex of the articular disk is inserted. That part of the head adjacent to the groove is semilunar in shape and plays upon the articular disk which thus excludes the ulna from the radio-carpal or wrist-joint. The margin of the head, **circumferentia articularis,** is also semilunar, and is received into the ulnar notch of the radius. In pronation

the head of the ulna makes the rounded prominence on the dorsal side of the wrist. The **styloid process** [processus styloideus] projects from the medial and back part of the bone, and appears as a continuation of the dorsal border. To its rounded summit the ulnar collateral ligament of the wrist-joint is attached, and its dorsal surface is grooved for the passage of the tendon of the extensor carpi ulnaris. Immediately above the articular margin of the head the radioulnar capsular ligament is attached in front and behind.

In contrast to the poor adaptation of the articular surfaces of the humerus and radius for security in the hinge-movements of the elbow is the perfect locking of the semilunar notch of the ulna with the trochlea of the humerus. The inferior extremity of the ulna is adapted mainly to the radius in the pivotal movements of pronation and supination, and has undergone regression in those mammals in which the antibrachium is permanently fixed in pronation, as, for example, in the horse and ox.

The ratio between the lengths of the forearm and the arm is expressed by the *humero-radial index*, $\frac{\text{length of radius} \times 100}{\text{length of humerus}}$. The index is higher in the infant than in the adult; higher in women than in men. In Europeans the index has been found to be 74; in the negro, 79; in Andamanese 81. In the anthropoid apes, the gorilla has an index of 90; the orang, 100.

Ossification.—The ulna is ossified from three centers. The primary nucleus appears near the middle of the shaft in the eighth week of intrauterine life. At birth the inferior extremity and the greater portion of the olecranon are cartilaginous. The nucleus for the lower end appears during the sixth year (sixth to seventh year in girls; eighth to ninth in boys, Pryor) and the epiphysis joins with the shaft from the eighteenth to the twentieth year (fig. 233). The greater part of the olecranon is ossified from the shaft, but an epiphysis is subsequently formed from a nucleus which appears in the tenth year.

The epiphysis varies in size, and may be either scale-like and form a thin plate on the summit, or involve the upper fourth of the olecranon and the corresponding articular surface. In the latter case the epiphysis is probably composed of two parts fused together: (1) The scale on the summit of the olecranon, and (2) the beak center which enters into the formation of the upper part of the semilunar notch. The epiphysis unites to the shaft in the sixteenth or seventeenth year.

Variations.—A sesamoid bone above the olecranon and lodged in the tendon of the triceps occurs rarely. Total absence of the ulna has been recorded.

Clinical Relations of the Forearm

Bony landmarks of the forearm.—The *posterior border of the ulna* can be easily traced down from the olecranon to the back of the styloid process; the bone becomes somewhat rounded below, and lies between the flexor and extensor carpi ulnaris. The tip of the *styloid process* corresponds to the medial end of the line of the wrist-joint. The *radius* is covered above by the brachioradialis and radial extensors of the carpus, and the outline of the bone is less easily followed. Its *styloid process* is readily made out about a finger's breadth above the thenar eminence. It is placed about 1.2 cm. (½ in.) lower than that of the styloid process of the ulna.

Thus, a line drawn straight between the two processes would fall a little below that of the wrist-joint, this being shown by a line drawn between the two processes forming a slight curve, with its concavity downward (corresponding to the concavity of the lower surface of the radius and fibrocartilage) about 1.2 cm. (½ in.) above the straight line given above.

The radial styloid process is covered by the abductor longus and extensor brevis pollicis, while farther out lies the extensor pollicis longus. Between the styloid process of the ulna and the rounded head is the groove for the extensor carpi ulnaris. The bones are nearest to each other in complete pronation, and farthest apart in complete supination. On section (fig. 428) the bones are found at every point nearer to the back than to the front of the limb, but increasingly so above. The lower the section proceeds down the limb, the less will the bones be covered at the sides, and the more equally will the soft parts be distributed about the anterior and posterior aspects of the limb. It will be noticed that where one bone is the more substantial, the other is the more slender, as near the elbow and wrist; and that it is about the center of the limb that the two are most nearly of equal strength (Treves). When the limb is pronated, the interosseous space is narrowed; in supination and in the midposition it is widened out. In pronation, both styloid processes can be distinctly made out by palpation, but the prominence seen on the ulnar side is caused by the *head* of the ulna.

Common fractures. *Olecranon.*—This usually takes place at the constricted center of the semilunar (greater sigmoid) notch or the junction of the olecranon with the shaft. A fall is here the usual cause, and the heavier the fall, the more frequently is the fracture nearer the shaft, though displacement is now likely to be slight, owing to the abundance of fibrous and muscular structures on both sides of the fracture. *The shaft of one or both bones.* Usual site, about the middle or a little below it, fracture of the radius being more frequent from its connection with the hand. In these fractures the chief muscular agencies are—(1) the extensors and flexors in drawing the lower fragment or fragments upward, forward, or backward, according to the direction of the fracture; (2) the biceps in drawing the upper fragment of the radius upward; (3) the influence of the pronator teres, if the fracture is, as usual, below it, and (4) that of the quadratus in drawing the lower fragments together. Thus the chief practical points are—(*a*) the reduction of displacement, whether anteroposterior or lateral; (*b*) the greater the number of fragments, the greater the tendency to union across the interosseous space, with its embarrassing results, and the greater the need of a supinated position in the setting; (*c*) the risk of gangrene here from the facility with which the vessels are compressed against the contiguous bones especially in flexion of the forearm; and the consequent need of attention to the width of the splints

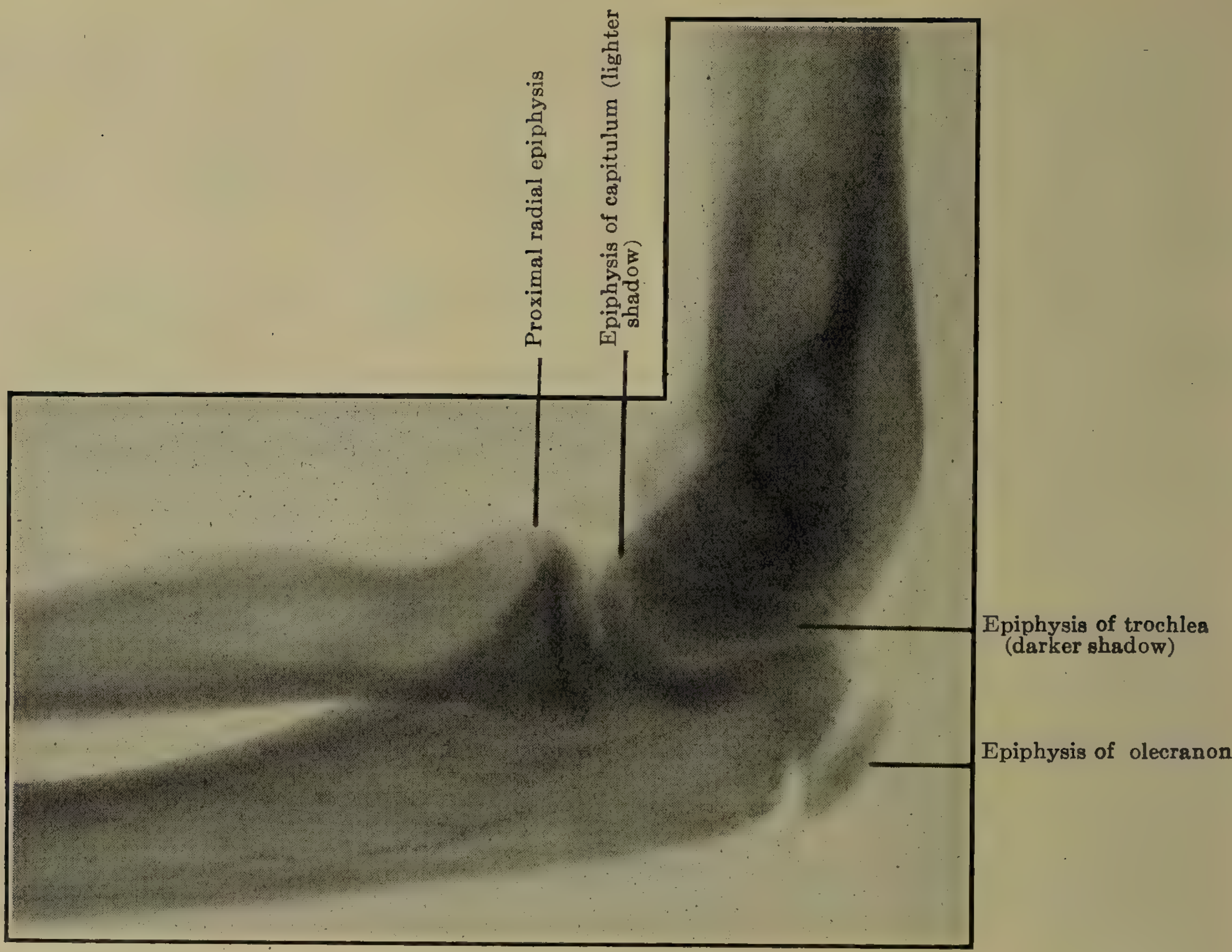


FIG. 234.—RIGHT ELBOW-JOINT OF A BOY AGED SIXTEEN. From an *X*-ray Plate by Dr. Sherwood Moore, Washington University. (Cf. fig. 227.)

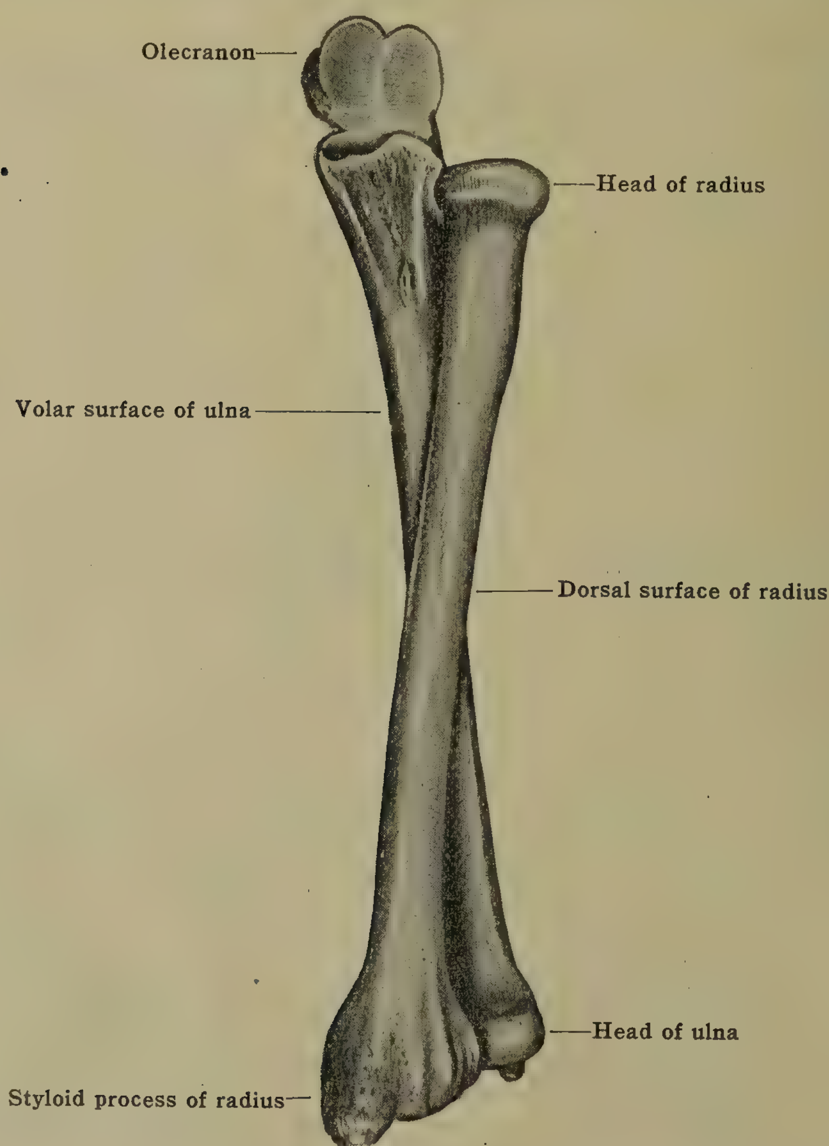


FIG. 235.—THE LEFT RADIUS AND ULNA IN PRONATION. (Anterior view.)

and the bandaging; (*d*) the readiness with which ischemic paralysis may rapidly and insidiously be caused. It is a good rule to remember in treating fractures that the long fragment which can be controlled should be dressed in line with the short fragment which cannot be controlled. The origins, insertions and actions of muscles on different fragments should be thoroughly understood if this principle is to be carried out. **Colles' fracture.** Here, after a fall on the hand, the radius gives way usually at its weakest part, about 18 mm. (¾ in.) above its extremity, where the narrow compact tissue is suddenly expanding into cancellous. There is frequently impaction of the upper into the lower fragment. There is a three-fold displacement of the lower fragment:—(1) It is driven and drawn upward and backward. (2) It is rotated so that its articular surface looks somewhat backward. (3) It is drawn to the radial side. The chief causes of the discreditable stiffness often allowed to result are non-reduction of the deformity, adhesions in the opened wrist-joint, tenosynovitis, and prolonged immobilization.

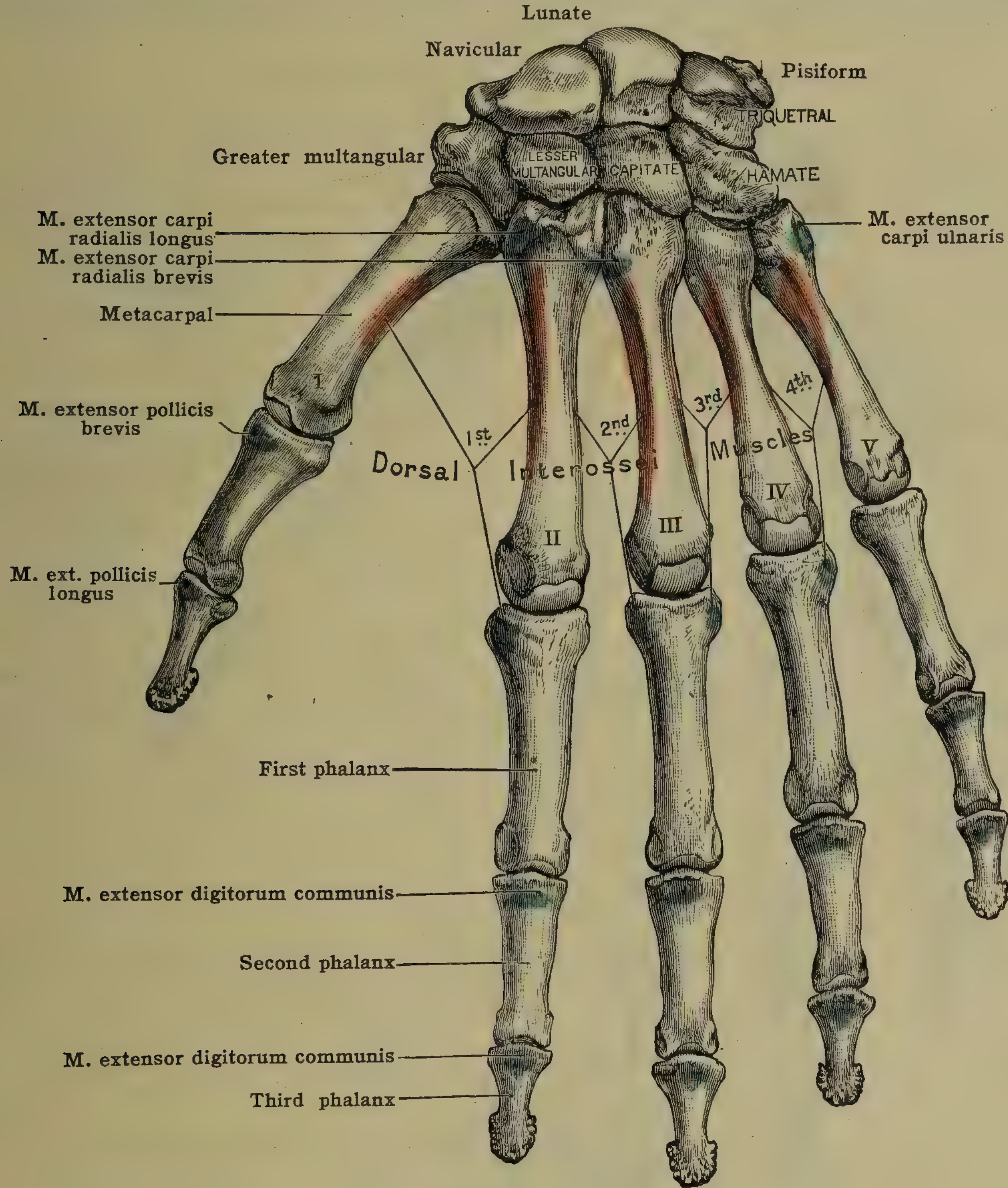


Fig. 236.—Bones of the Left Hand. (Dorsal surface.)

Separation of epiphysis.—This may take place in the **radius** up to about the age of eighteen: it is commoner before. Its possible importance in interfering with the symmetry of the growth of the bones is obvious. Here, as in Colles' fracture, the level of the styloid processes of the radius and ulna, and the relations of the two styloid processes to each other, are important in diagnosis. **Exposure of the bones.** In the case of ununited fracture or necrosis the **radius** may be reached—(*a*) *Behind*, by an incision in a line drawn from the lateral epicondyle to the back of the radius. The field opened here lies between the brachioradialis and the radial extensors on the one side, and the common extensor on the other. Care must be taken of the deep radial (posterior interosseous) nerve. (*b*) *In front.* The incision here lies in the sulcus between the brachioradialis and the flexors. The pronator teres and the flexor sublimis must, in part, be detached from the radius. If more room is required to reach an injured upper extremity of the radius, the incision will descend from above the lateral epicondyle in the groove between the anconeus and common extensors. In the detachment of the supinator the deep radial nerve will again need attention. The **ulna** is more easily reached by an incision between the flexor and extensor carpi ulnaris. In removal of the lower part of the bones for myeloid sarcoma or osteitis, the ulna is reached in the interval last mentioned. The **radius** is best exposed by an incision between the brachioradialis and extensor carpi radialis longus, the super-

ficial radial nerve being the guide (Morris). Finally, the so-called *'carrying angle'* of the forearm deserves mention. In extension the bones of the forearm are not in a straight line with the humerus, but directed slightly laterally, the angle at the elbow-joint being obtuse, and open laterally. This angle is so named from its facilitating carrying objects during walking. In flexion the forearm is deflected somewhat toward the middle line, mouth, etc. These properties are liable to be lost under many and widely different conditions, of which injuries to the epiphyses of the humerus, badly united fractures of the humerus (supracondylar) or forearm, and osteoarthritis of the elbow-joint are instances.

Amputation of forearm.—The 'mixed' method by skin-flaps roundly arched and circular division of the soft parts, the dorsal flap being the longer, is the most generally applicable. The bones should always be sawn below the pronator teres, when possible. In sawing them they must be kept parallel, the limb being in the supinated position. As the radius is the less securely held above, it is well to complete the section of this bone first. The relative position of the vessels and other parts is shown in figs. 428A, B.

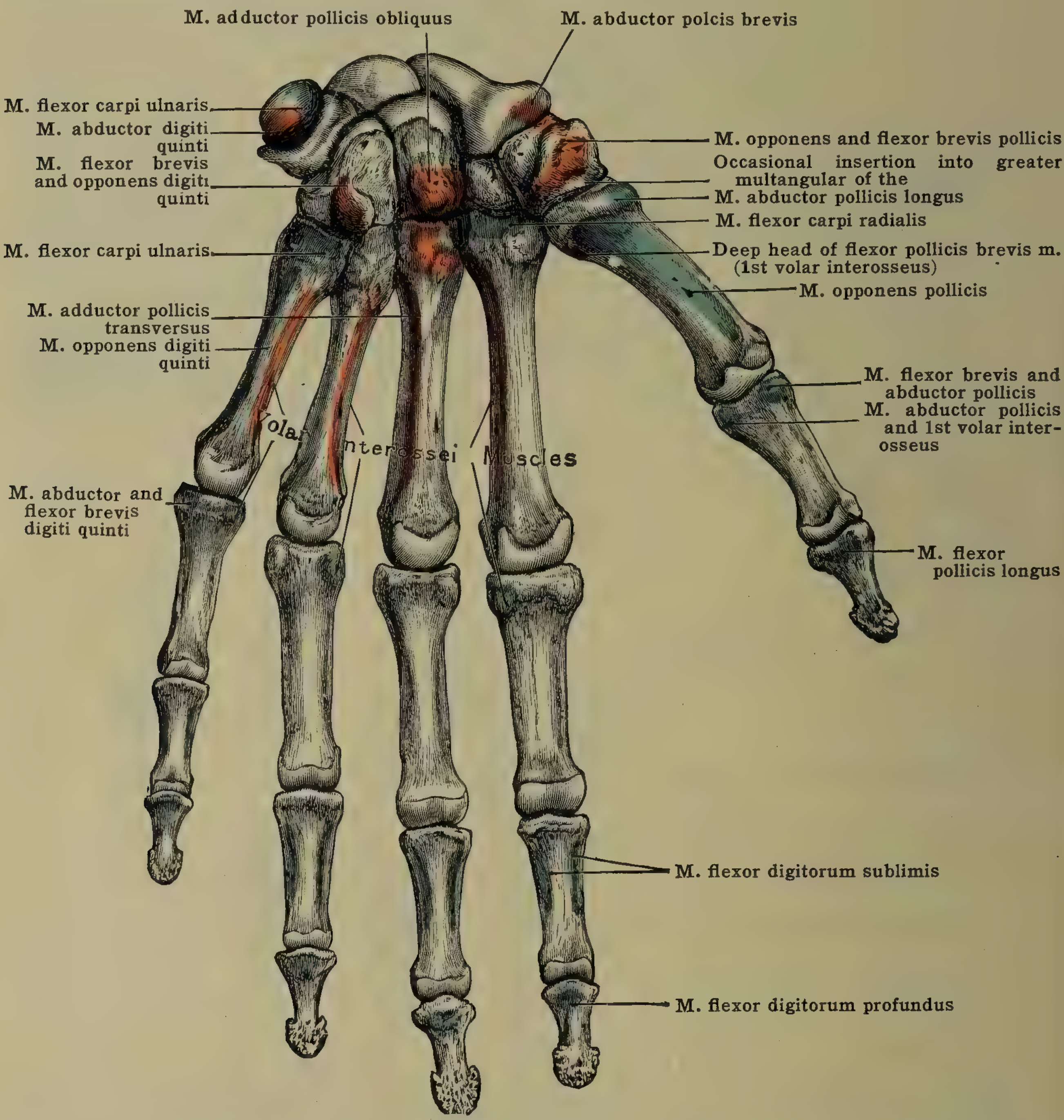


FIG. 237.—BONES OF THE LEFT HAND. (Volar surface.)

THE CARPUS

The **carpus** (figs. 236, 237) consists of eight bones [ossa carpi], arranged in two rows, four bones in each row. Enumerated from the radial to the ulnar side, the bones of the proximal row are named **navicular** (scaphoid) [os naviculare manus] **lunate** (semilunar) [os lunatum], **triquetral** (cuneiform) [os triquetrum], and **pisiform** [os pisiforme]; those of the distal row, **greater multangular** (trapezium), **lesser multangular** (trapezoid) [os multangulum minus], **capitate** (os magnum) [os capitatum] and **hamate** (unciform) [os hamatum].

An alternative nomenclature recommended by the NK is as follows: os naviculare = radiale; os lunatum = intermedium; os triquetrum = ulnare; os multangulum majus = carpale

distale I; os multangulum minus = carpale distale II; os capitatum = carpale distale III; os hamatum = carpale distale IV.

The individual carpal bones have several points of resemblance. Each bone (excepting the pisiform) has six surfaces, of which the anterior or volar and posterior or dorsal are rough for the attachment of ligaments, the volar surface being generally more extensive in the proximal row, the dorsal surface in the distal row. The superior and inferior surfaces are articular, the former being generally convex and the latter concave. The lateral surfaces, when in contact with adjacent bones, are also articular, but otherwise rough for the attachment of ligaments. Further, the whole of the carpus is cartilaginous at birth and each bone is ossified from a single center.

The Navicular Bone

The **navicular** [os naviculare] (fig. 238) is the largest bone of the proximal row, and so disposed that its long axis runs obliquely downward and lateralward.

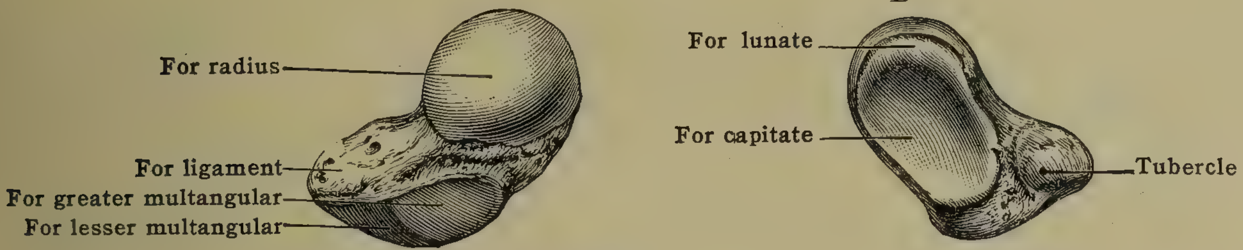


Fig. 238.—The Left Navicular Bone. (A, dorsal; B, volar-medial aspect.)

The **superior surface** is convex and somewhat triangular in shape for articulation with the lateral facet on the distal end of the radius. The **inferior surface**, smooth and convex, is divided into two parts by a ridge running from before backward. The lateral part articulates with the greater multangular, the medial with the lesser multangular. The **volar surface**, rough and concave above, is elevated below into a prominent **tubercle** [tuberculum oss. navicularis] for the attachment of the transverse carpal ligament and the abductor pollicis brevis. The **dorsal surface** is narrow, being reduced to a groove running the whole length of the bone; it is rough and serves for the attachment of the dorsal radiocarpal ligament. The **medial surface** is occupied by two articular facets, of which the upper is crescentic in shape for the lunate bone, whilst the lower is deeply concave for the reception of the head of the capitate. The **lateral surface** is narrow and rough for the attachment of the radial collateral ligament of the wrist-joint.

Articulations.—With the radius above, greater and lesser multangular below, lunate and capitate medially.

The Lunate Bone

The **lunate** [os lunatum] (fig. 239), placed in the middle of the proximal row of the carpus, is markedly crescentic in outline.

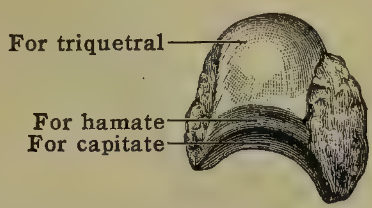


Fig. 239.—The Left Lunate Bone. (Medial-inferior aspect.)

The **superior surface** is smooth and convex and articulates with the medial of the two facets on the distal end of the radius. The **inferior surface** presents a deep concavity divided into two parts by a line running from before backward. Of these, the lateral and larger articulates with the capitate; the medial and smaller with the hamate. The **volar surface** is large and convex, the **dorsal surface** narrow and flat, and both are rough for the attachment of ligaments. The **medial surface** is marked by a smooth quadrilateral facet for the base of the triquetral. The **lateral surface** forms a narrow crescentic articular surface for the navicular.

Articulations.—With the radius above, capitate and hamate below, navicular laterally and triquetral medially.

The Triquetral Bone

The **triquetral** [os triquetrum] (fig. 240) is pyramidal in shape and placed obliquely, so that its base looks upward and laterally and the apex downward and medially.

The **superior surface** presents laterally near the base a small, convex articular facet which plays upon the articular disk interposed between it and the distal end of the ulna, and medially a rough non-articular portion for ligaments. The **inferior surface** forms a large, triangular undulating facet for articulation with the hamate. The **volar surface** can be readily recognized by the conspicuous oval facet near the apex for the pisiform bone. The **dorsal surface** is rough for the attachment of ligaments. The **lateral** and **medial surfaces** are represented by the base and the apex of the pyramid. The base is marked by a flat quadrilateral facet for the lunate. The apex forms the lowest part of the bone and is roughened for the attachment of the ulnar collateral ligament of the wrist.

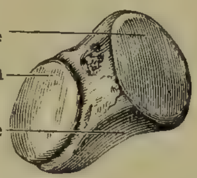


Fig. 240.—The Left Triquetral Bone. (Medial-volar-inferior aspect.)

Articulations.—With the pisiform in front, lunate laterally, hamate below, articular disk above.

The Pisiform Bone

The **pisiform bone** [os pisiforme] (fig. 241), the smallest of the carpal bones, is in many of its characters a complete contrast to the rest of the series. It deviates from the general type in its shape, size, position, use, and development. Forming a rounded bony nodule with the long axis directed vertically, it is situated on a plane in front of the other bones of the carpus.

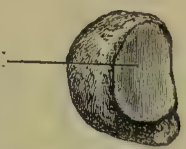


Fig. 241.—The Left Pisiform Bone. (Medial-dorsal aspect.)

On the **dorsal surface** is a single articular facet for the triquetral which reaches to the upper end of the bone, but leaves a free non-articular portion below. The **volar surface**, rough and rounded, gives attachment to the transverse carpal ligament, the flexor carpi ulnaris, the abductor digiti quinti muscles, the pisometacarpal and the pisohamate ligaments. The medial and lateral surfaces are also rough and the lateral presents a shallow groove for the ulnar artery. It is usually considered that the pisiform is a sesamoid bone developed in the tendon of the flexor carpi ulnaris muscle, though by some it is regarded as part of a rudimentary digit.

The Greater Multangular Bone

The **greater multangular bone** [os multangulum majus] (fig. 242), situated between the navicular and first metacarpal, is oblong in form with the lower angle prolonged downward and medially.

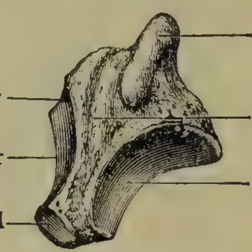


Fig. 242.—The Left Greater Multangular Bone. (Volar aspect.)

The **superior surface** is concave and directed upward and medially for articulation with the lateral of the two facets on the distal surface of the navicular, and the **inferior surface** possesses a saddle-shaped facet for the base of the first metacarpal. The **volar surface** presents a prominent **tubercle** [tuberculum oss. multang. majoris] with a deep groove on its medial side which transmits the tendon of the flexor carpi radialis. The tubercle gives attachment to the transverse carpal ligament, the abductor pollicis brevis, the opponens pollicis, and occasionally a tendinous slip of insertion of the abductor pollicis longus muscle. The **dorsal** and **lateral surfaces** are rough for ligaments. The **medial surface** is divided into two parts by a horizontal ridge. The upper and larger portion is concave and articulates with the lesser multangular; the lower—a small flat facet on the projecting lower angle—articulates with the base of the second metacarpal bone.

Articulations.—With the navicular above, first metacarpal below, the lesser multangular and second metacarpal on the medial side.

The Lesser Multangular Bone

The **lesser multangular bone** [os multangulum minus] (fig. 243), the smallest of the bones in the distal row, is somewhat wedge-shaped, with the broader end dorsally and the narrow end ventrally.

The **superior** surface is marked by a small, quadrilateral, concave facet, for the medial of the two facets on the lower surface of the navicular. The **inferior surface** is convex from side to side and concave from before backward, forming a saddle-shaped articular surface for the base of the second metacarpal. Of the **volar** and **dorsal surfaces**, the former is narrow and convex, the latter broad and rounded, constituting the widest surface of the bone, and both are rough for the attachment of ligaments. The **lateral surface** slopes downward and medially and

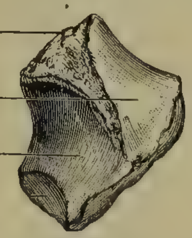


Fig. 243.—The Left Lesser Multangular Bone.

is convex for articulation with the corresponding surface of the greater multangular. On the **medial surface** in front is a smooth flat facet for the capitate; elsewhere it is rough for ligaments.

Articulations.—With the navicular above, second metacarpal below, greater multangular laterally, and the capitate medially.

The Capitate Bone

The **capitate bone** [os capitatum] (fig. 244) is the largest bone of the carpus. Situated in the center of the wrist, the upper expanded portion, globular in shape and known as the **head,** is received into the concavity formed above by the navicular and lunate. The cubical portion below forms the **body,** whilst the intermediate constricted part is distinguished as the **neck.**

Of the six surfaces, the **superior** is smooth and convex, elongated from before backward for articulation with the concavity of the lunate bone. The **inferior surface** is divided into three unequal parts by two ridges. The middle portion, much the larger, articulates with the base of the third metacarpal; the lateral, narrow and concave, looks laterally as well as downward to articulate with the second metacarpal, whilst the medial portion is a small facet, placed on the projecting angle of the bone dorsally, for the fourth metacarpal bone. The **volar surface** is convex and rough, giving origin to fibers of the oblique adductor pollicis; the **dorsal surface** is broad and deeply concave. The **lateral surface** presents, from above downward:—(1) a smooth convex surface, forming the outer aspect of the head, with the superior surface of which it is continuous, for articulation with the navicular; (2) a groove representing the neck, indented

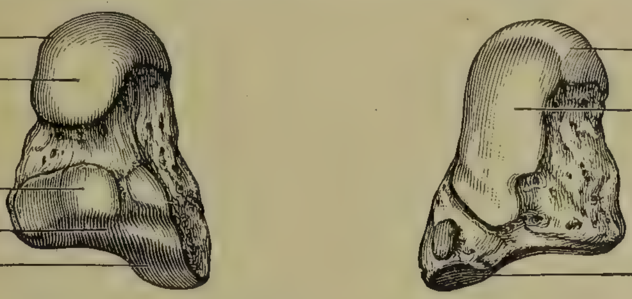


Fig. 244.—The Left Capitate Bone.

for ligaments; (3) a small facet, flat and smooth, for articulation with the lesser multangular. Behind this facet is a rough area for attachment of an interosseous ligament. The **medial surface** has extending along its whole hinder margin an oblong articular surface for the hamate; the lower part of this smooth area sometimes forms a detached facet. The volar part of the surface is rough for an interosseous ligament.

Articulations.—With the lunate and navicular above, second, third, and fourth metacarpals below, lesser multangular laterally, and hamate medially.

The Hamate Bone

The **hamate bone** [os hamatum] (fig. 245) is a large wedge-shaped bone, bearing a hook-like process, situated between the capitate and triquetral, with the base directed downward and resting on the two medial metacarpals.

The apex of the wedge forms the narrow **superior surface,** directed upward and laterally for articulation with the lunate. The **inferior surface** or base is divided by a ridge into two quadrilateral facets for the fourth and fifth metacarpal bones. The **volar surface** is triangular in outline and presents at its lower part a prominent **hamulus** (unciform process) [hamulus oss. hamati], a hook-like eminence, projecting forward and curved toward the carpal canal. It is

flattened from side to side so as to present two surfaces, two borders, and a free extremity. To the latter the transverse carpal ligament and the flexor carpi ulnaris (by means of the piso-hamate ligament) are attached, whilst the medial surface affords origin to the flexor brevis and the opponens digiti quinti. The lateral surface is concave and in relation to the flexor tendons. The **dorsal surface** is triangular and rough for ligaments. The **lateral surface** has extending along its upper and hinder edges a long flat surface, wider above than below, for articulation with the capitate. In front of this articular facet the surface is rough for the attachment of an interosseous ligament. The **medial surface** is oblong and undulating, *i. e.*, concavoconvex from base to apex, for articulation with the triquetral bone.

Articulations.—With the triquetral, lunate, capitate, and the fourth and fifth metacarpa bones.

When the bones of the carpus are articulated, they form a mass somewhat quadrangular in outline, wider below than above, and with the long diameter transverse. The dorsal surface is convex and the volar surface concave from side to side. The concavity is increased by two prominences, which project forward, the **radial and ulnar eminences of the wrist** [eminentia radialis; ulnaris]. The radial eminence is composed of the tubercle of the navicular and that of the greater multangular; the ulnar eminence by the pisiform and the hook of the hamate. The broad, deep groove so formed has been named the **sulcus carpi.** Stretched transversely between the prominences, in the recent state, is the transverse carpal ligament forming a canal for the passage of the flexor tendons and the median nerve into the palm of the hand. The proximal border of the carpus is convex and articulates with the distal end of the radius and the articular disk. The pisiform, however, takes no share in this articulation, being attached to the volar surface of the triquetral. The distal border forms an undulating

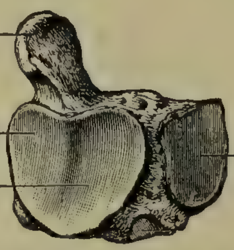


Fig. 245.—The Left Hamate Bone. (Inferior-lateral aspect.)

articular surface for the bases of the metacarpal bones. The line of articulation between the two rows of the carpus is concavoconvex from side to side, the lateral part of the navicular being received into the concavity formed by the greater multangular, lesser multangular, and capitate, and the capitate and hamate into that formed by the navicular, lunate, and triquetral bones.

Beginning Ossification Of The Carpal Bones

Capitate	first year	Greater multangular	fifth year
Hamate	second year	Navicular	sixth year
Triquetral	third year	Lesser multangular	eighth year
Lunate	fourth year	Pisiform	twelfth year

According to the investigations of Pryor the centers of ossification of the carpal bones appear earlier in the female than in the male.

Variations.—Additional carpal elements are occasionally met with, and the total number recorded is large. The **os centrale** occurs normally in the carpus of many mammals, and in the human fetus of two months it is present as a small cartilaginous nodule which soon becomes fused with the cartilage of the navicular. Failure of fusion, with subsequent ossification of the nodule, leads to the formation of an os centrale in the human carpus which is then found on the dorsal aspect, between the navicular, capitate and lesser multangular. In most individuals, however, it coalesces with the navicular or undergoes suppression.

Additional centers of ossification, leading to the formation of accessory carpal elements, occasionally appear in connection with the greater multangular and the hamate. An accessory element (*os Vesalianum*) also occurs occasionally in the angle between the hamate and the fifth metacarpal, and others occur between the second and third metacarpals and the lesser multangular and capitate. The *os styloideum* is accounted for by separate ossification and failure to unite, of the styloid process of the third metacarpal.

THE METACARPUS

The **metacarpus** (figs. 236, 237) consists of a series of five cylindrical bones [ossa metacarpalia I-V], well described as 'long bones in miniature.' Articulated with the carpus above, they descend, slightly diverging from each other, to support the fingers, and are numbered from the lateral to the medial side. With

the exception of the first, which in some respects resembles a phalanx, they conform to a general type.

A typical metacarpal bone presents a shaft and two extremities. The **body** [corpus] or **shaft** is prismatic and curved so as to be slightly convex toward the back of the hand. Of the three surfaces, two are placed on the sides, separated in the middle part of the shaft by a prominent volar ridge, and concave for the attachment of interosseous muscles. The third or **dorsal surface** presents a large, smooth, triangular area with the base below and apex above, covered in the recent state by the extensor tendons of the fingers, and two sloping areas, near the carpal extremity, also for interosseous muscles. The triangular area is bounded by two lines, which commence below in two dorsal tubercles, and, passing upward, converge to form a median ridge situated between the sloping areas on either side. A little above or below the middle of the shaft, and near the volar border, is the nutrient foramen, entering the bone obliquely upward. The **base** [basis] or carpal extremity, broader behind than in front, is quadrilateral, and both volar and dorsal surfaces are rough for ligaments; it articulates above with the carpus and on each side with the adjacent metacarpal bones. The **head** [capitulum] or phalangeal extremity presents a large rounded articular surface, extending further on the volar than on the dorsal aspect, for articulation with the base of the first phalanx. The volar surface is grooved for the flexor tendons and raised on each side into an articular eminence. On each side of the head is a prominent tubercle, and immediately in front of this a well-marked fossa, to both of which the collateral ligament of the metacarpophalangeal joint is attached.

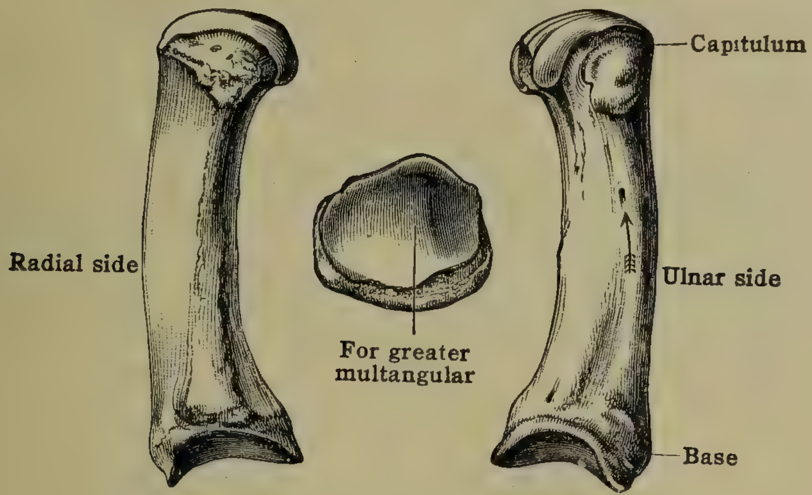


FIG. 246.—THE FIRST (LEFT) METACARPAL BONE.

The second is the longest of all the metacarpal bones, and the third, fourth, and fifth successively decrease in length. The several metacarpals possess distinctive characters by which they are readily identified.

The first metacarpal bone (fig. 246) is the shortest and thickest of the series. Diverging from the carpus more widely than any of the others the volar surface is directed medially and marked by a ridge placed nearer to the medial border. The lateral portion of the surface slopes gently to the lateral border and gives attachment to the opponens pollicis muscle; the medial portion, the smaller of the two, slopes more abruptly to the medial border, is in relation to the deep head of the flexor pollicis brevis, and presents the nutrient foramen, directed downward toward the head of the bone and transmitting a branch of the arteria princeps pollicis. The dorsal surface, wide and flattened, is in relation to the tendons of the extensor pollicis longus and brevis. The **base** presents a saddle-shaped articular surface for the greater multangular, prolonged in front into a thin process. There are no lateral facets, but laterally a small tubercle receives the insertion of the abductor pollicis longus. Medially is a rough area from which fibers of the inner head of the flexor pollicis brevis take origin. The margin of the articular surface gives attachment to the articular capsule of the carpometacarpal joint. The inferior extremity or **head** is rounded and articular, for the base of the first phalanx; the greatest diameter is from side to side and the surface is less convex than the corresponding surface of the other metacarpal bones. On the volar surface it presents two articular eminences corresponding to the two sesamoid bones of the thumb. Of the two margins, the medial gives origin to the lateral head of the first dorsal interosseous muscle, the lateral receives fibers of insertion of the opponens pollicis.

The second metacarpal bone (fig. 247)—The distinctive features of the four remaining metacarpals are almost exclusively confined to the carpal extremities. The second is easily recognized by its deeply cleft base. The proximal surface presents three articular facets, arranged as follows, from lateral to medial border:—(1) a small oval facet for the greater multangular; (2) a hollow for the lesser multangular; and (3) an elongated ridge for the capitate.

The dorsal surface is rough for the insertions of the extensor carpi radialis longus and a part of the extensor carpi radialis brevis; the volar surface receives the insertion of the flexor carpi radialis and gives origin to a few fibers of the oblique adductor pollicis. The lateral aspect of the extremity is rough and non-articular; the medial surface bears a bilobed facet for the third metacarpal. The shaft of the second metacarpal gives attachment to three interosseous muscles; the nutrient foramen, directed upward on the ulnar side, transmits a branch of the second volar metacarpal artery.

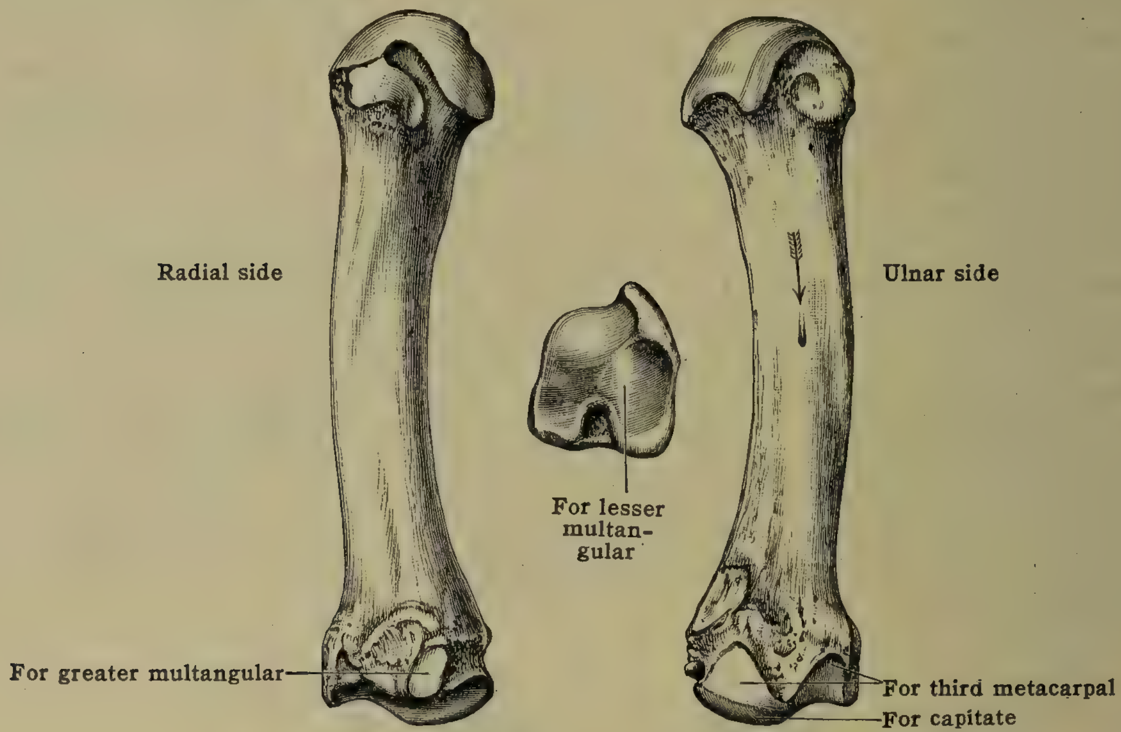


Fig. 247.—The Second (Left) Metacarpal Bone.

The **third metacarpal bone** (fig. 248) is distinguished by the prominent **styloid process** [processus styloideus] projecting upward from the dorsolateral angle of the base. Immediately below it, on the dorsal surface, is a rough impression for the extensor carpi radialis brevis. The carpal surface is concave behind and convex in front, and articulates with the middle of the three facets on the inferior surface of the capitate. On the lateral side is a bilobed articular facet for the second metacarpal, and on the medial side two small oval facets for the fourth metacarpal. The volar aspect of the base is rough and gives attachment to fibers of the oblique

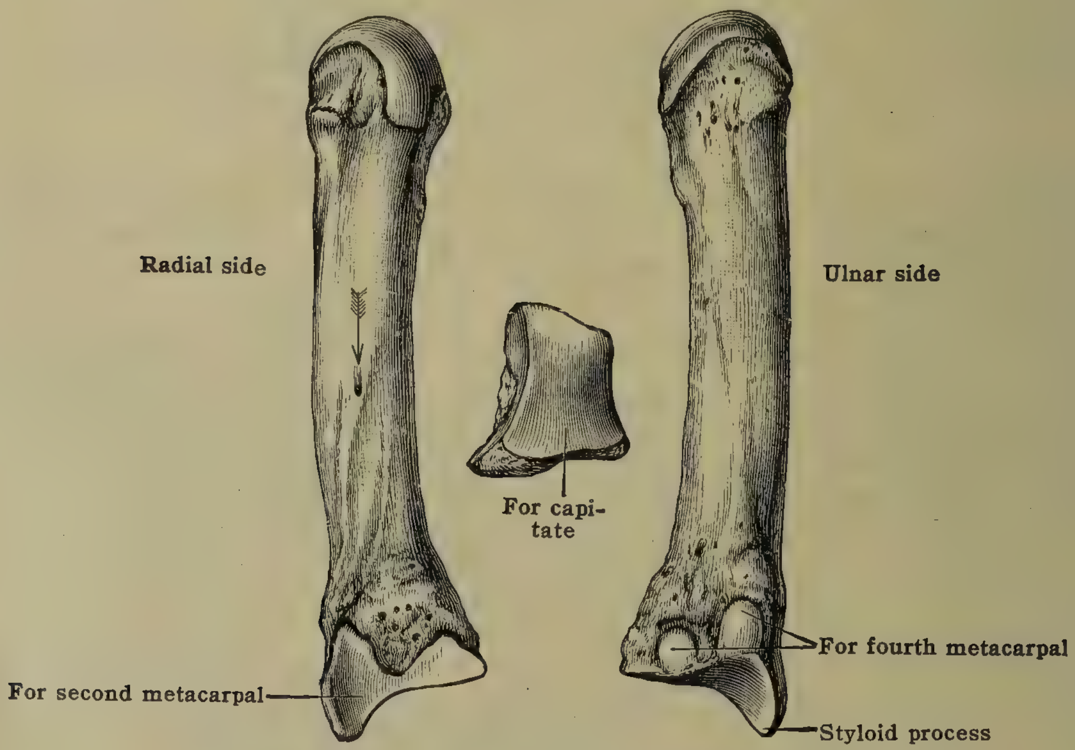


Fig. 248.—The Third (Left) Metacarpal Bone.

adductor pollicis and sometimes a slip of insertion of the flexor carpi radialis. The shaft of the third metacarpal serves for the origin of the transverse adductor pollicis and two interosseous muscles. The nutrient foramen is directed upward on the radial side and transmits a branch of the second volar metacarpal artery.

The **fourth metacarpal bone** (fig. 249) has a small base. The carpal surface presents two facets; a medial, large and flat, for articulation with the hamate, and a small facet, at the lateral

and posterior angle, for the capitate. On the lateral side are two small oval facets for the corresponding surfaces on the third metacarpal and a single concave facet on the medial side for the fifth metacarpal. The shaft of the fourth metacarpal gives attachment to three interosseous muscles; the nutrient foramen, directed upward on the radial side, transmits a branch of the third volar metacarpal artery.

The **fifth metacarpal bone** (fig. 250) is distinguished by a semilunar facet on the lateral side of the base for the fourth metacarpal, and a rounded tubercle on the medial side for the extensor carpi ulnaris, in place of the usual medial facet. The carpal surface is saddle-shaped for the hamate; the volar surface is rough for ligaments including the pisometacarpal prolongation

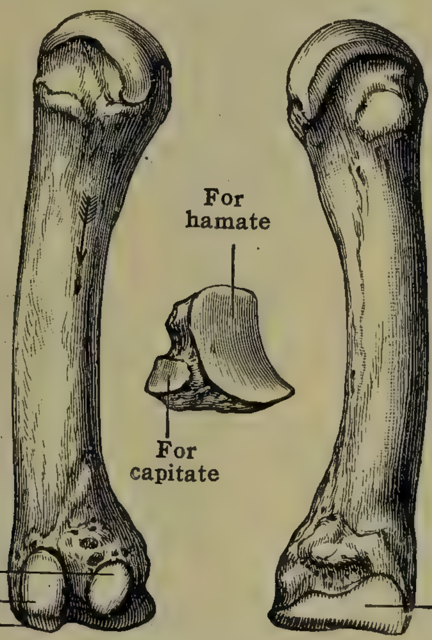


FIG. 249.—THE FOURTH (LEFT) METACARPAL BONE.

from the flexor carpi ulnaris. The dorsal surface of the shaft presents an oblique line separating a lateral concave portion for the fourth dorsal interosseous muscle from a smooth medial portion covered by the extensor tendons of the little finger. The volar surface gives attachment laterally to the third volar interosseous muscle and medially to the opponens digiti quinti. The nutrient foramen is directed upward on the radial side and transmits a branch of the fourth volar metacarpal artery.

THE PHALANGES

The **phalanges of the fingers** [phalanges digitorum manus] (fig. 251) are the bones of the fingers, and number in all fourteen. Each finger, excepting the

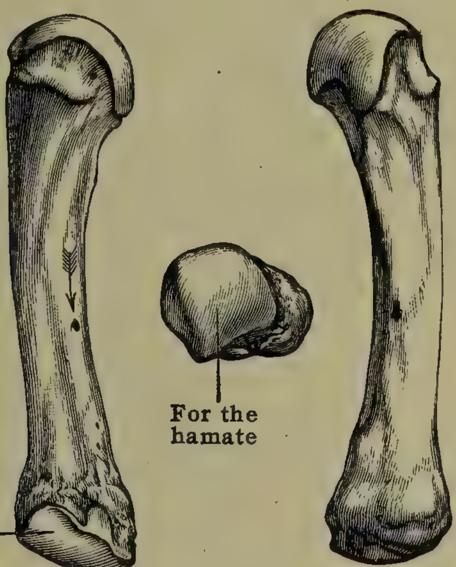


FIG. 250.—THE FIFTH (LEFT) METACARPAL BONE.

first, contains three phalanges distinguished as first or proximal, second or middle, and third or distal. In the thumb, the second phalanx is wanting. Arranged in horizontal rows, the phalanges of each row resemble one another and differ from those of the other two rows. In all the phalanges the nutrient canal is directed downward, toward the distal extremity.

First phalanx [phalanx prima] (phalanx proximalis NK).—The **body** or **shaft of the phalanx** [corpus phalangis] from the first row is flat on the volar surface, smooth and rounded on the dorsal surface, *i. e.*, semi-cylindrical in shape. The borders of the volar surface are rough for the attachment of the sheaths of the flexor tendons. The **base** [basis phalangis] or metacarpal

extremity presents a single concave articular surface, oval in shape, for the convex head of the metacarpal bone. The distal extremity forms a pulley-like surface, the **trochlea** [trochlea phalangis], grooved in the center and elevated at each side to form two miniature condyles, for articulation with the base of a second phalanx.

Second phalanx [phalanx secunda] (phalanx media NK).—The second phalanges are four in number and are shorter than those of the first row, which they closely resemble in form. They are distinguished, however, by the articular surface on the **base** or proximal extremity, which presents two shallow depressions, separated by a ridge and corresponding to the two condyles of the first phalanx. The **trochlea** or distal end for the base of the third phalanx is pulley-like, but smaller than that of the first phalanx. The volar surface of the shaft presents on each side an impression for the insertion of the flexor digitorum sublimis, and the dorsal aspect of the base is marked by a projection for the insertion of the extensor digitorum communis.

Third phalanx [phalanx tertia] (phalanx distalis NK).—The third phalanx is readily recognized by its small size. The **base** is identical in shape with that of a second phalanx, and bears a depression in front for the insertion of the flexor digitorum profundus. The free, flattened and expanded distal extremity presents on its volar surface a rough semilunar elevation for the support of the pulp of the finger. The somewhat horseshoe-shaped free extremity is known as the **ungual tuberosity** [tuberositas unguicularis], and the bone is accordingly referred to as the **ungual phalanx.**

Sesamoid bones [ossa sesamoidea].—The sesamoid bones are small and rounded and occur imbedded in certain tendons where they exert a considerable amount of pressure on subjacent bony structures. In the hand five sesamoid bones are of almost constant occurrence, namely, two over the metacarpophalangeal joint of the thumb in the tendons of the flexor pollicis brevis,

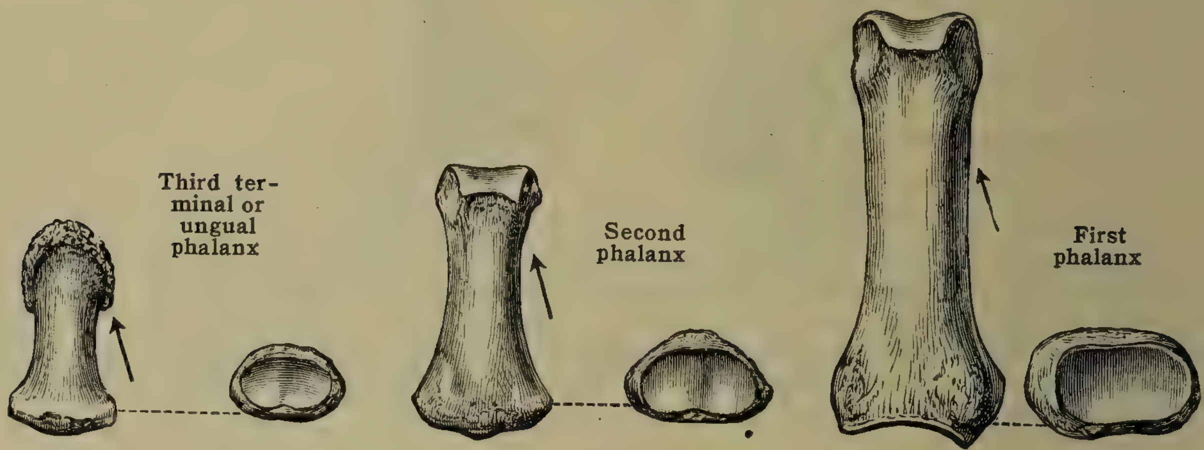


Fig. 251.—The Phalanges of the Third Digit of the Hand. (Dorsal view.) (The arrows indicate the direction of the nutrient canals.)

one over the interphalangeal joint of the thumb, and one over the metacarpophalangeal joints of the second and fifth fingers. Occasionally sesamoids occur over the metacarpophalangeal joint of the third and fourth digits, and an additional one may occur over that of the fifth.

Ossification of the Metacarpus and Phalanges

Each of the metacarpal bones and phalanges is ossified from a primary center for the greater part of the bone, and from one epiphysial center. The primary nucleus appears from the eighth to the tenth week of intrauterine life. In four metacarpal bones the epiphysis is distal, while in the first metacarpal bone, and in all the phalanges, it is proximal. The epiphysial nuclei appear from the third to the fifth year and are united to their respective shafts about the twentieth year. In many cases the first metacarpal has two epiphyses, one for the base in the third year and an additional one for the head in the seventh year, but the latter is never so large as in the other metacarpal bones. The third metacarpal occasionally has an additional nucleus for the prominent styloid process which may remain distinct and form a *styloid bone*, and traces of a proximal epiphysis have been observed in the second metacarpal bone. In many of the Cetacea (whales, dolphins, and porpoises) and in the seal, epiphyses are found at both ends of the metacarpal bones and phalanges (Flower).

The ossification of a terminal phalanx is peculiar. Like the other phalanges, it has a primary nucleus and a secondary nucleus for an epiphysis. But whereas in other phalanges the primary center appears in the middle of the shaft, in the case of the distal phalanges the earthy matter is deposited in the free extremity of the cartilaginous bar, the epiphysis ossifying in membrane.

Bony landmarks of the wrist and hand.—On the medial side the *styloid process* and, further laterally, the *head of the ulna* can be made out. On the lateral side, the *radial styloid process* descends about 1.2 cm. (½ in.) lower than that of the radius, and is somewhat anterior to it. Abduction of the hand is to some extent limited by the styloid process of the radius and is thus less free than adduction. Between the apex of the styloid process and the ball of the thumb a bony ridge can be felt, with some difficulty, formed by the *tubercle of the navicular* and the ridge of the *greater multangular* (trapezium). At the base of the hypothenar eminence the *pisiform* can be more readily distinguished. The *hook of the hamatum* (unciform) lies below and to the radial side of the pisiform. On the front of the metacarpophalangeal joint of the thumb, the *sesamoid bones* can be distinguished.

At the back of the wrist and hand the *triquetrum* (cuneiform) bone can be felt below the head of the ulna; and more toward the middle line the prominence of the *capitatum* (os magnum) which supports the third or longest digit.

A line drawn from the base of the fifth metacarpal bone to the radiocarpal joint, slightly curved downward, will give the line of the carpometacarpal joints. (Windle.) When the fingers are flexed, it will be seen that in each case it is the proximal bone which forms the prom-

FIG. 252.—SKELETON OF THE RIGHT HAND OF A BOY AGED 16 YEARS. (From an *X*-ray plate by Dr. Sherwood Moore, Washington University.)

inence; thus, the knuckle is formed by the head of the metacarpal, the interphalangeal prominence by the head of the first phalanx, and the distal one by the head of the second. Thus, the joint in each case lies below the prominence, the distal joint being 2 mm. (1/12 in.), the interphalangeal 4 mm. (1/6 in.), and the metacarpophalangeal 8 mm. (1/3 in.) below its prominence.

B. THE BONES OF THE LOWER EXTREMITY

The **bones of the lower extremity** [ossa extremitatis inferioris] (ossa extremitatis pelvinae NK) may be arranged in four groups corresponding to the division of the limb into the *hip*, *thigh*, *leg*, and *foot*. In the *hip* is the coxal or hip-bone, which constitutes the **pelvic girdle** [cingulum extremitatis inferioris], and contributes to the formation of the pelvis; in the *thigh* is the femur; in the *leg*, the tibia and fibula, and in the *foot* the tarsus, metatarsus, and phalanges. Associated with the lower end of the femur is a large sesamoid bone, the patella or knee-cap.

THE HIP BONE

The **hip** (innominate) **bone** [os coxæ] (figs. 253, 254) is a large, irregularly shaped bone articulated behind with the sacrum, and in front with its fellow of the opposite side, the two bones forming the anterior and side walls of the **pelvis.** The hip bone consists of three parts, named **ilium, ischium,** and **pubis,** which, though separate in early life (figs. 256, 257), are firmly united in the adult. The three parts meet together and form the **acetabulum,** a large, cup-like socket situated near the middle of the lateral surface of the bone for articulation with the head of the femur.

The **ilium** [os ilium] is the upper portion of the bone, divisible into a superior, broad **ala** [ala ossis ilium] and an inferior **body** [corpus ossis ilium] forming the upper two-fifths of the acetabulum.

Borders.—When viewed from above, the thick **iliac crest** [crista iliaca] or superior border of the ilium is curved somewhat like the letter *f*, being concave medially in front and concave laterally behind. Its anterior extremity forms the **anterior superior iliac spine** [spina iliaca anterior superior], which gives attachment to the inguinal (Poupart's) ligament and the sartorius muscle; the posterior extremity forms the **posterior superior iliac spine** [spina iliaca posterior superior] and affords attachment to the sacrotuberous (great sacrosciatic) ligament, the posterior sacroiliac ligament, and the multifidus muscle. The crest is narrow in the middle, thick at its extremities, and may be divided into an inner lip, an outer lip, and an intermediate line. About 6 cm. (2½ in.) from the anterior superior spine is a prominent tubercle on its external lip.

The **external lip** [labium externum] of the crest gives attachment in front to the tensor faciæ latæ; along its whole length, to the fascia lata; along its anterior half to the external oblique muscle; and behind this, for about an inch, to the latissimus dorsi. The anterior two-thirds of the **intermediate line** [linea intermedia] gives origin to the internal oblique. The **internal lip** [labium internum] gives origin, by its anterior two-thirds, to the transversus, behind this is a small area for the quadratus lumborum muscle, and the remainder is occupied by the sacrospinalis (erector spinæ). The internal lip, in the anterior two-thirds, also serves for the attachment of the iliac fascia.

The iliac crest is readily felt beneath the skin throughout its whole length. The posterior superior iliac spine corresponds in level to the second sacral spine and the center of the sacroiliac joint.

The **anterior border** of the ilium extends from the anterior superior iliac spine to the margin of the acetabulum. Below the spine is a prominent notch from which fibers of the sartorius muscle arise, and this is succeeded by the **anterior inferior iliac spine** [spina iliaca anterior inferior] (tuberculum ilicum NK), smaller and less prominent than the superior, to which the straight head of the rectus femoris muscle and the iliofemoral ligament are attached. On the medial side of the anterior inferior spine is a broad, shallow groove for the iliopsoas muscle as it passes from the abdomen into the thigh, limited below by the **iliopectineal eminence** [eminentia iliopectinea], which indicates the place of union of the ilium and pubis.

The **posterior border** of the ilium presents the posterior superior iliac spine and below this, a shallow notch terminating in the **posterior inferior iliac spine** [spina iliaca posterior inferior] which corresponds to the posterior extremity of the auricular surface and gives attachment to a portion of the sacrotuberous (great sacrosciatic) ligament. Below the spine the posterior border of the ilium forms the upper limit of the greater sciatic notch.

Surfaces.—The **external surface** or **dorsum** is concave behind, convex in front, limited above by the thick superior border or crest, and traversed by three **gluteal lines.**

The **posterior gluteal line** [linea glutaea posterior] (linea glutaea dorsalis NK) commences at the crest about 5 cm. (2 in.) from the posterior superior iliac spine and curves downward to the upper margin of the **greater sciatic notch.** The space included between this ridge and the crest affords origin at its upper part to the gluteus maximus muscle, and at its lower part, to a few fibers of the piriformis muscle, while the intermediate portion is smooth and free from muscular attachment. The **anterior gluteal line** [linea glutaea anterior] (linea glutaea cranialis NK) begins at the crest, 2.5 cm. (1 in.) behind its anterior superior iliac spine, and curves across the dorsum to terminate near the lower end of the posterior line, at the upper margin of the greater sciatic notch. The surface of bone between this line and the crest gives origin to the gluteus medius muscle. The **inferior gluteal line** [linea glutaea inferior] (linea glutaea acetabularis NK) commences at the notch immediately below the anterior superior iliac spine and terminates

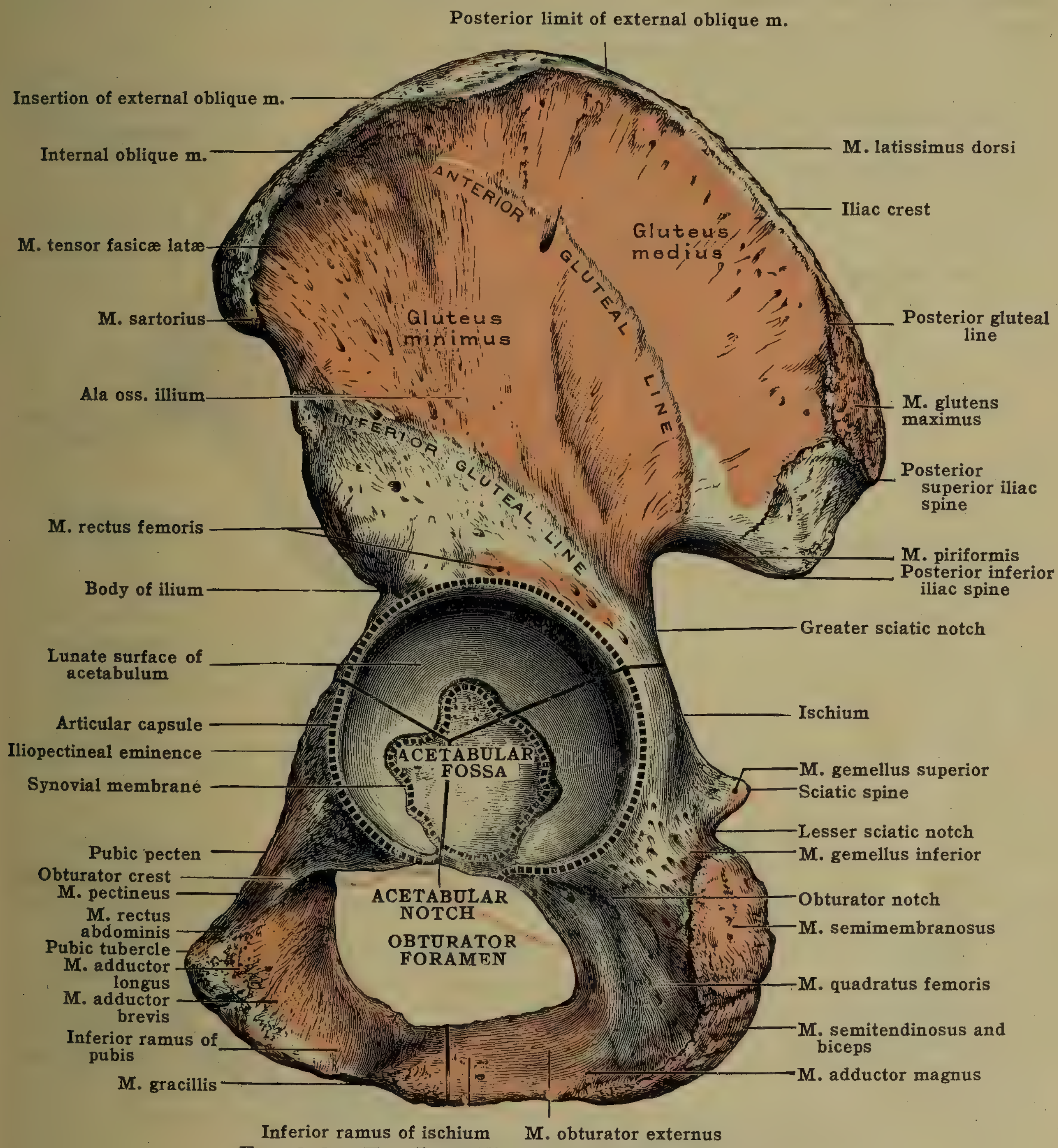


FIG. 253.—THE LEFT HIP-BONE. (Lateral view.)

posteriorly at the front part of the greater sciatic notch. The space between the anterior and inferior gluteal lines, with the exception of a small area adjacent to the anterior end of the spine for the tensor fasciæ latæ, gives origin to the gluteus minimus muscle. Between the inferior gluteal line and the margin of the acetabulum the surface affords attachment to the capsule of the hip-joint, and on a rough area (sometimes a depression) toward its anterior part, to the reflected tendon of the rectus femoris.

The **internal surface** of the ala presents in front a smooth concave portion termed the **iliac fossa** [fossa iliaca], which lodges the iliacus muscle. Behind the iliac fossa the bone is uneven and presents an **auricular surface** [facies auricularis] covered with cartilage in the recent state, for articulation with the auricular surface of the sacrum; behind the auricular surface and also in front, are some

depressions, **sulci paraglenoidales,** for the sacroiliac ligaments, and a rough area reaching as high as the crest, from which parts of the sacrospinalis and multifidus muscles take origin. The rough surface above the auricular surface is known as the **tuberosity of the ilium** [tuberositas iliaca]. The ala is limited below by the **linea arcuata,** the iliac portion of the terminal (iliopectineal) line. This is a rounded border separating the ala from a portion of the internal surface of the body of the ilium below the line, which gives attachment to the obturator internus muscle and enters into the formation of the minor (true) pelvis.

The **ischium** [os ischii] consists of a body, tuberosity, and two rami. The **body** [corpus ossis ischii], which has somewhat the form of a triangular pyramid,

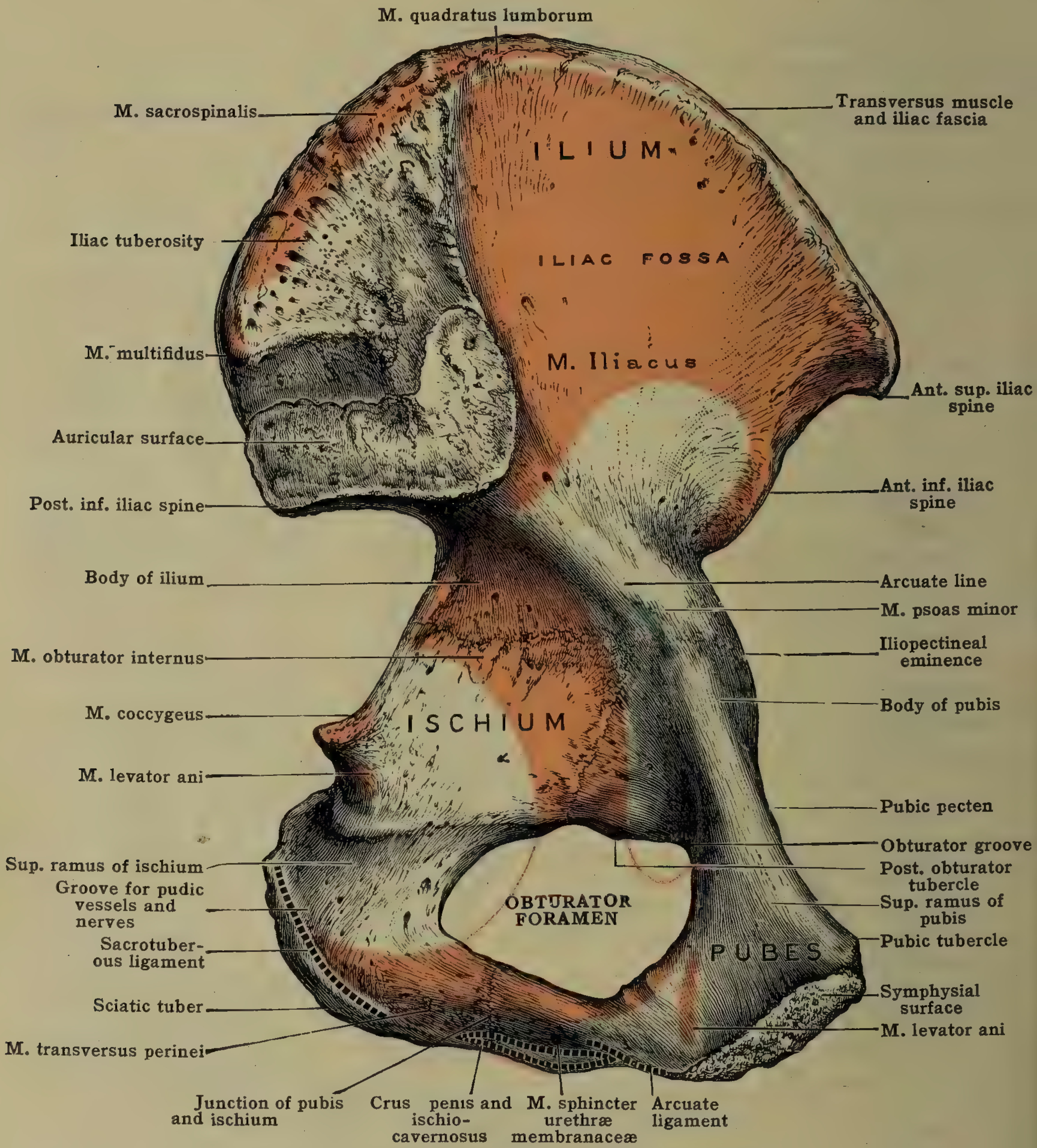


FIG. 254.—THE LEFT HIP-BONE. (Medial aspect.)

enters superiorly into the formation of the acetabulum, to which it contributes a little more than two-fifths, and forms the chief part of the non-articular portion or floor. The **inner surface** forms part of the minor (true) pelvis and gives origin to the obturator internus. It is continuous with the ilium a little below the terminal (iliopectineal) line, and with the pubis in front, the line of junction with the latter being frequently indicated in the adult bone by a rough line extending from the iliopectineal eminence to the margin of the obturator foramen. The **outer surface** includes the portion of the acetabulum formed by the ischium. The **posterior surface** is broad and bounded laterally by the margin of the acetabu-

lum and behind by the posterior border. The capsule of the hip-joint is attached to the lateral part and the piriformis muscle, the great sciatic and posterior femoral cutaneous nerves, the inferior gluteal (sciatic) artery, and the nerve to the quadratus femoris muscle lie on the surface as they leave the pelvis. Inferiorly this surface is limited by a broad notch (obturator notch), which receives the posterior fleshy border of the obturator externus when the thigh is flexed.

Of the three borders, the **external,** forming the prominent rim of the acetabulum, separates the posterior from the external surface and gives attachment to the glenoid lip. The **inner border** is sharp and forms the lateral boundary of the obturator foramen. The **posterior border** is continuous with the posterior border of the ilium, with which it joins to complete the margin of the **greater sciatic notch** [incisura ischiadica major]. The notch is converted into a foramen by the sacrospinous (small sacrosciatic) ligament (see fig. 356), and transmits the piriformis muscle, the gluteal vessels, the superior and inferior gluteal nerves, the sciatic and posterior femoral cutaneous nerves, the internal pudendal vessels and pudendal nerve, and the nerves to the obturator internus and quadratus femoris muscles. Below the notch is the prominent **sciatic spine** [spina ischiadica], which gives attachment internally to the coccygeus and levator ani,

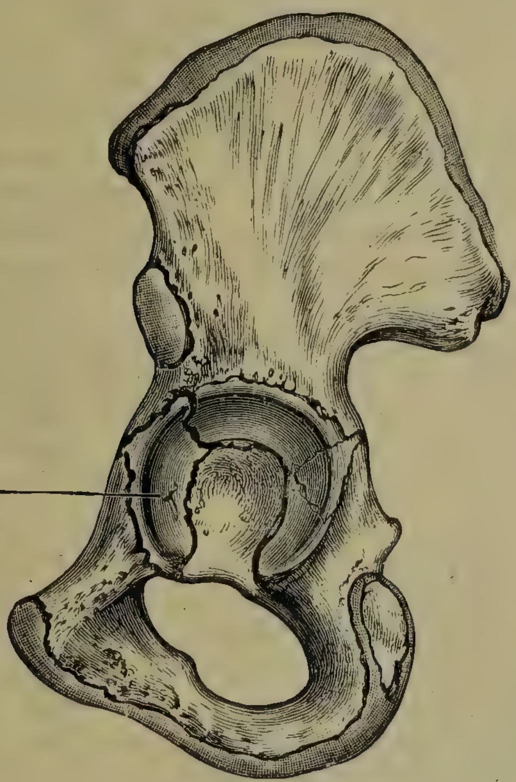


Fig. 255.—An Immature Hip Bone, showing a Cotyloid Bone.

externally to the gemellus superior muscle, and at the tip to the sacrospinous ligament. Below the spine is the **lesser sciatic notch** [incisura ischiadica minor], covered in the recent state with cartilage, and converted into a foramen by the sacrotuberous (great sacrosciatic) ligament. It transmits the tendon of the obturator internus, its nerve of supply, and the internal pudendal vessels and pudendal nerve.

The **rami** form the flattened part of the ischium which runs first downward, then upward, forward and medially from the tuberosity toward the inferior ramus of the pubis, with which it is continuous. The rami together form an L-shaped structure with a vertical **upper ramus** [ramus superior oss. ischii (pars acetabularis NK)] and a horizontal **lower ramus** [ramus inferior oss. ischii (pars pubica NK)]. The outer surface of the rami gives origin to the adductor magnus and obturator externus muscles, the inner surface, forming part of the anterior wall of the pelvis, receives the crus penis (or clitoridis) and the ischiocavernosus muscle, and gives origin to a part of the obturator internus. Of the two borders, the upper is thin and sharp, and forms part of the boundary of the obturator foramen; the lower is rough and corresponds to the inferior ramus. It is somewhat everted and gives attachment to the fascia of Colles, and the transversus perinei muscle. To a ridge immediately above the impression for the crus penis (or clitoridis) and the ischiocavernosus, the urogenital diaphragm is attached. The posterior

and inferior aspect of the superior ramus is an expanded area forming the **sciatic tuberosity** [tuber ischiadicum] (tuber ossis ischii NK).

The **tuberosity** is that portion of the ischium which supports the body in the sitting posture. It forms a rough, thick eminence of the posterior surface of the superior ramus, continuous with the inferior border of the inferior ramus, and is marked by an oblique line separating two impressions, an upper and lateral for the origin of the semimembranosus, and a lower and medial for the common tendon of the biceps and semitendinosus muscles, while the lower part is markedly uneven and gives origin to the adductor magnus muscle. The upper border gives origin to the inferior gemellus; the inner border, sharp and prominent, receives the sacrotuberous (great sacrosciatic) ligament, while the surface of the tuberosity immediately in front is in relation with the internal pudendal vessels and pudendal nerve. The outer border gives origin to the quadratus femoris muscle. The tuberosities are readily felt by surface pressure on either side of the anus. In erect posture they are covered by the lower margins of the gluteus maximus muscles.

The **pubis** [os pubis] consists of a **body** and two **rami—superior** and **inferior.** The **body** [corpus oss. pubis] helps to form the acetabulum and therefore in the adult hip bone presents no free margins. The iliopectineal eminence marks the junction of the ilium and body of the pubis. Between the eminence and the anterior inferior iliac spine is the broad groove occupied by the iliopsoas muscle. From the iliopectineal eminence the **upper ramus of the pubis** [ramus superior oss. pubis] (pars acetabularis NK) extends medially, downward and forward, presenting a prismatic form in its lateral two-thirds, compressed anteroposteriorly in its medial third. Concerning the latter portion the **anterior surface** looks downward, forward and slightly outward, and gives origin to the adductor longus and the obturator externus muscles. The **posterior surface** is smooth, looks into the pelvis, and affords origin to the levator ani, and obturator internus muscles, and the puboprostatic ligaments. The **upper border** is rough and presents laterally a prominent bony point, known as the **pubic tubercle** [tuberculum pubicum] or spine, for the attachment of the inguinal (Poupart's) ligament. The upper border, from the pubic tubercle medialward to the upper end of the symphysis, gives attachment to the rectus abdominis and pyramidalis muscles. The **medial border** [facies symphyseos] is oval in shape, rough, and articular, forming with the bone of the opposite side the joint called symphysis pubis. The **lateral border** is sharp and forms part of the boundary of the obturator foramen. The lateral prismatic part of the superior ramus presents superiorly a sharp ridge, the **pecten ossis pubis** or pubic portion of the terminal (iliopectineal) line continuous with the iliac portion at the iliopectineal eminence, and affording attachment to the conjoined tendon [falx aponeurotica inguinalis], the lacunar (Gimbernat's) ligament, the reflected inguinal ligament, and the pubic portion of the fascia lata. Immediately in front of the pubic portion of the line is the **pectineal surface**; it gives origin at its posterior part to the pectineus muscle, and is limited below by the **obturator crest** [crista obturatoria], which extends from the pubic tubercle to the acetabular notch. The **inferior surface** of the superior ramus forms the upper boundary of the obturator foramen and presents the deep **obturator groove** [sulcus obturatorius] for the passage of the obturator vessels and nerve. The **posterior surface** is smooth, forms part of the anterior wall of the pelvic cavity, and gives attachment to a few fibers of the obturator internus muscle.

The **inferior ramus** [ramus inferior oss. pubis] (pars symphysica NK), continuous with the superior ramus at the symphyseal surface extends downward, laterally and backward. Like the inferior ramus of the ischium, with which it is continuous, it is thin and flattened. To its **anterior surface** are attached the adductor brevis, adductor magnus, and obturator externus muscles. The **posterior surface** is smooth and gives attachment to the crus penis or clitoridis, the sphincter urethræ (urogenitalis), the obturator internus, and the urogenital diaphragm. The **lateral border** forms part of the circumference of the obturator foramen, and the **medial border** forms part of the pubic arch and gives attachment to the gracilis muscle.

The **acetabulum** (figs. 253, 255) is a deep hemispherical cavity which receives the head of the femur and consists of an articular and a non-articular portion. The articular portion is circumferential and semilunar in shape [**facies lunata**], with the deficiency in the lower segment. One-fifth of the acetabulum is formed by the pubis, two-fifths by the ischium, and the remaining two-fifths are formed by the ilium. The non-articular portion [**fossa acetabuli**] is formed mainly by

the ischium, and is continuous below with the margin of the obturator foramen. The articular lunate surface presents a lateral rim to which the glenoid lip is attached, and a medial margin to which the synovial membrane, which excludes the ligamentum teres from the synovial cavity, is connected. The opposite extremities of the articular lunate surface, which limit the **acetabular notch** [incisura acetabuli], are united by the transverse ligament, and through the **acetabular foramen** thus formed a nerve and vessels enter the joint.

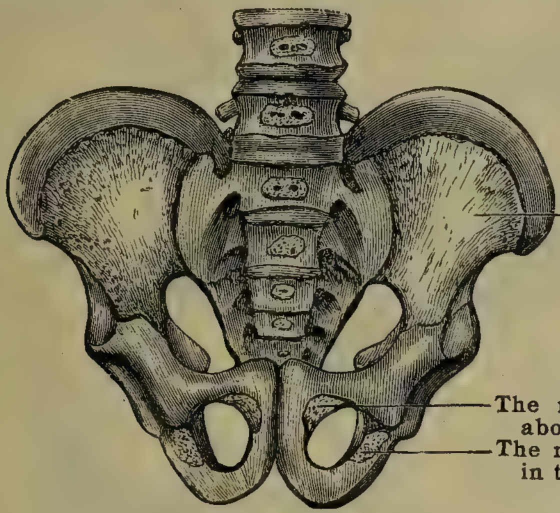


FIG. 256.—THE PELVIS OF A CHILD AT BIRTH, TO SHOW THE THREE PORTIONS OF THE HIP BONES.

The **obturator foramen** [foramen obturatum] (figs. 253, 254) is situated between the ischium and pubis. Its margins are thin, and serve for the attachment of the obturator membrane. At the upper and posterior angle it is deeply grooved for the passage of the obturator vessels and nerve.

Blood-supply.—The chief vascular foramina of the hip-bone are found where the bone is thickest. On the inner surface, the ilium receives twigs from the iliolumbar, deep circumflex iliac, and obturator arteries, by foramina near the crest, in the iliac fossa, and below the terminal line near the greater sciatic notch. On the outer surface the chief foramina are found below the inferior gluteal line and the nutrient vessels are derived from the gluteal arteries. The

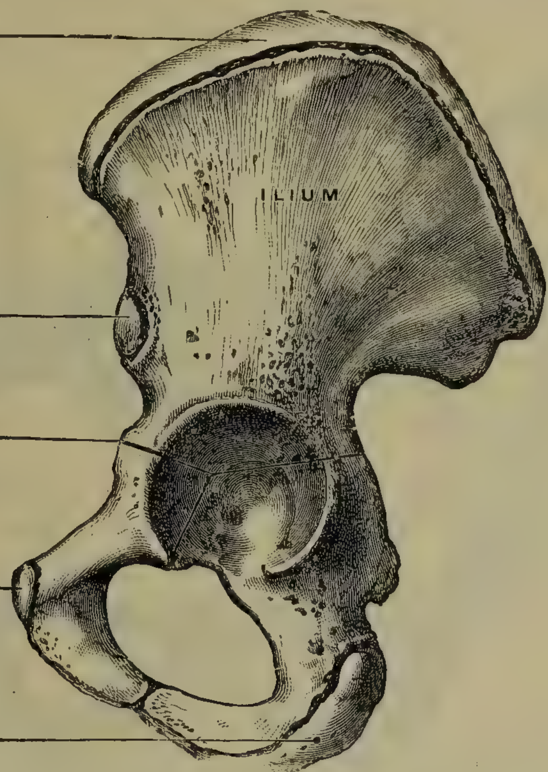


FIG. 257.—HIP-BONE (OUTER SURFACE) AT THE EIGHTEENTH YEAR.

ischium receives nutrient vessels from the obturator, medial and lateral circumflex arteries, and the largest foramina are situated between the acetabulum and the sciatic tuber. The pubis is supplied by twigs from the obturator, medial and lateral circumflex arteries.

Ossification.—The cartilaginous representative of the hip-bone consists of three distinct portions, an **iliac**, an **ischiatic**, and a **pubic** portion; the iliac and ischiatic portions first unite, and later the pubic portion, so that eventually there is found a single cartilaginous mass. In the second month a center of ossification appears above the acetabulum for the ilium. Later a second nucleus appears below the cavity, for the ischium, and this is followed in the

fourth month by a deposit in the pubic portion of the cartilage. At birth, the three nuclei are of considerable size, but are surrounded by relatively wide tracts of cartilage (fig. 256); ossification has, however, extended into the margin of the acetabulum. In the eighth year the rami of the pubes and ischia become united by bone, and in the twelfth year the triradiate cartilage which separates the three segments of the bone in the acetabulum begins to ossify from several centers. Of these, one is more constant than the others and is known as the acetabular nucleus. The triangular piece of bone to which it gives rise is regarded as the representative of the *cotyloid* or acetabular bone (fig. 255), constantly present in a few mammals.

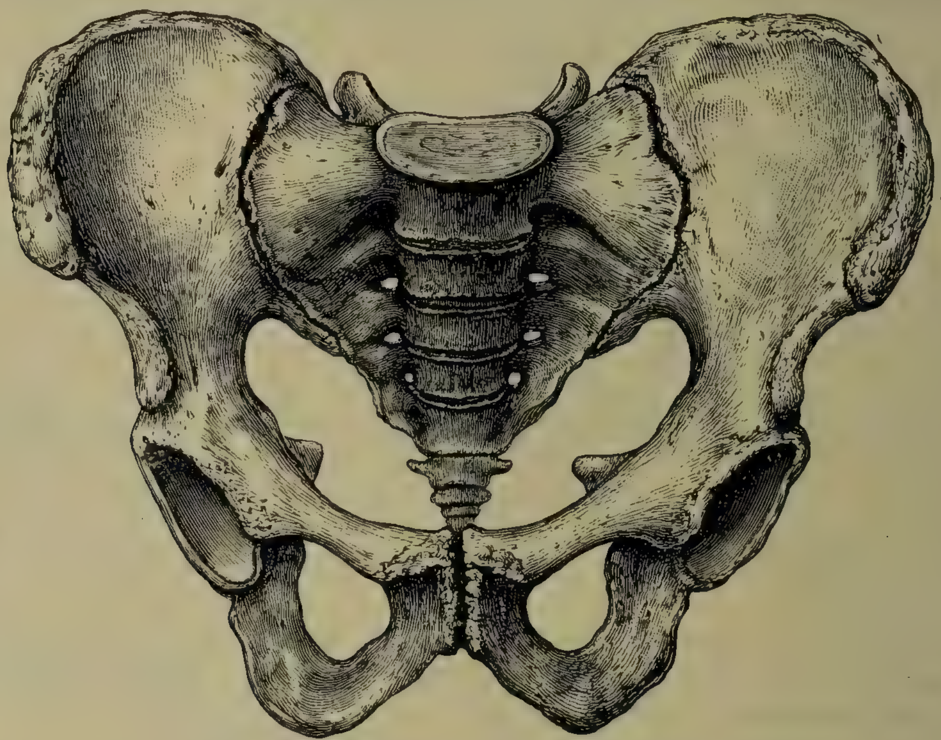


Fig. 258.—The Male Pelvis. (Ventral view.)

It is situated at the medial part of the acetabulum and is of such a size as to exclude entirely the pubis from the cavity. With this bone, however, it eventually fuses, and afterward becomes joined with the ilium and ischium, so that by the eighteenth or twentieth year the several parts of the acetabulum have become united. In the fifteenth year other centers appear in the cartilage of the crest of the ilium, the anterior inferior iliac spine, the sciatic tuber, and the pubic pecten. The epiphyses fuse with the main bone about the twentieth year. The fibrous tissue connected with the tubercle of the pubis is believed to represent the epipubic bones of marsupials.

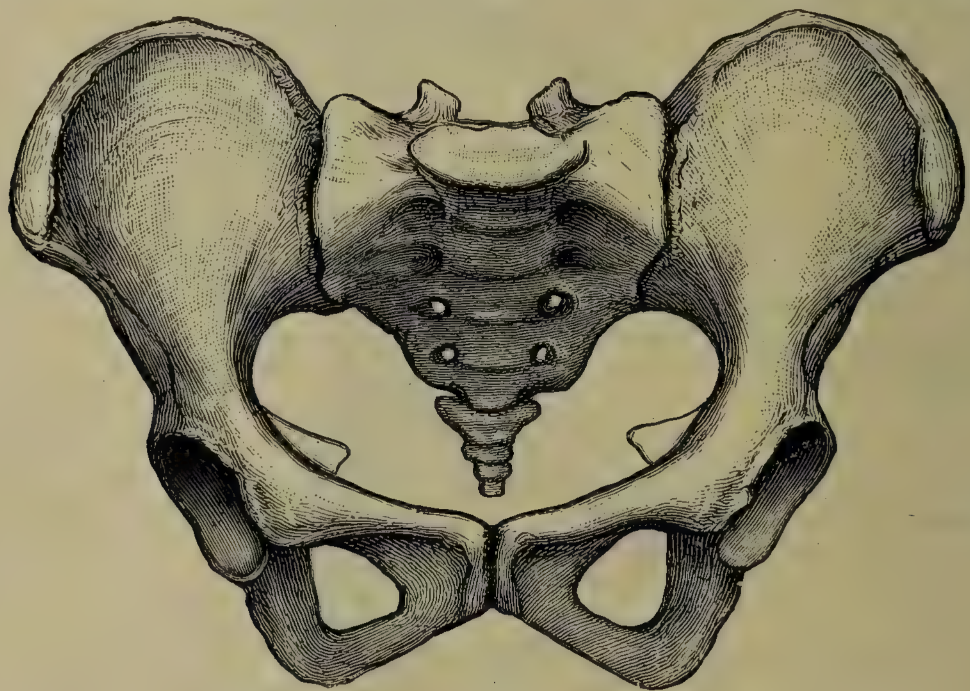


Fig. 259.—The Female Pelvis. (Ventral view.)

Variations.—The hip-bone is subject to relatively little variation. The cotyloid bone was noted above. Conversion of the obturator groove into a bony walled foramen, and defective union of the rami of the pubis and ischium are the chief variations observed.

THE PELVIS

The **pelvis** (figs. 258, 259) includes four bones: the two hip-bones, the sacrum, and the coccyx. The hip-bones form the lateral and anterior boundaries, meeting

each other in front to form the pubic symphysis [symphysis ossium pubis]; posteriorly they are separated by the sacrum. The interior of the pelvis is divided into the **major** and **minor pelvic cavities** by the **linea terminalis.** This is composed of the pubic pecten (pars pubica lineæ terminalis), the arcuate line (pars iliaca lineæ terminalis), and the rounded angle between the base and pelvic surfaces of the sacrum (pars sacralis lineæ terminalis).

The **major pelvis** [pelvis major] is that part of the cavity which lies above the terminal (iliopectineal) lines and between the iliac fossæ. This part belongs really to the abdomen, and is in relation with the hypogastric and iliac regions.

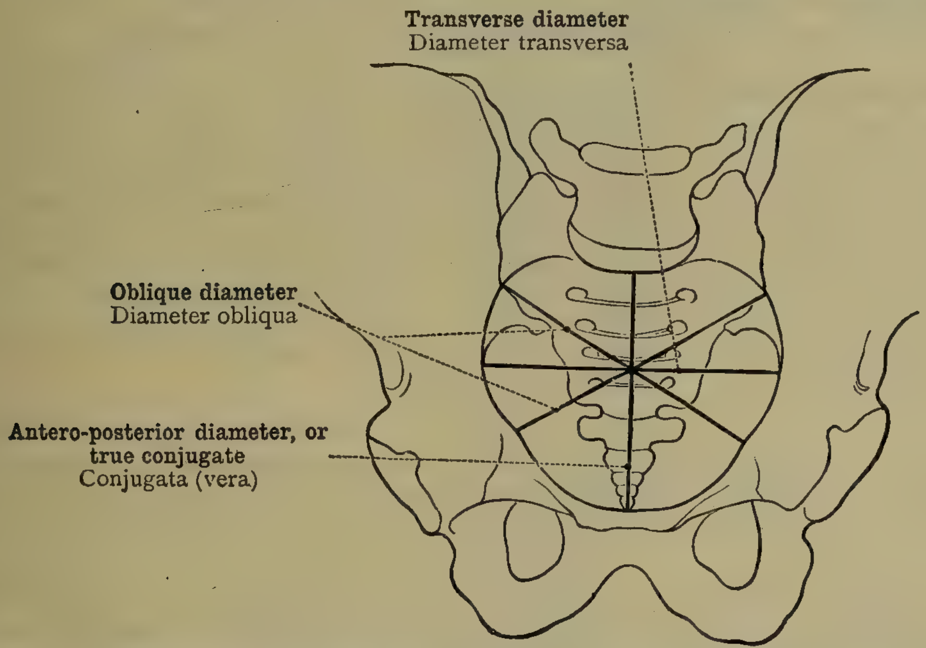


Fig. 260.—The Diameters of the Pelvic Inlet (Apertura Pelvis Superior). (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

The **minor pelvis** [pelvis minor] is situated below the terminal lines. The upper circumference, known as the **superior aperture of the lesser pelvis** [apertura pelvis minoris superior], is bounded anteriorly by the crest and pecten of the pubis on each side, posteriorly by the anterior margin of the base of the sacrum, and laterally by the terminal lines. The inlet in normal pelves is heart-shaped, being obtusely pointed in front; posteriorly it is encroached upon by the promon-

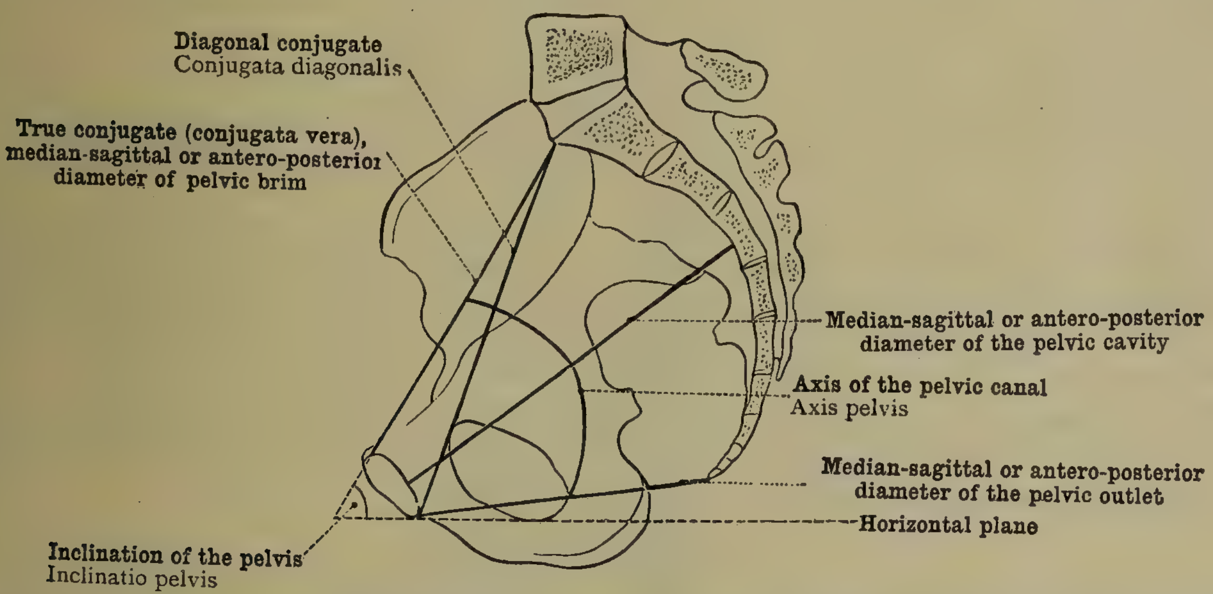


Fig. 261.—The Median-sagittal or Antero-posterior Diameters of the True Pelvis. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

tory of the sacrum. It has three principal **diameters** (fig. 260). The anteroposterior, called the **conjugate diameter** [conjugata] (diameter medianus NK), is measured from the **sacrovertebral angle** to the symphysis. The **transverse diameter** [diameter transversus] represents the greatest width of the pelvic cavity. The **oblique diameter** [diameter obliqua] is measured from the sacroiliac articulation of one side to the iliopectineal eminence of the other.

The **cavity** of the minor pelvis is bounded in front by the pubes, behind by the sacrum and coccyx, and laterally by a smooth wall of bone formed in part by the

ilium and in part by the ischium. The cavity is shallow in front, where it is formed by the pubes, and is deepest posteriorly.

The **inferior aperture of the minor pelvis** [apertura pelvis minoris inferior] (exitus pelvis NK) is very irregular, and encroached upon by three bony processes: the posterior process is the coccyx, and the two lateral processes are the sciatic tubers. They separate three notches. The anterior notch is the **pubic angle** [angulus pubis], and is bounded on each side by the conjoined rami of the pubes and ischia the **pubic arch** [arcus pubis]. The two remaining gaps, bounded by the ischium anteriorly, the sacrum and coccyx posteriorly, and the ilium above, correspond to the greater and lesser sciatic notches. These are converted into foramina by the sacrotuberous and sacrospinous ligaments.

The inclination of the pelvis [inclinatio pelvis] (fig. 261).—In the erect posture the plane of the superior aperture forms an angle with the horizontal plane, which varies in individuals from 50° to 60°. The base of the sacrum in an average pelvis lies nearly ten cm. (four inches) above the upper margin of the symphysis pubis.

The axis of the pelvis [axis pelvis].—This is an imaginary curved line drawn through the minor pelvis at right angles to the planes of the superior aperture, cavity, and inferior aperture through their central points. As the posterior wall, formed by sacrum and coccyx, is 12 cm. (five inches) long and concave, and the anterior wall at the symphysis pubic 3.5 to 5 cm long, it follows that the axis must be curved.

The average measurements of the diameters of the minor pelvis in the three planes are given below:—

	Conjugate.	Oblique.	Transverse.
Superior aperture....	10.6 cm. (4¼ inches)	12.5 cm. (5 inches)	13.0 cm. (5¼ inches)
Cavity..............	11.8 cm. (4¾ inches)	13.0 cm. (5¼ inches)	11.8 cm. (4¾ inches)
Inferior aperture.....	9.0 cm. (3¾ inches)	11.2 cm. (4½ inches)	10.6 cm. (4¼ inches)

There is, however, a difference between the sexes, the diameters of the male pelvis in general averaging slightly less, and those of the female slightly greater than the figures above given.

Differences according to sex.—There is a marked difference in the size and form of the male and female pelvis, the peculiarities of the latter being necessary to qualify it for its functions in parturition. The various points of divergence may be tabulated as follows:—

Male.	Female.
Bones heavier and rougher.	Bones more slender.
Sacrum narrower; more curved.	Sacrum broader; less curved.
Ilia less vertical.	Ilia more vertical.
Iliac fossæ deeper.	Iliac fossæ shallower.
Great sciatic notch narrower.	Great sciatic notch wider.
Major pelvis relatively wider.	Major pelvis relatively narrower.
Minor pelvis deeper and narrower.	Minor pelvis shallower and wider.
Capacity of minor pelvis less.	Capacity of minor pelvis greater.
Superior aperture more heart-shaped.	Superior aperture more oval.
Symphysis deeper.	Symphysis shallower.
Sciatic tubers inflexed.	Sciatic tubers everted.
Pubic angle narrow and pointed.	Pubic arch wider and more rounded.
Margins of ischiopubic rami more everted.	Margins of ischiopubic rami less everted.
Obturator foramen oval.	Obturator foramen triangular.

In comparison with the pelves of lower animals, which, speaking generally, are elongated and narrow, the human pelvis is characterized by its breadth, shallowness, and great capacity. Differences are also to be recognized in the form of the pelvis in the various races of mankind, the most important being the relation of the conjugate to the transverse diameter, measured at the superior aperture. This is expressed by the *pelvic index* $= \frac{100 \times \text{conjugate diameter}}{\text{transverse diameter}}$.

In the average European male the index is about 80; in the primitive races of mankind, 90 to 95. Pelves with an index below 90 are *platypellic*, from 90 to 95 are *mesatipellic*, and above 95 *dolichopellic*. (Sir William Turner.)

For the **development** and **growth** of the pelvis, see p. 35.

THE FEMUR

The **femur** (os femoris NK) or thigh-bone (figs. 262, 263) is the largest and longest bone in the skeleton, and transmits the entire weight of the trunk from the hip to the tibia. In the erect posture it inclines from above downward, slightly backward and medially, approaching at the lower extremity its fellow of the opposite side, but separated from it above by the width of the minor pelvis. It presents a superior extremity, including the head, neck and two trochanters, a shaft, and an inferior extremity, expanded laterally into two condyles.

The **upper extremity** is surmounted by a smooth, globular portion called the **head of the femur** [caput femoris] forming more than half a sphere, directed upward and medially for articulation with the acetabulum. Its surface is covered

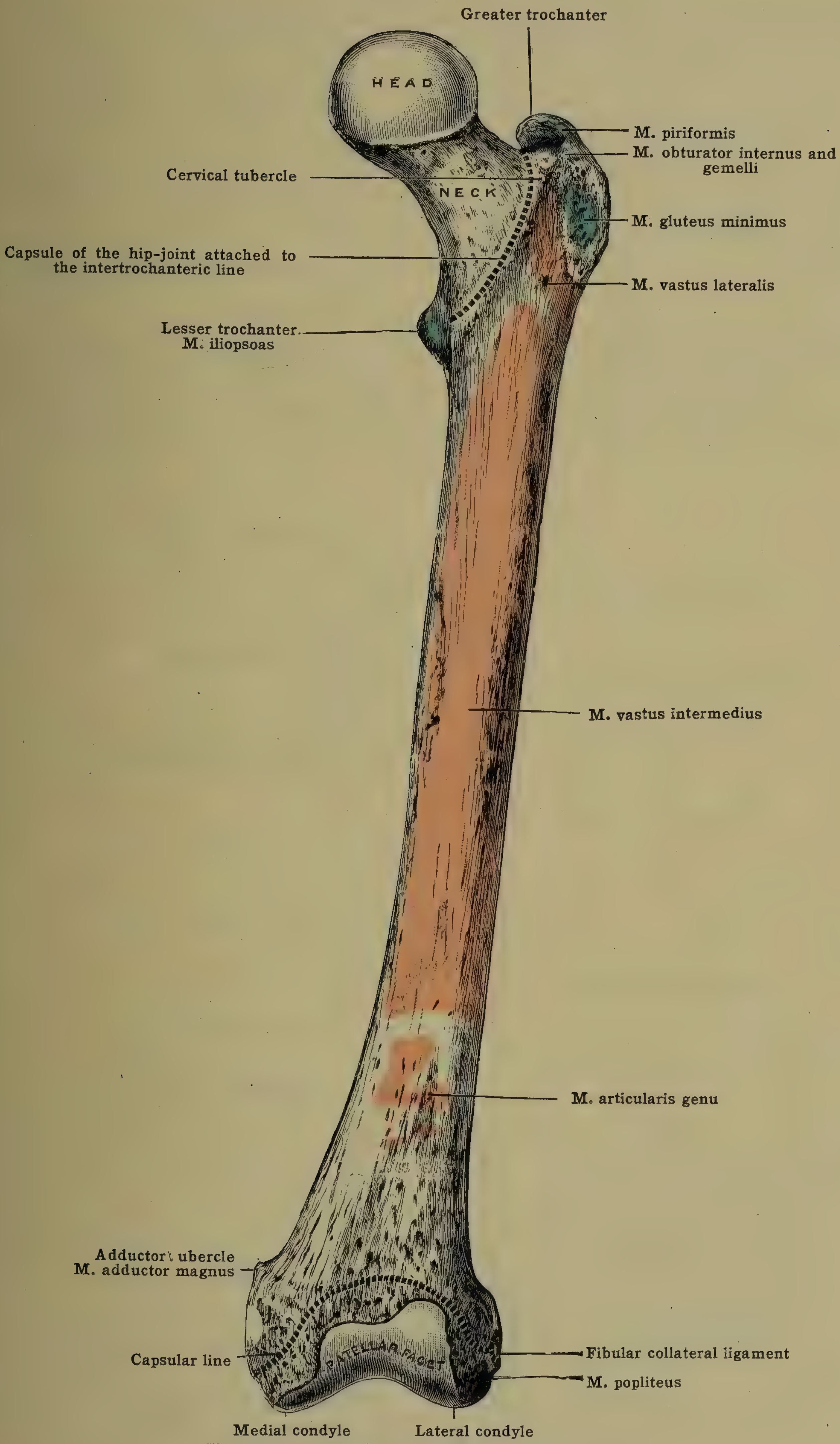


Fig. 262.—The Left Femur. (Ventral view.)

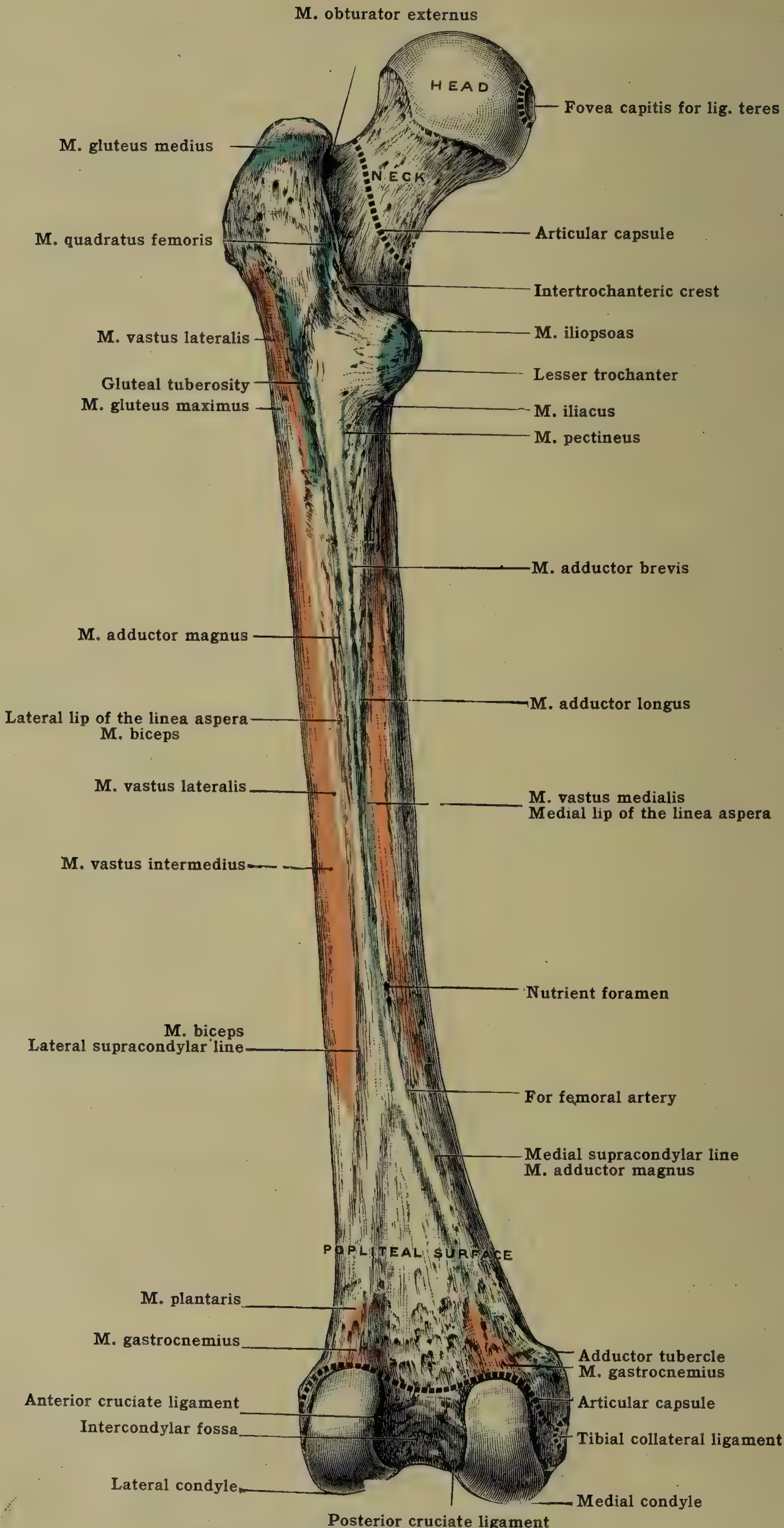


Fig. 263.—The Left Femur. (Dorsal view.)

with cartilage in the recent state, with the exception of a small rough depression, the **fovea capitis femoris,** for the ligamentum teres, a little below and behind the center of the head. The head is connected with the shaft by the **neck of the femur** [collum femoris], a stout rectangular column of bone which is directed upward, forward and medially; it forms with the shaft, in the adult, an angle of about 125°. The anterior surface of the neck is in the same plane with the front aspect of the shaft, but is marked off from it by a line to which the capsule of the hip-joint is attached. The line, which commences at the greater trochanter in a small prominence, the **cervical tubercle,** extends obliquely downward, and winding to the back of the femur, passes the lesser trochanter and becomes continuous with the medial lip of the linea aspera, on the posterior aspect of the shaft. To this spiral line the inaccurate term **intertrochanteric line** [linea intertrochanterica] has been given.

The intertrochanteric line receives the bands of the iliofemoral thickening of the capsule of the hip-joint. The posterior surface of the neck is smooth and concave and its medial two-thirds is enclosed in the capsule of the hip-joint. The superior border of the neck, perforated by large vascular foramina, is short and thick, and runs downward to the great trochanter. The inferior border, longer and narrower than the superior, curves downward to terminate at the lesser trochanter. At the junction of the neck and head there is a sharp line of demarcation excepting in front, where the iliofemoral ligament exerts great pressure upon the bone.

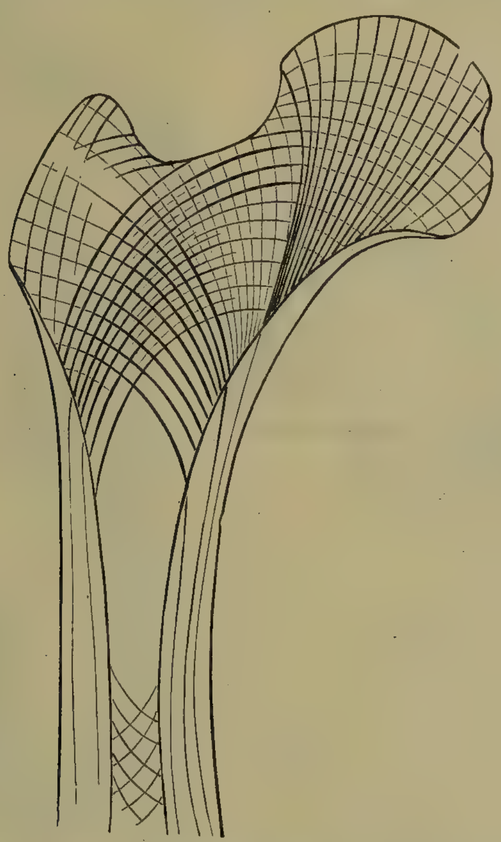


FIG. 264.—A DIAGRAM TO SHOW THE PRESSURE AND TENSION CURVES OF THE FEMUR. (After Wagstaffe.)

The **trochanters** are the prominences which afford attachment to the rotator muscles of the thigh; they are two in number—greater and lesser.

The **greater trochanter** [trochanter major] is a thick, quadrilateral process surmounting the junction of the neck with the shaft, and presents two surfaces and four borders. The lateral surface is broad, rough, and continuous with the lateral surface of the shaft. It is marked by a diagonal ridge running from the posterosuperior to the anteroinferior angle, which receives the insertion of the gluteus medius muscle. The ridge divides the surface into two triangular areas: an upper, covered by the gluteus medius, and occasionally separated from it by a bursa, and a lower, covered by a bursa permitting the free gliding of the tendon of the gluteus maximus. Of the medial surface the lower and anterior portion is joined with the rest of the bone; the upper and posterior portion is free, concave, and presents a deep depression, the **trochanteric fossa** [fossa trochanterica], which receives the tendon of the obturator externus. The fore part of the surface is marked by an impression for the insertion of the obturator internus and two gemelli.

Of the four borders, the superior, thick and free, presents near the center an oval mark for the insertion of the piriformis; the anterior border, broad and irregular, receives the gluteus minimus; the posterior border, thick and rounded, is continuous with the **intertrochanteric**

crest [crista intertrochanterica], the prominent ridge uniting the two trochanters behind. Above the middle of this crest is an elevation, termed the **tubercle of the quadratus**, for the attachment of the upper part of the quadratus femoris. The inferior border corresponds with the line of junction of the base of the trochanter with the shaft; it is marked by a prominent ridge for the origin of the upper part of the vastus lateralis muscle.

The **lesser trochanter** [trochanter minor] is a conical eminence projecting medially from the posterior and medial aspect of the bone, where the neck is continuous with the shaft. Its summit is rough and gives attachment to the tendon of the iliopsoas muscle. The fibers of the iliacus extend beyond the trochanter and are inserted into the surface of the shaft immediately below.

The **body** or **shaft of the femur** [corpus femoris] is curved in the sagittal plane, with the convexity forward. It is almost cylindrical, but is slightly flattened in front and strengthened behind by a projecting longitudinal ridge, the **linea aspera** (crista femoris NK), for the origin and insertion of muscles. The linea aspera extends along the middle third of the shaft and presents a **medial lip** [labium mediale] and a **lateral lip** [labium laterale] separated by a narrow interval. When followed into the upper third of the shaft, the three parts diverge. The lateral lip becomes continuous with the **gluteal tuberosity** [tuberositas glutaea]

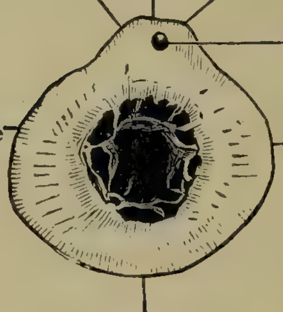


Fig. 265.—Transverse Section of Shaft of Femur to show the Medullary Cavity.

Fig. 266.—Section of Upper End of Femur to show the Calcar Femorale.

and ends at the base of the greater trochanter. The tuberosity affords insertion to the gluteus maximus, and when very prominent is termed the **third trochanter** [trochanter tertius]. The medial lip curves medialward below the lesser trochanter, where it becomes continuous with the intertrochanteric line; the intervening portion bifurcates and is continued upward as two lines, one of which ends at the small trochanter, and receives some fibers of the iliacus, whereas the other is the **linea pectinea** and marks the insertion of the pectineus muscle.

Toward the lower third of the shaft the medial and lateral lips of the linea aspera again diverge, and are prolonged to the condyles by the **medial and lateral supracondylar lines**, enclosing between them a triangular surface of bone, the **popliteal surface** [**planum popliteum**] of the femur, which forms the upper part of the floor of the popliteal fossa. The lateral line is the more prominent and terminates below in the lateral epicondyle. The medial one is interrupted above, where the femoral vessels are in relation with the bone, better marked below, where it terminates in the **adductor tubercle**, a small sharp projection at the summit of the medial epicondyle, which affords insertion to the tendon of the adductor magnus.

Near the center of the linea aspera is the **nutrient foramen** for the medullary artery, directed upward toward the head of the bone. From the medial lip of the linea aspera and the lower part of the intertrochanteric line arises the vastus medialis, and from the lateral lip and the side of the gluteal ridge arises the vastus lateralis. The adductor magnus is inserted into the intermediate lip of the linea aspera, from the medial side of the gluteal tuberosity above, and the medial supracondylar line below. Between the adductor magnus and vastus medialis four muscles are attached: the pectineus and iliacus above, then the adductor brevis, and lowest of all, the adductor longus. Above, in the interval between the adductor magnus and the vastus lateralis, the gluteus maximus is inserted; in the interval lower down is the short head of the biceps, taking origin from the lower two-thirds of the lateral lip of the linea aspera and the upper two-thirds of the lateral supracondylar line. On the popliteal surface of the bone, just above the condyles, are two rough areas from which the two heads of the gastrocnemius take origin. Above the area for the lateral head of the gastrocnemius is a slight roughness for the plantaris muscle.

For purposes of description it is convenient to regard the shaft of the femur as presenting anterior, medial, and lateral surfaces, although all three surfaces are rounded and the anterior is not separated from the others by ridges of any kind. In the middle third of the shaft the medial and lateral surfaces approach each other behind, being separated by the linea aspera.

The shaft is overlapped on its medial side by the vastus medialis, and on its lateral side by the vastus lateralis muscle. The upper three-fourths of the anterior and lateral surfaces afford origin to the vastus intermedius, and the lower fourth of the anterior surface, to the articularis genu. The medial surface is free from muscular attachment.

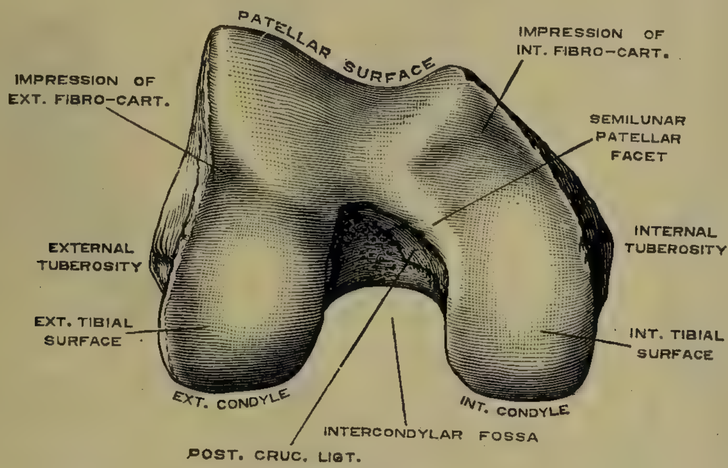


Fig. 267.—Distal Extremity of the Right Femur. (From below.) (Drawn by T. W. P. Lawrence. From Quain's Anatomy.)

The **lower extremity** presents two cartilage-covered eminences or **condyles**, separated behind by the **intercondyloid fossa**. The **lateral condyle** [condylus lateralis] is wider than its fellow and more prominent anteriorly; the **medial condyle** [condylus medialis] is narrower and longer, to compensate for the obliquity of the shaft. When the femur is in the natural position, the inferior surfaces of the condyles are on the same plane, and almost parallel, for articulation with the upper surfaces on the head of the tibia. The two condyles are continuous in front, forming a smooth trochlear **patellar surface** [facies patellaris] for articulation with the patella.

The sagittal curve of the condylar surface takes the form of a spiral, the sharper turn being posterior. Seen from behind the condyles show spheroidal contours, but from below they appear roller-like. The medial condylar surface, however, is bent in its anterior part and prolonged laterally to the patellar surface, whereby it exceeds in length the lateral condylar surface.

The patellar surface presents a median vertical groove and two convexities, the lateral of which is wider, more prominent, and prolonged farther upward. The patellar surface is faintly marked off from the tibial articular surfaces by two irregular grooves, best seen while the lower end is still coated with cartilage. The lateral groove commences on the medial margin of the lateral condyle near the front of the intercondyloid fossa, and extends obliquely forward to the lateral margin of the bone. The general direction of the medial groove is from front to back, turning medially in front and extending backward as a faint ridge which marks off from the rest of the medial condyle a narrow semilunar facet for articulation with the medial perpendicular facet of the patella in extreme flexion. The grooves receive the menisci (see fig. 267) in the extended position of the joint.

The opposed surfaces of the two condyles form the boundaries of the **intercondyloid fossa** [fossa intercondyloidea] and give attachment to the cruciate ligaments which are lodged within it. The posterior cruciate ligament is attached

to the fore part of the lateral surface of the medial condyle and the anterior cruciate ligament to the back part of the medial surface of the lateral condyle. Posteriorly, the intercondyloid fossa is limited toward the popliteal surface by the sharp **intercondyloid line** [linea intercondyloidea]. The two remaining surfaces of the condyles are broad and convex, and each presents an **epicondyle** (tuberosity) for the attachment of lateral ligaments. The **medial epicondyle** [epicondylus medialis] the larger of the two, is surmounted by the adductor tubercle, behind which is an impression for the medial head of the gastrocnemius muscle on the upper aspect of the condyle; below and behind the **lateral epicondyle** [epicondylus lateralis] is a deep groove (sulcus popliteus NK) which receives the tendon of the popliteus muscle when the knee is flexed, its anterior end terminating in a pit from which the tendon takes origin. Above the lateral epicondyle is a rough impression for the lateral head of the gastrocnemius.

The interior of the shaft of the femur is hollowed out by a large medullary cavity and the extremities are composed of spongy tissue invested by a thin compact layer (figs. 264–265). The arrangement of the bony plates in the upper end of the bone forms a good illustration of the adaptation to mechanical conditions to which bones are subject. In the upper end of the bone

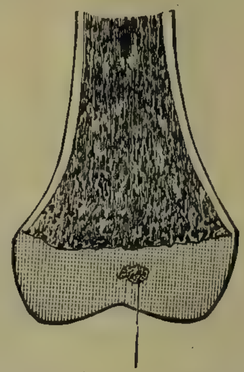


Fig. 268.—The Femur at Birth.

the spongy tissue is arranged in divergent curves. One system springs from the lower part of the neck and upper end of the shaft medially and spreads into the greater trochanter ('pressure lamellæ'). A second system springs from the lateral part of the shaft and arches upward into the neck and head ('tension lamellæ'), crossing the former almost at right angles. A second set of pressure lamellæ springs from the lower thick wall of the neck, and extends into the upper part of the head to end perpendicularly in the articular surface mainly along the lines of greatest pressure. A nearly vertical plate of compact tissue, the **calcar femorale** (fig. 266) projects into the neck of the bone from the inferior cervical region toward the greater trochanter. This is placed in the line through which the weight of the body falls, and adds to the stability of the neck of the bone; it is said to be liable to absorption in old age. In the lower end of the bone the vertical and horizontal bony plates are so disposed as to form a rectangular meshwork.

Blood-supply.—The head and neck of the femur receive branches from the inferior gluteal, obturator, and circumflex arteries, and the trochanters from the circumflex arteries. The nutrient vessel of the shaft is derived from either the second or third perforating artery, or there may be two nutrient vessels arising usually from the first and third perforating. The vessels of the inferior extremity arise from the articular branches of the popliteal and from the a. genu suprema.

The angle which the neck of the femur forms with the shaft at birth measures, on an average, 160°. In the adult it varies from 110° to 140°; hence the angle decreases greatly during the period of growth. When once growth is completed, the angle, as a rule, remains fixed (Humphry).

Ossification.—The femur is ossified from one primary center for the shaft and from four epiphysial centers. The shaft begins to ossify in the seventh week of intrauterine life. Early in the ninth month a nucleus appears for the lower extremity. During the first year the nucleus for the head of the bone is visible, and in the fourth year that for the trochanter major. The center for the lesser trochanter appears about the eleventh or twelfth year. The lesser trochanter joins the shaft at the seventeenth, the greater trochanter at the eighteenth, the head about the nineteenth, and the lower extremity at the twentieth year (figs. 268, 269).

Variations.—*Platymerism* is the name given to a tendency to anteroposterior flattening and broadening of the upper one-third of the femoral shaft. The variation of the gluteal tuberosity to form a third trochanter has been referred to; the tuberosity may be absent and its place taken by a hypotrochanteric fossa. Prominence of the linea aspera to form a pilaster, a variation of the European femur, is constant in certain other human races. The adductor tubercle may form a large spine.

Clinical Relations of Hip and Thigh

The **length of the lower limb** is measured from the anterior superior spine to the tip of the corresponding medial malleolus. The pelvis must be horizontal and the limbs parallel.

The head and shaft of the **femur** are well covered in, save in the emaciated. The head lies just below the inguinal (Poupart's) ligament, under the iliopsoas, and a little to the lateral side of the center of that ligament. A line drawn horizontally laterally from the pubic tubercle

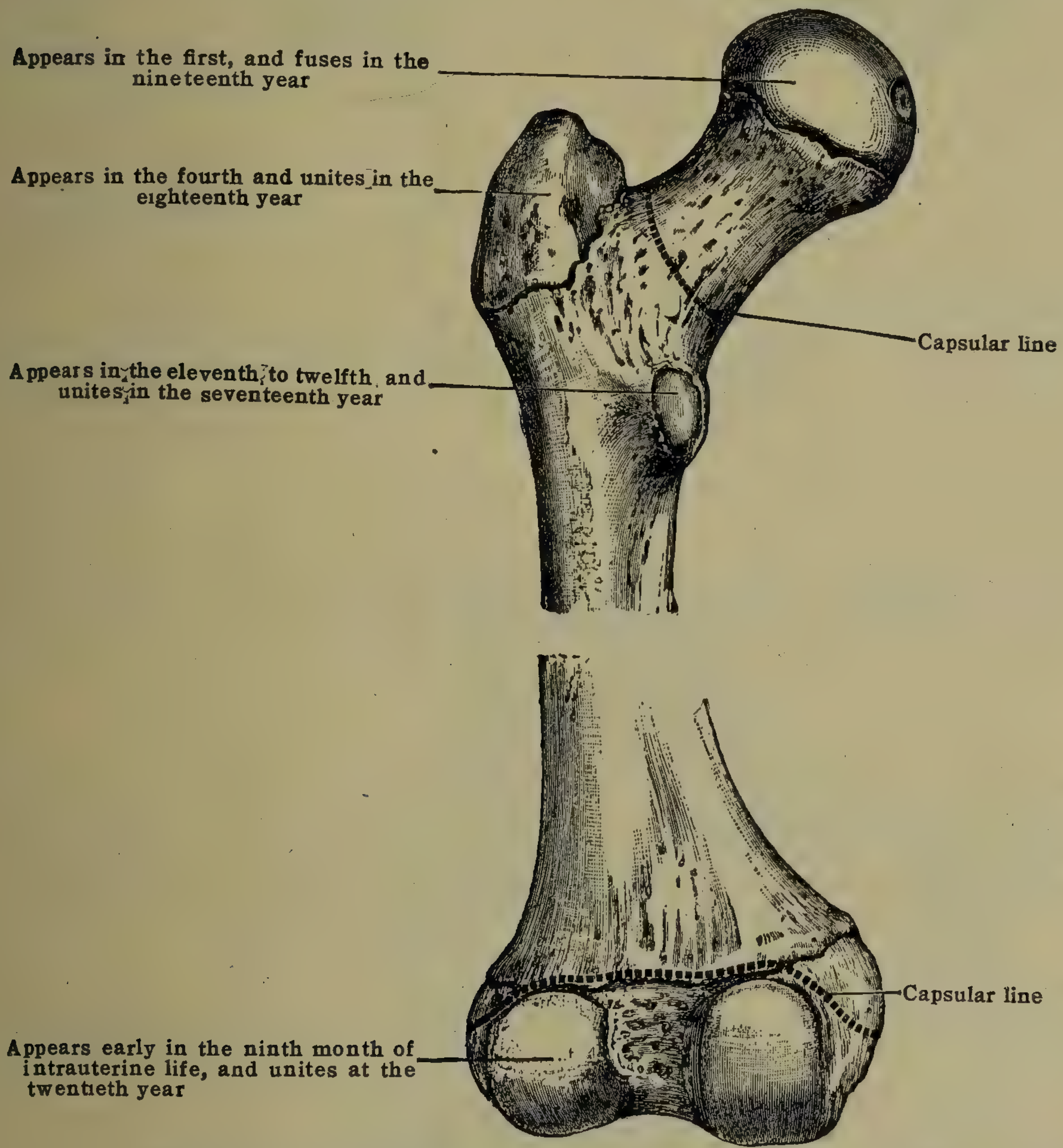


Fig. 269.—The Left Femur at the Twentieth Year. (Dorsal view.) The figure shows the relations of the epiphysial and capsular lines.

will cross the lower part of the head. All the head and the front of the neck, but only two-thirds of the back, are within the capsule; this intracapsular position of the upper epiphysis, which, appearing at the first year, does not unite till eighteen or twenty, accounts largely for the extreme gravity of acute epiphysitis here. The spongy structure of the neck, i. e., the two sets of lamellæ, vertical supporting the weight, transverse and intersecting, which meet the pull of the muscles, and the wasting of these after middle life, has an important influence on injuries. The strong process, *femoral spur* or *calcar* (Merkel) which, arising from the compact tissue on the medial and under side of the neck, just above the lesser trochanter, spreads laterally toward the trochanteric (digital) fossa, also affords strength, and its degeneration probably plays an important part in the fractures of the neck.

Trochanter major.—This valuable landmark is most prominent when the limb is rotated medially or adducted; it lies at the bottom of a depression when the femur is everted.

The chief structure of importance between it and the skin is the upper part of the insertion of the gluteus maximus, that going to the fascia lata, and the trochanteric bursa beneath the muscle. This is often multilocular. It is, not very uncommonly, the seat of tuberculous inflammation which readily invades the spongy tissue of the trochanter. The top of the great trochanter is about 1.8 cm. (¾ in.) below the level of the femoral head, and, when the femur is

extended, is a little below the center of the hip-joint. This part of the bone is covered by the gluteus medius. The slightness of the prominence of the greater trochanter in the living subject compared with that in the skeleton is explained by fig. 371, which shows how the descending gluteus medius and minimus fill up the space between the ilium and trochanter. To examine the greater trochanter, the thigh should be abducted, so as to relax the strong fascia lata passing over the tensor fasciæ latæ and glutei to the iliac crest.

Access to the femur is best attained on the lateral side of the shaft along the line of the lateral intermuscular septum (fig. 474), the biceps being pulled backward, and the vastus lateralis detached anteriorly. On the medial side the bone may be exposed by an incision starting from a point midway between the medial margin of the patella and the adductor tubercle and passing obliquely upward and laterally, but the parts here are more vascular. **Fractures** of the shaft usually occur about the center. The main tendency to displacement is of the lower fragment upward by the hamstrings. The upper fragment is displaced anteriorly in fractures through the middle of the shaft. In fractures below the lesser trochanter—i. e., through the upper third of the femur the upper fragment will be flexed, abducted and rotated laterally. In the lower third the forward curve of the femur and its more superficial position explain the fact that it is here that compound fractures of the femur may, occasionally, occur. **Ossification.**—The unstable nature of the tissues about the upper epiphysis, which appears at the end of the first year and unites about nineteen, and the frequency of tuberculous disease in early life are well known. In the lower epiphysis ossification begins before birth, a point of medicolegal importance in deciding whether a newly born child has reached the full period of uterine gestation. From this epiphysis, the level of which is denoted by a line drawn horizontally laterally from the adductor tubercle, and the vascular growing tendon of the adductor magnus—the origin of an exostosis is not uncommon. **Displacement of this epiphysis** (it unites about twenty) in boyhood and adolescence is a grave injury from the immediate risk of the popliteal vessels. The mischief is usually done by overextension of the leg, as when this is caught in a rapidly moving motor-wheel; the epiphysis is carried forward in front of the diaphysis, the lower end of which is directed backward, endangering the vessels which are posterior and closely adjacent.

Amputation through the thigh.—This is usually performed in the lower third, by anterior and posterior flaps, the former being the longer, so as to ensure a scar free from pressure, and circular division of the muscles, vessels, and nerves. The vessels requiring attention are the femoral, which lie at the medial side, and more posteriorly, the lower the amputation; the descending branch of the lateral circumflex, and the termination of the profunda near the linea aspera. The femoral artery has a marked tendency to retract in the adductor canal. Care should be taken not to include the saphenous nerve when the femoral vessels are tied, and to cut the sciatic cleanly and high up. When amputation has to be performed in the upper third of the thigh, the tendency of the iliopsoas to flex the shortened limb and thus bring the sawn femur against the end of the stump must be remembered, and met by keeping the patient propped up and the stump as horizontal as possible. (Some of the structures now divided are shown in fig. 474).

THE PATELLA

The **patella** (figs. 270, 271) or knee-pan, situated in front of the knee-joint, is a sesamoid bone, triangular in shape, developed in the tendon of the quadriceps femoris muscle. Its **anterior surface**, marked by numerous longitudinal striæ, is slightly convex, and perforated by small openings which transmit nutrient vessels to the interior of the bone. It is covered in the recent state by a few fibers prolonged from the common tendon of insertion (suprapatellar tendon) of the quadriceps femoris, into the ligamentum patellæ (infrapatellar tendon), and is separated from the skin by one or more bursæ. The **posterior surface** [facies articularis] is largely articular, covered with a thick layer of cartilage in the recent state, and divided by a slightly marked vertical ridge, corresponding to the groove on the patellar surface of the femur, into a lateral larger portion for the lateral condyle, and a medial smaller portion for the medial condyle. Close to the medial edge a faint vertical ridge sometimes marks off a narrow articular facet, for the lateral margin of the medial condyle of the femur in extreme flexion of the leg. Below the articular surface is a rough, non-articular depression, giving attachment to the ligamentum patellæ, and separated by a mass of fat from the head of the tibia.

The **base of the patella** [basis patellæ] or superior border is broad, sloped from behind downward and forward, and affords attachment, except near the posterior margin, to the common tendon of the quadriceps. The **borders**, thinner than the base, converge to the apex below, and receive parts of the two vasti muscles. The **apex of the patella** [apex patellæ] forms a blunt point directed downward, and gives attachment to the ligamentum patellæ, by which the patella is attached to the tibia.

Structurally the patella consists of dense spongy tissue covered by a thin compact layer, and it receives nutrient vessels from the articular branch of the a. genu suprema, the anterior tibial recurrent, and the inferior articular branches of the popliteal.

Ossification.—The cartilaginous deposit in the tendon of the quadriceps muscle takes place in the fourth month of intrauterine life. Ossification begins from a single center during the third year, and is completed about the age of puberty.

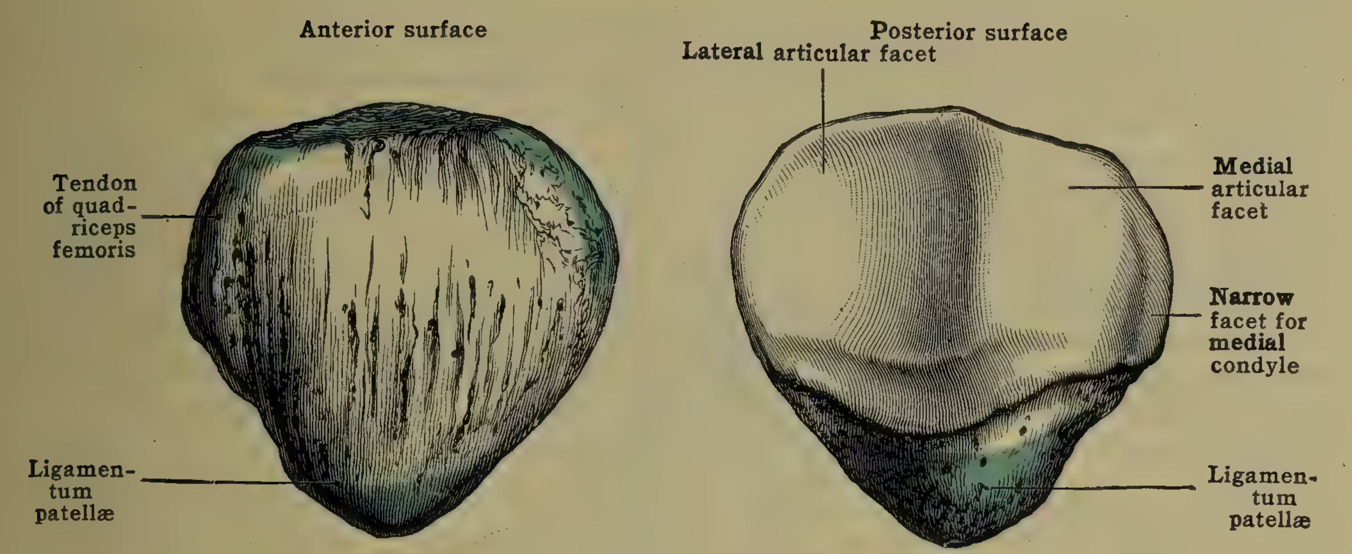


FIG. 270.—THE LEFT PATELLA.

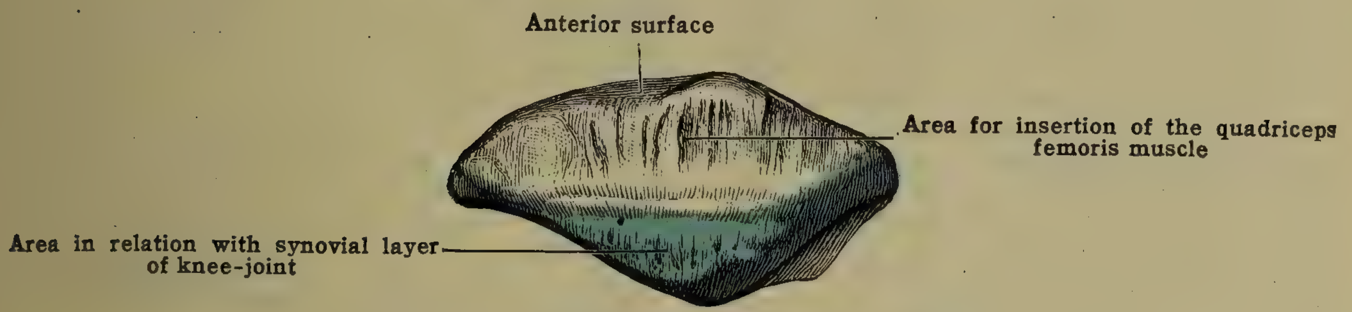


FIG. 271.—THE BASE OF THE LEFT PATELLA.

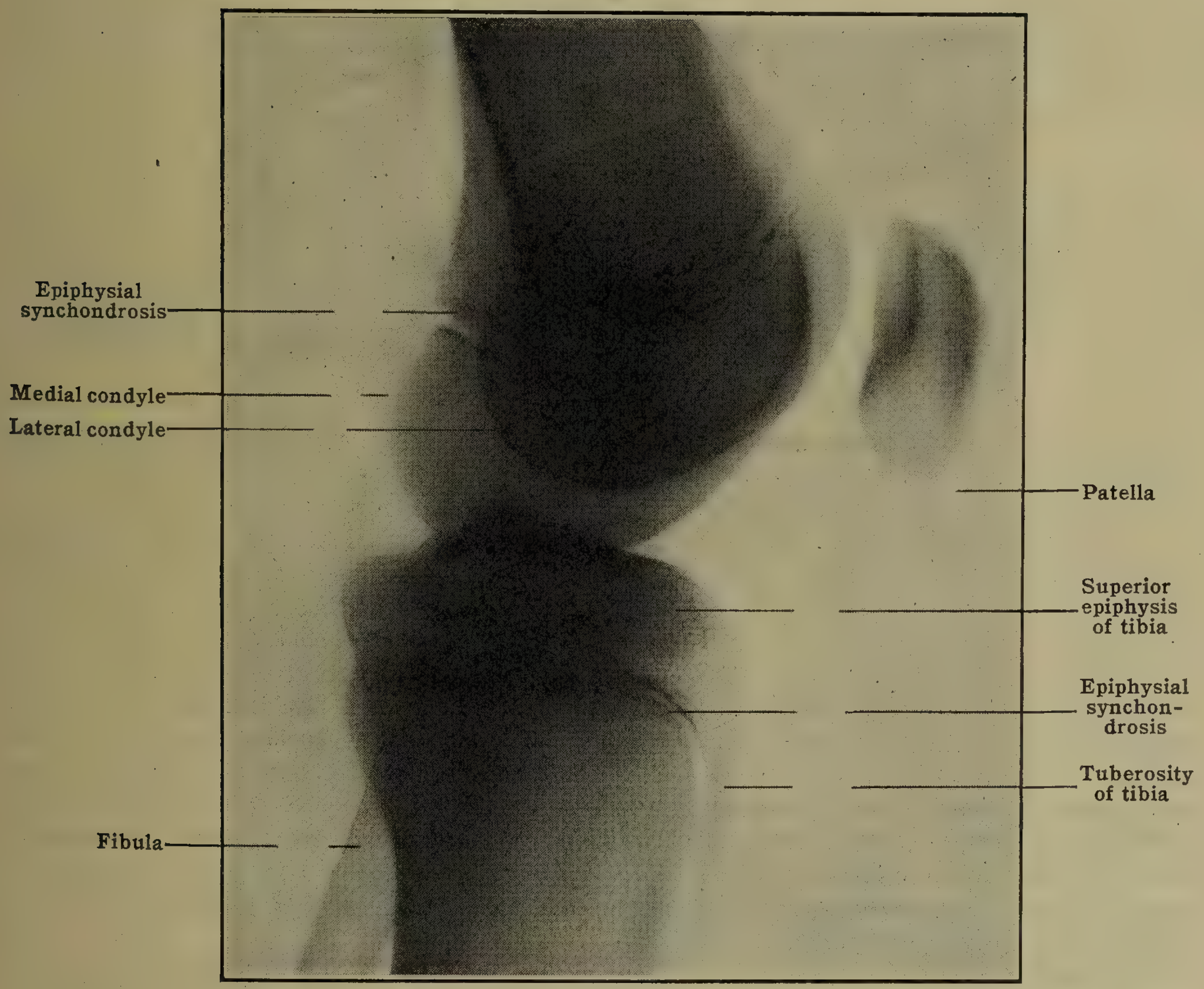


FIG. 272.—KNEE-JOINT OF A BOY OF SIXTEEN YEARS. From an X-ray plate by Dr. Sherwood Moore, Washington University.

THE TIBIA

The **tibia** (figs. 273, 274) or shin-bone is situated at the front and medial side of the leg and nearly parallel with the fibula. Excepting the femur, it is the largest bone in the skeleton, and alone transmits the weight of the trunk to the foot. It articulates above with the femur, below with the talus, and laterally with the fibula. It is divisible into two extremities and a shaft.

The **upper extremity** (or head) consists of two lateral eminences, or **condyles (medial and lateral)** [condylus medialis; lateralis] which contribute to the roundness of the knee and are subcutaneous in front and at either side. Their **superior articular surface** [facies articularis superior] receives the condyles of the femur, and is subdivided into two faces by a non-articular interval, to which ligaments are attached.

The *medial articular surface* is oval in shape and concave for the medial condyle of the femur. The *lateral articular surface* is smaller, somewhat circular in shape, and presents an almost plane surface for the lateral condyle. This surface is extended for a short distance upon the posterior aspect of the condyle. The peripheral portion of each articular surface is overlaid by a fibrocartilaginous meniscus of semilunar shape, connected with the margins of the condyles by the fibrous tissue of the articular capsule (fig. 377). Each meniscus is attached firmly to the rough interval separating the articular surfaces. This interval is broad and depressed in front, the **anterior intercondyloid fossa** [fossa intercondyloidea anterior], where it affords attachment to the anterior extremities of the medial and lateral menisci and the anterior cruciate ligament; elevated in the middle to form the **intercondyloid eminence** [eminentia intercondyloidea], a prominent elevation, presenting at its summit two compressed **intercondyloid tubercles** [tuberculum intercondyloideum mediale; laterale], on to which the condylar articular surfaces are prolonged; the posterior aspect of the base of the eminence affords attachment to the posterior extremities of the lateral and medial menisci. A deep notch, the **posterior intercondyloid fossa** [fossa intercondyloidea posterior], separates the condyles on the posterior aspect of the head and gives attachment to the posterior cruciate ligament, and part of the posterior ligament of the knee-joint.

Anteriorly, the two condyles are confluent, and form a somewhat flattened surface of triangular outline, the apex of which forms the **tuberosity of the tibia** [tuberositas tibiæ]. The tuberosity is divisible into two parts: the upper part is rounded and smooth; the lower part is rough, and receives the insertion of the ligamentum patellæ.

The medial condyle is less prominent though more extensive than the lateral, and near the posterior part of its circumference is a deep horizontal groove for the attachment of the central portion of the semimembranosus tendon. On the inferior and lateral aspect of the lateral condyle is an **articular facet** for the head of the fibula, flat and nearly circular in outline, directed downward, backward, and laterally. The circumference of the facet is rough and gives attachment to the ligaments of the superior tibiofibular joint, while above and in front of the facet, at the junction of the anterior and lateral surfaces of the condyle, is a ridge for the iliotibial band. Slips from the tendons of the biceps, the extensor digitorum longus and peroneus longus muscles are attached to the lateral condyle below the iliotibial band.

The **shaft** or **body of the tibia** [corpus tibiæ], thick and prismatic above, becomes thinner as it descends for about two-thirds of its length, and then gradually expands toward its lower extremity. It presents three borders and three surfaces. The **anterior border** is very prominent, subcutaneous, and known as the **anterior crest** [crista anterior] (crista dorsalis NK) of the tibia. It commences above on the lateral edge of the tuberosity and terminates below at the anterior margin of the medial malleolus. It runs a somewhat sinuous course, and gives attachment to the deep fascia of the leg. The **medial border** [margo medialis] extends from the back of the medial condyle to the posterior margin of the medial malleolus, and affords attachment above, for about eight centimeters, to the tibial collateral ligament of the knee-joint and in the middle third, to the soleus muscle. The **interosseous crest** [crista interossea] or lateral border, thin and prominent, gives attachment to the interosseous membrane. It commences in front of the fibular facet, on the upper extremity, and toward its termination bifurcates to enclose a triangular area for the attachment of the interosseous ligament uniting the lower ends of the tibia and fibula.

The **medial surface** [facies medialis] is bounded by the medial margin and the anterior crest; it is broad above, where it receives the insertions of the sartorius, gracilis, and semitendinosus; convex and subcutaneous in the remainder of its extent. The **lateral surface** [facies lateralis] lies between the crest of the tibia and the interosseous crest. The upper two-thirds presents a hollow for the origin

of the tibialis anterior muscle; the rest of the surface is convex and covered by the extensor tendons and the anterior tibial vessels. The **posterior surface** [facies posterior] (facies plantaris NK) is limited by the interosseous crest and the medial border. The upper part is crossed obliquely by a rough **popliteal line** [linea

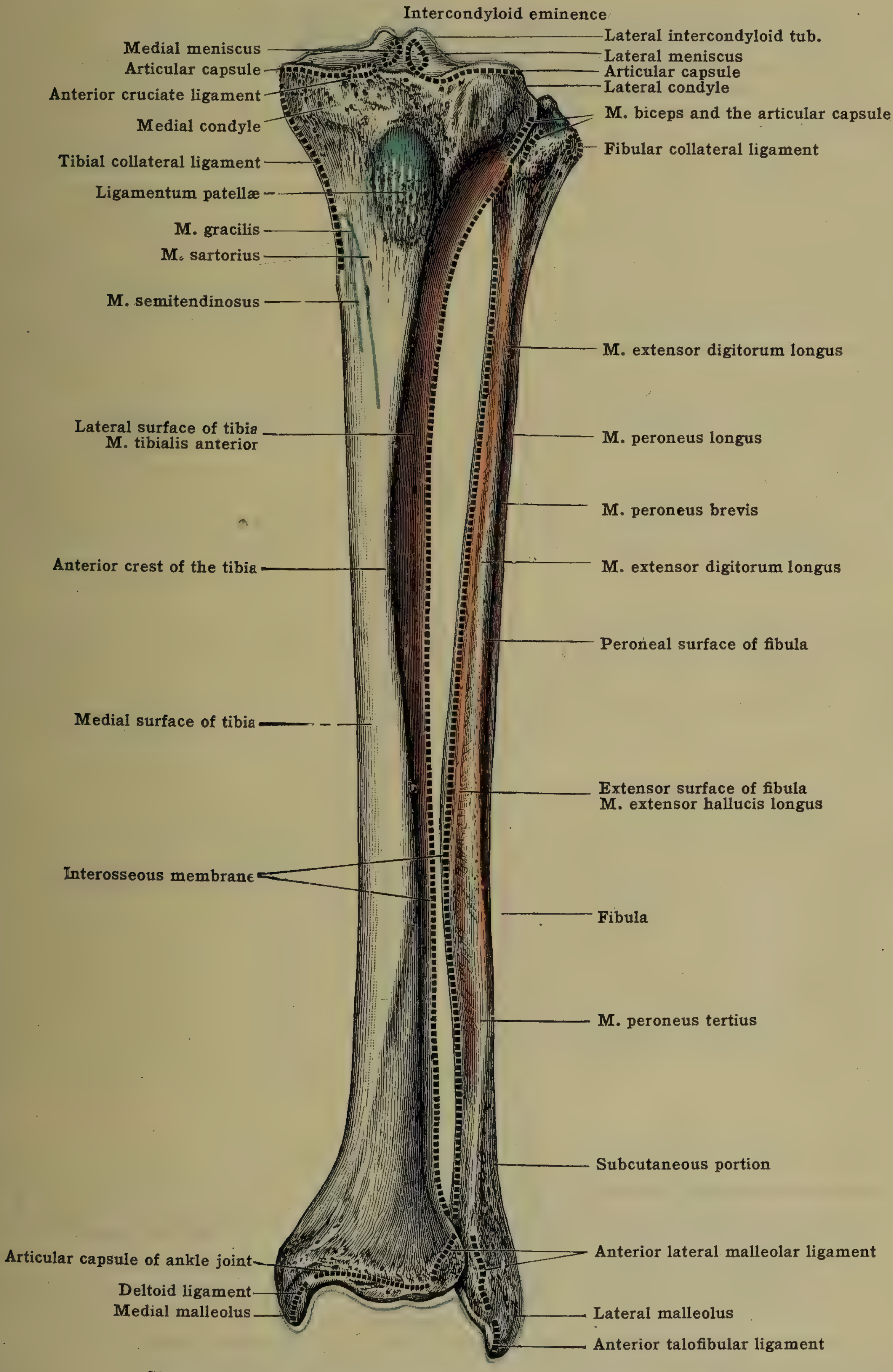


Fig. 273.—The Left Tibia and Fibula. (Anterior view.)

poplitea], extending from the fibular facet on the lateral condyle to the medial border, a little above the middle of the bone.

The popliteal line gives origin to the soleus muscle and attachment to the popliteal fascia, while the triangular surface above is occupied by the popliteus muscle. Descending along the posterior surface from near the middle of the popliteal line is a vertical ridge, well marked at its commencement, but gradually becoming indistinct below. The portion of the surface

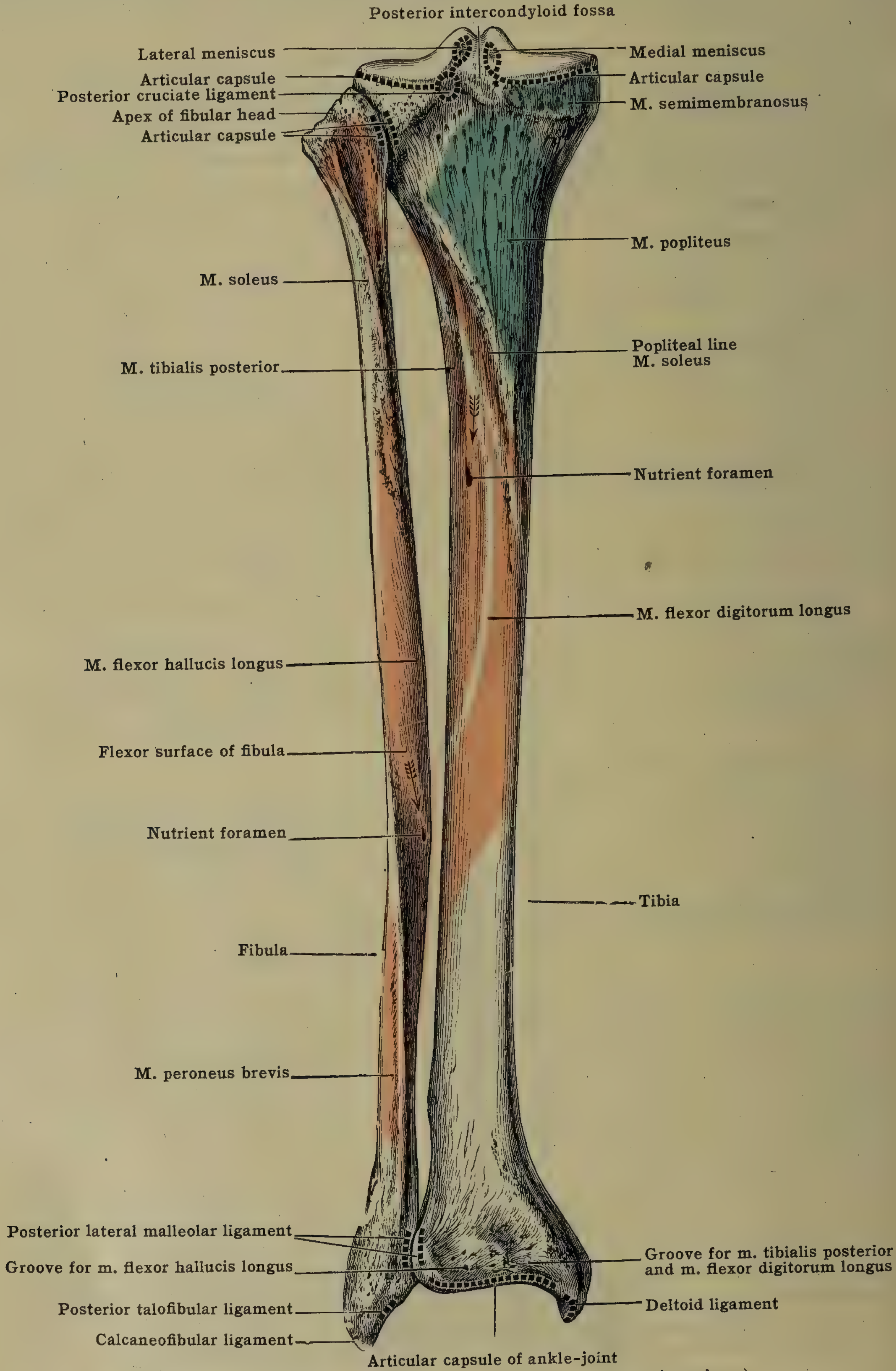


FIG. 274.—THE LEFT TIBIA AND FIBULA. (Posterior view.)

between the ridge and the medial border gives origin to the flexor digitorum longus; the lateral and narrower part, between the ridge and the interosseous border, to fibers of the tibialis posterior. The lower third of the posterior surface is covered by flexor tendons and the posterior tibial vessels. Immediately below the popliteal line and near the interosseous border is the large **nutrient foramen** directed obliquely downward.

The **lower extremity**, much smaller than the upper, is quadrilateral in shape and presents a strong process called the **medial malleolus** [malleolus medialis] (malleolus tibiæ NK), projecting downward from its medial side. The anterior surface of the lower extremity is smooth and rounded above, where it is covered by the extensor tendons, rough and depressed below for the attachment of the articular capsule of the ankle-joint. It sometimes bears a facet for articulation with the neck of the talus (astragalus). The posterior surface is rough and is marked by two grooves. The medial and deeper of the two, **malleolar groove** [sulcus malleolaris], encroaches on the malleolus, and receives the tendons of the tibialis posterior and flexor digitorum longus; the lateral, very shallow and sometimes indistinct, is for the tendon of the flexor hallucis longus muscle. The lateral surface is triangular and presents the **fibular notch** [incisura fibularis] for the reception of the lower end of the fibula and rough for the interosseous ligament which unites the two bones, except near the lower border, where there is usually a narrow surface, elongated from before backward, sometimes covered with cartilage in the recent state for articulation with the fibula. The lines in front of and behind the triangular surface afford attachment to the anterior and posterior lateral malleolar ligaments of the inferior tibiofibular articulation. The medial surface, prolonged downward on the medial malleolus, is rough, convex, and subcutaneous. The lateral aspect of this process is smooth and cartilage covered in recent state, **malleolar articular surface** [facies articularis malleolaris], for articulation with the facet on the medial side of the talus (astragalus). Its lower border is notched, and from the notch, as well as from the tip and anterior border, the deltoid ligament of the ankle-joint descends. The terminal or **inferior articular surface** [facies articularis inferior], by which the tibia articulates with the talus, is of quadrilateral form, concave from before backward, wider in front than behind, and also laterally, where it is continuous with the malleolar articular surface.

Variations.—The occasional facet on the anterior surface of the lower extremity of the tibia in the adult has been observed in higher frequency in the fetus. It is constantly present in aboriginal peoples who assume the squatting position and is therefore sometimes designated as the 'squatting facet.' Two other variations are: the bilateral compression of the shaft called *platycnemism;* and the retroversion of the head of the tibia. Both have been observed in ancient races and also in some of the living aboriginal races.

The tibia is relatively longer in the black races than in white and yellow people as shown by the femorotibial index: $\frac{\text{length of tibia} \times 100}{\text{length of femur}}$.

Blood-supply.—The tibia is a very vascular bone. The nutrient artery of the shaft is furnished by the posterior tibial, and is the largest of its kind in the body. The head of the bone receives numerous branches from the inferior articular arteries of the popliteal and the recurrent branches of the anterior and posterior tibial. The lower extremity receives twigs from the posterior and anterior tibial, the peroneal, and the medial malleolar arteries.

Ossification.—The tibia is ossified from one principal center for the shaft, which appears in the seventh week (forty-second day, Mall) of intrauterine life, and two centers for epiphyses, which appear, (*a*) in the cartilaginous head of the bone toward the end of the ninth month, and (*b*) in the lower extremity during the second year. The latter unites with the shaft at eighteen, (figs. 272, 275) the union of the head with the shaft takes place between the nineteenth and twenty-fourth years, and it may even be delayed until twenty five. The tubercle of the tibia is ossified from a nucleus which appears from the seventh to the fifteenth year in a strip of cartilage prolonged down from the cartilage of the head of the bone; the center fuses with the proximal epiphysis about the fifteenth year.

THE FIBULA

The **fibula** (figs. 273, 274) is situated on the lateral side of the leg and, in proportion to its length is the most slender of all the long bones. It is placed nearly parallel to the tibia with which it is connected in its whole extent. In man it is a rudimentary bone and bears none of the weight of the trunk, but is of importance on account of its muscular attachments and its participation in the formation of the ankle-joint. Like other long bones, it is divisible into a shaft and two extremities.

The **head** [capitulum fibulæ] or upper extremity, is a rounded expansion of the bone which produces the prominence at the lateral side of the knee posterior and inferior to the lateral condyle of the tibia. Its upper surface presents laterally a rough eminence for the attachment of the biceps tendon and the fibular collateral ligament of the knee-joint, and medially a circular or oval **articular facet of the head** [facies articularis capituli], directed upward, forward, and med-

ially, for articulation with the lateral condyle of the tibia. The margin of the facet gives attachment to the articular capsule of the superior tibiofibular articulation. Posteriorly, the head rises into a pointed **apex** [apex capituli fibulæ], which affords attachment to the arcuate popliteal ligament of the knee-joint, and on the lateral side, to part of the biceps tendon.

The posterior aspect of the head gives attachment to the soleus, the lateral aspect, extending also in front of the eminence for the biceps, to the peroneus longus; from the anterior aspect fibers of the extensor digitorum longus arise, whilst the medial side lies adjacent to the tibia.

The **shaft of the fibula** [corpus fibulæ], in its upper three-fourths, is quadrangular, possessing four borders and four surfaces, whereas its lower fourth is flattened from side to side, so as to be somewhat triangular. The borders and surfaces vary exceedingly so that their description is difficult.

The **anterior crest** [crista anterior] (crista dorsalis NK) (or anterolateral border) commences in front of the head and terminates below by dividing to enclose a subcutaneous surface, triangular in shape, immediately above the lateral malleolus. It gives attachment to the anterior intermuscular septum separating the extensor muscles in front from the peroneal muscles on the lateral aspect. The **interosseous crest** [crista interossea] (or anteromedial border), so named from giving attachment to the interosseous membrane, also commences in front of the head, close to the anterior crest, and terminates below by dividing to enclose a rough triangular area immediately above the articular surface of the malleolus; this area gives attachment to the interosseous membrane, and may present at its lower end a narrow facet for articulation with the tibia. The **medial crest** [crista medialis] (or posteromedial border), sometimes described as the **oblique line** of the fibula, commences at the medial side of the head and terminates below by joining the interosseous crest, in the lower fourth of the shaft. It gives attachment to an aponeurosis separating the tibialis posterior from the soleus and flexor hallucis longus. The **lateral crest** (or posterolateral border) runs from the back of the head to the medial border of the peroneal groove on the back of the lower extremity; it gives attachment to the posterior intermuscular septum separating the peroneal from the flexor muscles.

The **anterior** or **extensor surface** [facies medialis BNA] is the interval between the interosseous and anterior crests. In the upper third it is extremely narrow, but broadens out below, where it is slightly grooved longitudinally. It affords origin to three muscles: laterally, in the upper two-thirds, to the extensor digitorum longus, and, in the lower third, to the peroneus tertius; medially, in the middle third, also to the extensor hallucis longus. The **medial surface,** situated between the interosseous and medial crests, is narrow above and below, and broadest in the middle. It is grooved and sometimes crossed obliquely by a prominent ridge, the **secondary oblique line** of the fibula; the surface gives origin to the tibialis posterior, and the ridge to a tendinous septum in the substance of the muscle. The **posterior surface** [facies posterior] (facies plantaris NK) is the interval between the medial and lateral crests, and is somewhat twisted so as to look backward above and medially below. It serves, in its upper third, for the origin of the soleus, and in its lower two-thirds for the flexor hallucis longus muscle. Near the middle of the surface is the **nutrient foramen,** directed downward toward the ankle. The **lateral surface** [facies lateralis] situated between the anterior and lateral crests, is also somewhat twisted, looking laterally above and backward below, where it is continuous with the groove on the back of the lateral malleolus. The surface is often deeply grooved and is occupied by the peroneus longus in the upper two-thirds and by the peroneus brevis in the lower two-thirds.

The **lateral malleolus** [malleolus lateralis] (malleolus fibulæ NK) or lower extremity is pyramidal in form, somewhat flattened from side to side, and continuous by its base with the shaft. It is longer, more prominent, and descends lower than the medial malleolus. Its lateral surface is convex, subcutaneous, and continuous with the triangular subcutaneous surface on the shaft, immediately above. The medial surface is divided into an anterior and upper area [**facies articularis malleoli**], triangular in outline and convex from above downward for articulation with the lateral side of the talus (astragalus), and a lower and posterior excavated area, the **digital fossa,** in which are attached the transverse tibiofibular ligament and the posterior talofibular ligament of the ankle. The anterior border is rough and gives attachment to the anterior talofibular ligament of the ankle, and the anterior lateral malleolar, and calcaneofibular ligaments. The posterior border is grooved slightly for the peroneal tendons, and near its upper part gives attachment to the posterior ligament of the lateral malleolus. The apex of the malleolus affords attachment to the calcaneofibular ligament of the ankle.

Blood-supply.—The shaft of the fibula receives its nutrient artery from the peroneal branch of the posterior tibial. The head is nourished by branches from the inferior lateral articular branch of the popliteal artery, and the lateral malleolus is supplied mainly by the peroneal, and its perforating and posterior lateral malleolar branches.

Ossification.—The shaft of the fibula commences to ossify in the eighth week (fifty-fifth day, Mall) of intrauterine life. A nucleus appears for the lower extremity in the second year, and one in the upper extremity during the fourth or fifth year. The lower extremity fuses with the shaft about twenty (fig. 94), but the upper extremity remains separate until the twenty-second year or even later.

It is interesting, in connection with the times of appearance of the two epiphyses of the fibula, to note that the ossification of the lower epiphysis is contrary to the general rule—viz., that the epiphysis toward which the nutrient artery is directed is the last to unite with the shaft. This is perhaps explained by the rudimentary nature of the upper extremity. In birds the head of the bone is large and enters into the formation of the knee-joint; and in human embryos, during the second month, the fibula is quite close to the femur.

The human fibula is characterized by the length of its malleolus, for in no other vertebrate does this process descend so far below the level of the tibial malleolus. On the other hand, in the majority of mammals the tibial descends to a lower level than the fibular malleolus. In

FIG. 275.—RADIOGRAM OF THE KNEE-JOINT SHOWING THE FABELLA. (Sesamoid bone of the lateral head of the gastrocnemius muscle.)

the human embryo of the third month, the lateral is equal in length to the medial malleolus; but the former grows more rapidly and by the second year it assumes its adult proportion.

The chief **variations** of the fibula are fluctuations in the form and relative size of the surfaces of the shaft, correlated with the attachment of muscles, and the occasional absence of the bone. In seven per cent. of the fibulæ examined by Edwards (Am. Jour. Anat., 42, 1928) the posterior margin of the lateral malleolus was not grooved, but on the contrary, convex transversely.

CLINICAL RELATIONS OF THE LEG

Bony landmarks.—From the *tuberosity* (tubercle) *of the tibia* descends the *anterior border* or 'shin.' This soon becomes sharp, and continues so for its upper two-thirds; in the lower third it disappears, to be overlaid by the extensor tendons. It is curved somewhat laterally above and medially below. The *medial border* can also be felt from the medial condyle to the medial malleolus. Between these two borders lies the *medial surface*, subcutaneous save above, where it is covered by the three tendons of insertion of the gracilis and semitendinosus and sartorius. The tibia is narrowest and weakest at the junction of the middle and lower thirds, the most common site of fracture. Behind the *medial malleolus*, part of the groove for, and the tendon of, the tibialis posterior can be felt. The *head of the fibula* can be felt distinctly, but the shaft soon becomes buried among muscles. About 7.5 cm. (3 in.) above the *lateral malleolus*, the fibula expands into a large triangular subcutaneous surface. This lies between the peroneus tertius and the other two peronei. The peroneus longus overlaps the brevis, especially in the upper two-thirds of the leg. In the lower third the brevis tends to become anterior. Behind the lateral malleolus these tendons descend on its posterior border into the foot. The shaft of the fibula is placed on a plane posterior to that of the tibia, and curves backward in a direction reverse to that of the tibia.

Access.—That to the **tibia** is easy and is made along the medial aspect. The **fibula** is best explored by a free incision along the line of the posterior peroneal septum, which lies between the peronei and the muscles at the back (p. 544). The presence of the superficial peroneal (musculocutaneous) nerve perforating the deep fascia in the lower third below, and that of the the common peroneal (external popliteal) in relation to the neck of the fibula above, must be remembered.

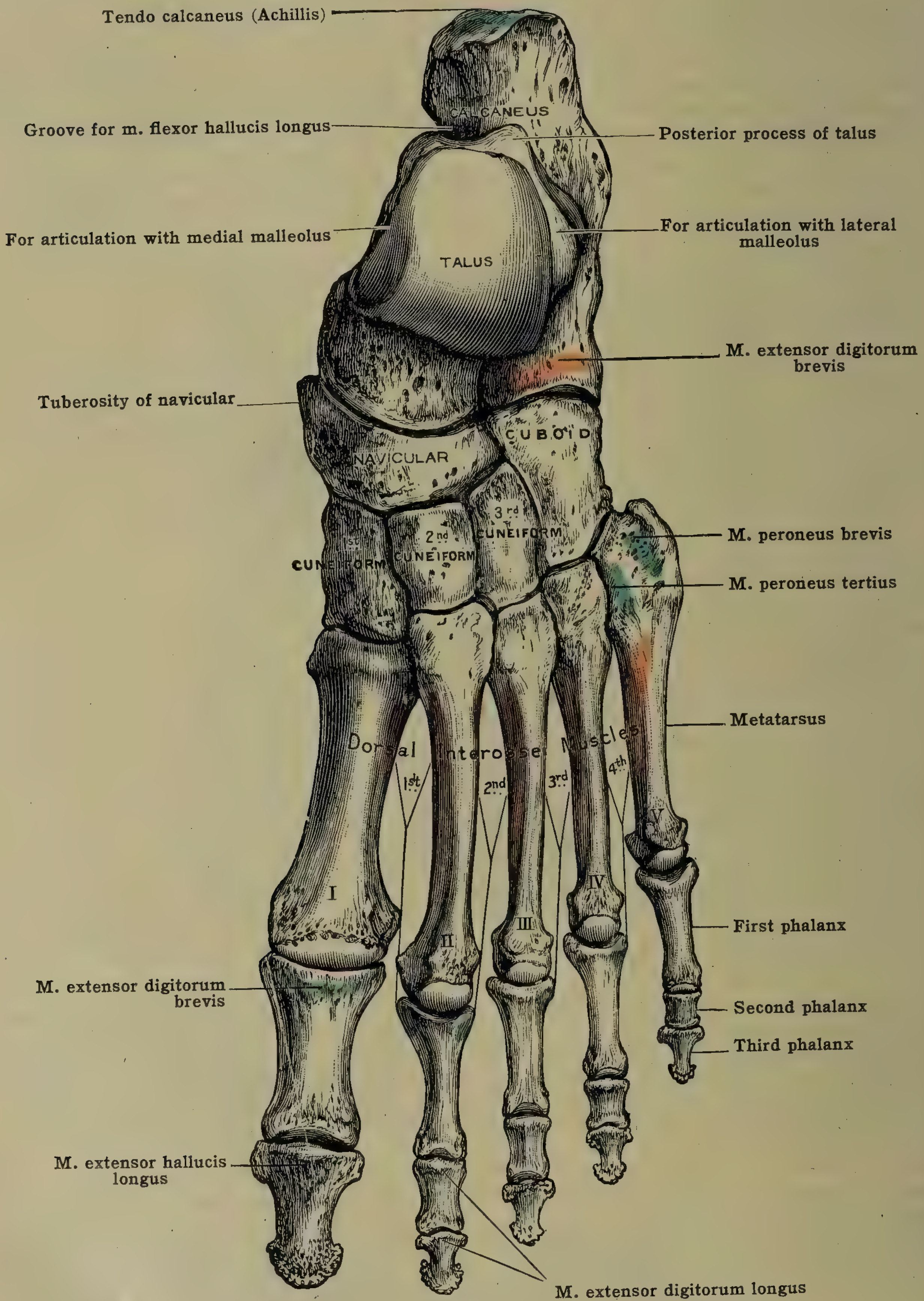


Fig. 276.—Bones of the Left Foot. (Dorsal surface.)

Fractures.—When, as is most frequent, the tibia gives way from indirect violence, the fracture is usually at the weakest spot, *i.e.*, the junction of the middle and lower thirds. The line of obliquity is generally marked, and from above downward and forward. The lower fragment, pulled upward by the powerful calf muscles, rides behind the upper, which projects forward under the skin. The fibula, bending more than the tibia, snaps at a higher level. Tenderness on pressure is the best guide here, as it is in suspected fractures of the upper tibia, transverse from direct violence. The most common variety of **fracture of the fibula** is that called after **Pott**, complicated with displacement of the foot. Here, from abduction of the foot,

a severe strain is thrown upon the deltoid ligament, which gives way; the talus (astragalus) is pressed against the lateral malleolus, and the inferior tibiofibular ligaments resisting, the fibula yields 5 to 7 cm. (2 to 3 in.) above the ankle, the upper end of the lower fragment being usually displaced toward the tibia. If the deltoid ligament is strong, the strain often tears off the medial malleolus. The medial margin of the foot is turned toward the ground, the lateral raised (pes valgus). The foot is also displaced backward. On the medial side of the

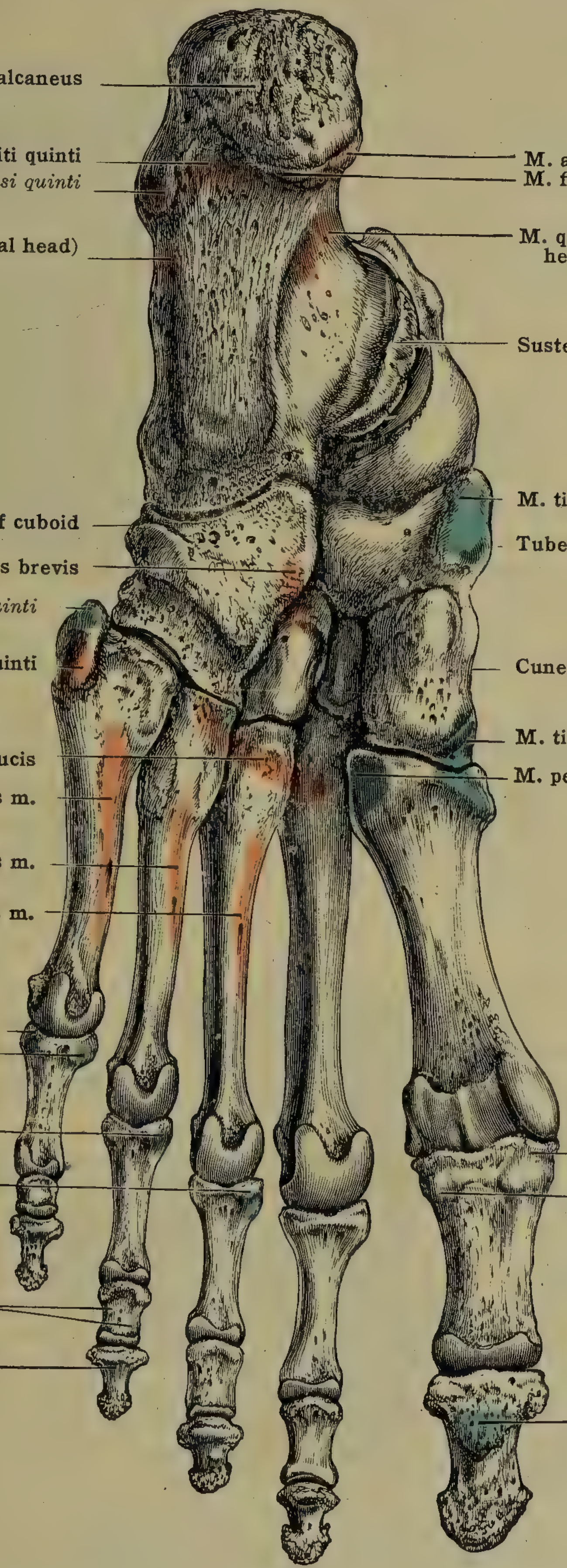


Fig. 277.—Bones of the Left Foot. (Plantar surface.)

ankle there is a marked projection of the lower end of the tibia; higher up, on the lateral side, a depression where the fibula is broken. The need of replacing the foot and the weight-bearing talus (astragalus) accurately, the fact that the ankle-joint is opened and the numerous tendons likely to be matted are the chief points to bear in mind. In **Dupuytren's fracture** there is not only fracture of the lower end of the fibula, but the malleolar ligaments are now torn. The foot is displaced upward and laterally, together with the lower end of the fibula.

Epiphyses.—The upper one of the tibia appears shortly before birth and includes the condyle and tuberosity (fig. 272). It does not fuse with the shaft till the age of twenty or later. This

fact and the powerful strain of the quadriceps on this epiphysis explain the obscure pain sometimes complained of in young adults much given to athletics, over the tibial tuberosity. The lower epiphysis, including the medial malleolus, appears in the second and joins about the eighteenth year. Separation here is not very uncommon up to puberty. In **osteotomy** of the tibia, simple or cuneiform, when the curve is anteroposterior as well as lateral, the close proximity of the tibialis anterior tendon to the lateral border of the crest must be remembered, and when the fibula does not yield to careful force, it, also, must be divided, or damage may be done to the superior tibiofibular and malleolar ligaments, or to the epiphyses of the bones.

In examining X-ray plates of the knee-joint following injury, it is well to remember the presence of a sesamoid bone called the **fabella**, which normally occurs in the tendon of the lateral head of the gastrocnemius (fig. 275).

Amputation of the leg.—To give one instance only, amputation at the seat of election, or a hand's-breadth below the knee-joint, will be alluded to. The above name was given because the pressure of the body is well carried on the prominences about the knee-joint, especially the tuberosity of the tibia, when the patient walks with the knee flexed on a "bucket" artificial limb. Thus the scar, being central, is here not of importance. Two broadly oval lateral flaps of skin and fasciæ are raised, and the remaining soft parts severed down to the bones with circular sweeps of the knife. In sawing the bone, the smaller size of the fibula and its position in a plane behind the tibia must be remembered. The parts cut through are shown in fig. 478.

THE TARSUS

The **tarsal bones** [ossa tarsi] (figs. 276, 277) are grouped in two rows:—a proximal row, consisting of the **talus** and **calcaneus**, and a distal row, consisting of four bones which, enumerated from the tibial side, are the **first, second,** and **third cuneiform** bones and the **cuboid.** Interposed between the two rows on the tibial side of the foot is a single bone, the **navicular;** on the fibular side the proximal and distal rows come into contact.

An alternative nomenclature recommended by the NK is as follows: talus = os tarsi tibiale; calcaneus = os tarsi fibulare; os naviculare pedis = os centrale tarsi; os cuneiforme I = os tarsale distale I; os cuneiforme II = os tarsale distale II; os cuneiforme III = os tarsale distale III; os cuboideum = os tarsale distale IV.

Compared with the carpus, the tarsal bones present fewer common characters, and greater diversity of size and form, modifications correlated with the function of supporting the weight of the trunk. On each, however, six surfaces can generally be recognized, articular when in contact with neighboring bones, elsewhere subcutaneous or rough for the attachment of ligaments. In regard to ossification, they correspond in the main with the bones of the carpus.

The Talus

The **talus** (or astragalus) (figs. 278, 279) is, next to the calcaneus, the largest of the bones of the tarsus. Above it supports the tibia, below it rests on the calcaneus, at the sides it articulates with the two malleoli, and in front it is received into the navicular. For descriptive purposes, it may be divided into a **body, head** and **neck.**

The **body of the talus** [corpus tali] is somewhat quadrilateral in shape. The **upper surface** [facies superior] presents a broad, smooth surface for the tibia, slightly concave from side to side, convex from before backward, and wider in front than behind. The diminution in width posteriorly is associated with an obliquity of the lateral margin, which is directed medially as well as backward and downward. The **inferior surface** is occupied by a transversely disposed oblong facet [**facies articularis calcanea posterior**], deeply concave from side to side, which articulates with a corresponding surface on the calcaneus. The **lateral malleolar surface** [facies malleolaris lateralis] is almost entirely occupied by a large triangular facet, broad above, where it is continuous with the superior surface, concave from above downward, for articulation with the lateral malleolus; on the **medial malleolar surface** [facies malleolaris medialis] is a narrow, sickle-form facet continuous with the superior surface, broad in front and narrow behind, which articulates with the medial malleolus. Below this facet the medial surface is rough for the attachment of the deep fibers of the deltoid ligament of the ankle. The superior surface and the two malleolar surfaces together constitute the **trochlea tali.** The **posterior surface** is of small extent and marked by a groove which lodges the tendon of the flexor hallucis longus [sulcus m. flexoris hallucis longi]. Bounding the groove on either side are two tubercles, of which the lateral, the **posterior process of the talus** [processus posterior tali], is usually the more prominent, for attachment of the posterior talofibular ligament of the ankle-joint; the medial tubercle gives attachment to the medial talocalcaneal ligament. Continuous with the anterior aspect of the body is the **neck of the talus** [collum tali], a constricted part of the bone supporting the head. Above it is rough, and perforated by numerous vascular foramina. Below, it presents a deep groove [**sulcus tali**], directed from behind forward and lateralward. When the talus is articulated with the calcaneus, this furrow is converted into a canal [**sinus tarsi**] in which is lodged the interosseous talocalcaneal ligament. The **head of the talus** [caput tali] is the rounded anterior end of the bone, and its large articular surface is divisible into three parts: in front, a smooth, oval convex area, **facies articularis navicularis,** directed downward and forward for the navicular bone; below, an elongated facet, convex from front to back,

facies articularis calcanea anterior, for articulation with the sustentaculum tali of the calcaneus; and between these is a small facet **facies articularis calcanea media,** which rests on the plantar calcaneonavicular ligament, and on the anterior articular surface of the dorsal aspect of the calcaneus.

Articulations.—The talus articulates with four bones. Above and medially with the tibia, below with the calcaneus, in front with the navicular, laterally with the fibula. The head rests upon the calcaneonavicular ligament and the lateral border of the superior surface of the body, at its posterior part, is in contact with the posterior ligament of the lateral malleolus of the inferior tibiofibular joint.

Fig. 278.—The Right Talus. (Dorsal view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

The talus is a very vascular bone and is nourished by the dorsalis pedis artery and its tarsal branch. It gives attachment to no muscles.

Ossification.—The talus is ossified from one nucleus, occasionally from two. The principal center for this bone appears in the middle of the cartilaginous talus at the seventh month of intrauterine life. The additional center is deposited in the posterior portion of the bone, and forms the lateral tubercle of the posterior process, which may remain separate and form **the os trigonum** (fig. 302). At birth, the talus presents some important peculiarities in the disposition of the articular facet on the tibial side of its body, and in the obliquity of its neck. If, in the adult talus, a line be drawn through the middle of the superior trochlear surface parallel with its medial border, and a second line be drawn along the lateral side of the neck of the bone so as to intersect the first, the angle formed by these two lines will express the obliquity of the neck of the bone. This in the adult varies greatly, but the average may be taken as 10°.

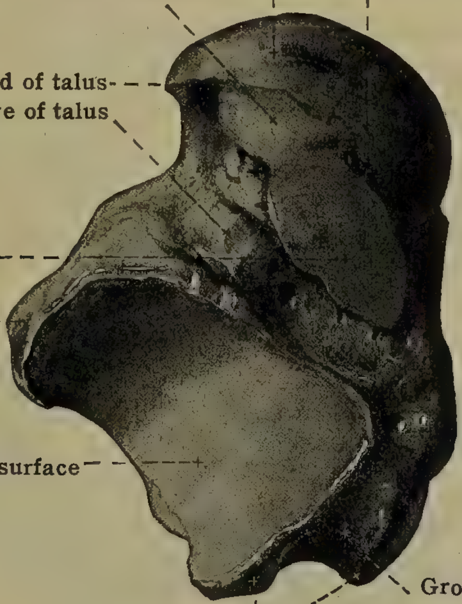


Fig. 279.—The Right Talus. (Plantar view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

At birth the angle averages 35°. In the normal adult talus the articular surface on the tibial side is limited to the body of the bone. In the fetal talus it extends for some distance on to the neck, and sometimes reaches almost as far forward as the navicular facet on the head of the bone. This disposition of the medial malleolar facet is a characteristic feature of the talus in the chimpanzee and the orang. It is related to the inverted position of the foot which is found in the human fetus almost up to the period of birth, and is of interest to the surgeon in connection with some varieties of club-foot (Shattock and Parker).

The Calcaneus

The **calcaneus** (figs. 280, 281) is the largest and strongest bone of the foot. It is of an elongated form, flattened from side to side, and expanded at its posterior

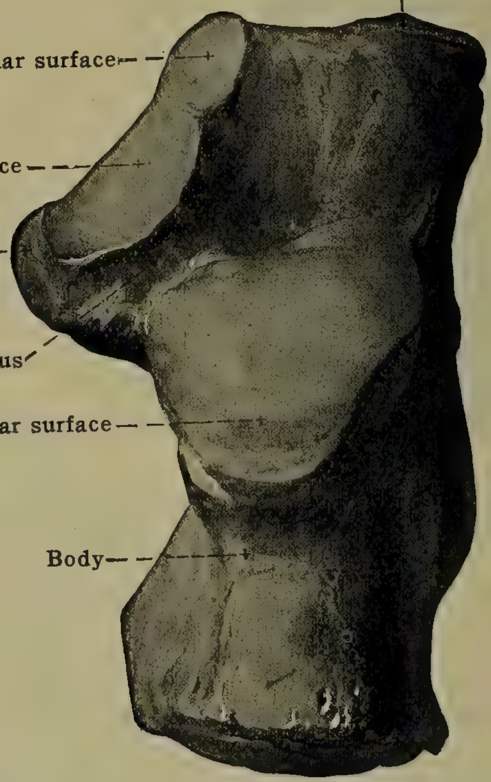


Fig. 280.—The Right Calcaneus. (Dorsal view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

extremity, which projects downward and backward to form the heel. It presents six surfaces, superior, inferior, lateral, medial, anterior and posterior.

The **superior surface** presents in the middle a large, oval, convex, articular facet, **facies articularis posterior,** directed forward and upward for the posterior calcaneal articular surface of the inferior aspect of the body of the talus. In front of the facet the bone is marked by the deep **calcaneal groove** [sulcus calcanei], the floor of which is rough for the attachment of ligaments, especially the interosseous talocalcaneal, and the origin of the extensor digitorum brevis muscle; when the calcaneus and talus are articulated, this portion of the bone forms the

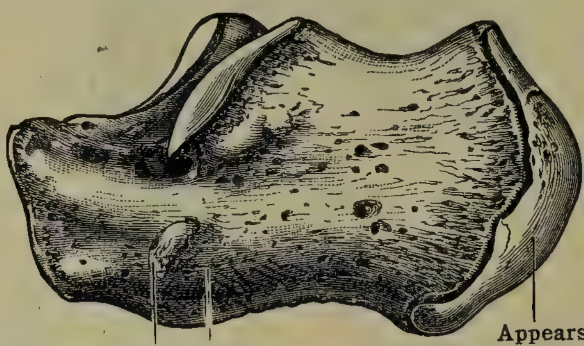


Fig. 281.—The Left Calcaneus at the Fifteenth Year, Showing the Epiphysis. (Lateral view.)

floor of a cavity called the **sinus tarsi.** Medially, the upper surface of the bone presents a well-marked process, the **sustentaculum tali,** furnished with an elongated concave facet, **facies articularis media,** for articulation with the middle calcaneal articular surface of the under aspect of the head of the talus. In front of the sustentaculum tali, the superior surface presents the small **facies articularis anterior** for the anterior calcaneal surface of the head of the talus. The posterior part of the upper surface is continued as far as the tuberosity of the calcaneus, is non-articular, convex from side to side, and in relation with a mass of fat placed in front of the tendo Achillis.

The **inferior surface** is narrow, rough, uneven, and ends posteriorly in the tuberosity. Its rough surface gives attachment to the long plantar ligament and the lateral head of the quadratus plantæ. Near its anterior end this surface forms a rounded eminence, the **anterior tubercle,** from which (as well as from the shallow groove in front) the plantar calcaneocuboid ligament arises.

The **lateral surface** is broad, flat, and slightly convex. It presents near the middle a small eminence for the calcaneofibular ligament of the ankle-joint. Below and in front of this is a variable prominence—the **trochlear process** [processus trochlearis], separating the tendons of the peroneus brevis and the peroneus longus, the latter occupying a slight groove [sulcus m. peronæi]. Behind the trochlear process is the more constant retrotrochlear process.

The **medial surface** is deeply concave, the hollow being increased by the prominent medial process of the tuberosity behind and the overhanging **sustentaculum tali** in front. The latter forms a prominence of bone projecting horizontally, concave and articular above, grooved below for the tendon of the flexor hallucis longus [sulcus m. flexoris hallucis longi], and giving attachment to a slip of the tendon of the tibialis posterior, the plantar calcaneonavicular ligament, and

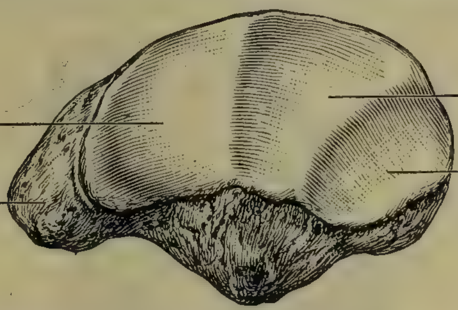


FIG. 282.—THE LEFT NAVICULAR BONE. (Anterior view.)

some fibers of the deltoid ligament of the ankle-joint. The hollow below the process receives the plantar vessels and nerves and its lower part gives attachment to the medial head of the quadratus plantæ.

The **anterior surface** is somewhat quadrilateral in outline with rounded angles, and presents a saddle-shaped articular surface for the cuboid, **facies articularis cuboidea.**

The **posterior surface** is oval in shape, rough, and convex and belongs to the expanded posterior extremity of the bone known as the **tuber calcanei.** It is divided into three parts:—an upper, smooth and separated by a bursa from the tendo Achillis; a middle part giving insertion to the tendo Achillis and the plantaris; and a lower part in relation to the skin and fat of the heel. The tuberosity presents inferiorly two **processes:** the **medial** [processus medialis tuberis calcanei] is the larger and broader, the **lateral** [processus lateralis tuberis calcanei] is narrower but prominent. The medial process affords origin to the abductor hallucis, the flexor digitorum brevis, and the abductor digiti quinti; the last muscle also arises from the lateral process and from the ridge of bone between.

Articulations.—The calcaneus articulates with two bones, the talus above and the cuboid in front.

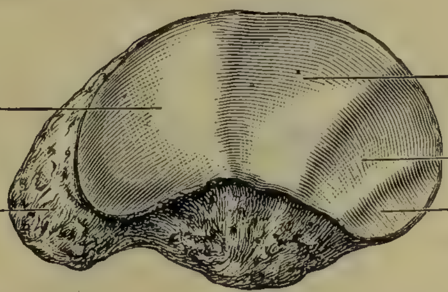


FIG. 283.—THE LEFT NAVICULAR BONE SHOWING A FACET FOR THE CUBOID.

Blood-supply.—The calcaneus is nourished by numerous branches from the posterior tibial and the medial and lateral malleolar and calcaneal arteries. They enter the bone chiefly on the inferior and medial surfaces.

Ossification.—The primary nucleus appears in the sixth month of intrauterine life. The epiphysis, for its posterior extremity, begins to be ossified in the sixth to the tenth year and is united to the body of the bone between the thirteenth and twentieth years (girls earlier than boys). The epiphysis may extend over the whole of the posterior surface, as shown in fig. 281, or over the lower two-thirds only, leaving a part above in relation to the bursa beneath the tendo Achillis, which is formed from the primary nucleus. The medial and lateral processes are formed by the epiphysis.

THE NAVICULAR

The **navicular bone of the foot** [os naviculare pedis] (figs. 282, 283) is oval in shape, flattened from before backward, and situated between the talus behind and the three cuneiform bones in front. Its long axis is directed downward and medially. It is characterized by a large oval, concave, articular facet on the **posterior surface,** which receives the head of the talus; a broad, rough, rounded eminence on the **medial surface,** named the **tuberosity of the navicular bone** [tuberositas oss. navicularis], the lower part of which projects downward and gives

insertion to the tendon of the tibialis posterior; and an oblong-shaped **anterior surface**, convex and divided by two vertical ridges into three facets which articulate with the three cuneiform bones. The **superior** (dorsal) **surface** is rough, convex, and slopes downward to the tuberosity; the **inferior** (plantar) **surface** is irregular and rough for the attachment of the plantar calcaneonavicular ligament; the **lateral surface** is rough and sometimes presents a small articular surface for the cuboid.

The tuberosity can be easily distinguished by palpation and constitutes an important surgical landmark of the foot.

Articulations.—With the talus behind, with the three cuneiform bones in front, and occasionally with the cuboid on its lateral aspect.

Ossification.—The nucleus for the navicular appears in the course of the fourth year. The tuberosity of the navicular, into which the tibialis posterior acquires its main insertion, occasionally develops separately, and sometimes remains distinct from the rest of the bone.

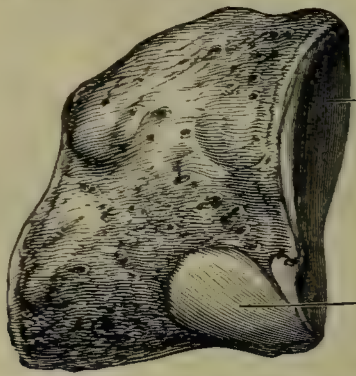


Fig. 284.—The Left First Cuneiform Bone. (Medial surface.)

The Cuneiform Bones

Of the three cuneiform bones (figs. 284–289); the first is the largest, the second is the smallest, and the third intermediate in size. They are wedge-shaped bones placed between the navicular and the first, second and third metatarsal bones. Posteriorly, the ends of the bones lie in the same transverse line, but in front, the first and third project farther forward than the second, and form the sides of a deep recess into which the base of the second metatarsal bone is received.

The **first cuneiform bone** [os cuneiforme primum] (figs. 284, 285) is distinguished by its large size and by the fact that when articulated, the base of the wedge is directed downward and the apex upward. The **posterior surface** is concave and pyriform for articulation with the medial facet on the anterior surface of the navicular. The **anterior surface** forms a reniform articular

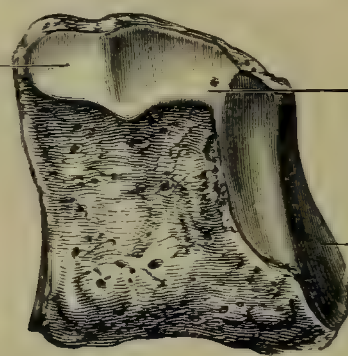


Fig. 285.—The Left First Cuneiform. (Lateral surface.)

facet for the base of the first metatarsal. The **medial surface** is rough, and presents an oblique groove for the tendon of the tibialis anterior; this groove is limited inferiorly by an oval facet into which a portion of the tendon is inserted. The **lateral surface** is concave and presents along its superior and posterior borders a reversed L-shaped facet for articulation with the second cuneiform, and, at its anterior extremity, with the second metatarsal. Anteriorly it is rough for ligaments. The **inferior surface** is rough for the insertion of the peroneus longus, tibialis anterior, and (usually) the tibialis posterior. The **superior surface** is the narrow part of the wedge and is directed upward.

Articulations.—With the navicular behind, second cuneiform and second metatarsal on its lateral side, and first metatarsal in front.

Ossification.—From a single nucleus which appears in the course of the third year.

The **second cuneiform bone** [os cuneiforme secundum] (figs. 286, 287) is placed with the broad extremity upward and the narrow end downward, and is readily recognized by its nearly square base. The **posterior surface**, triangular and concave, articulates with the middle facet on the anterior surface of the navicular. The **anterior surface,** also triangular, but narrower than the posterior surface, articulates with the base of the second metatarsal. The **medial surface** has a reversed L-shaped facet running along its superior and posterior margins for articulation with the corresponding facet on the first cuneiform, and is rough elsewhere for the

attachment of ligaments. On the **lateral surface** near its posterior border is a vertical facet, sometimes bilobed, for the third cuneiform, and occasionally a second facet at the anterior inferior angle. The **superior surface** forms the square-cut base of the wedge and is rough for the attachment of ligaments. The **inferior surface** is sharp and rough for ligaments and a slip of the tendon of the tibialis posterior muscle.

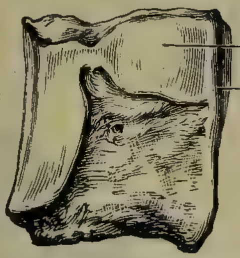


FIG. 286.—THE LEFT SECOND CUNEIFORM. (Medial surface.)

Articulations.—With the navicular behind, second metatarsal in front, third cuneiform on the lateral side, and first cuneiform on the medial side.

Ossification.—From a single nucleus which appears in the fourth year.

The **third cuneiform bone** (figs. 288, 289) also placed with the broad end directed upward and the narrow end downward, is distinguished by the oblong shape of its base. Like the second cuneiform, the **posterior surface** presents a triangular facet for the navicular; and the **anterior surface** a triangular facet, longer and narrower, for the third metatarsal. The **medial surface** has a large facet extending along the posterior border for the second cuneiform, and along the anterior border a narrow irregular facet for the lateral side of the base of the second metatarsal. Occasionally, a small facet is present near the anterior inferior angle for the second cuneiform. The **lateral surface** has a large distinctive facet near its posterior superior angle for the cuboid, and at the anterior superior angle there is usually a small facet for the medial side of the base of the fourth metatarsal. The **superior surface,** oblong in shape, is rough for ligaments, and the **inferior,** forming a rounded margin, receives a slip of the tibialis posterior and gives origin to a few fibers of the flexor hallucis brevis.

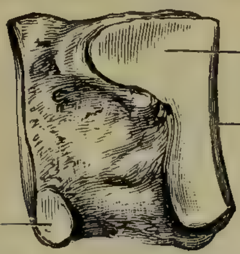


FIG. 287.—THE LEFT SECOND CUNEIFORM. (Lateral surface.)

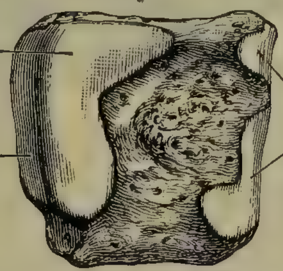


FIG. 288.—THE LEFT THIRD CUNEIFORM. (Medial surface.)

Articulations.—With the navicular behind, third metatarsal in front, cuboid and fourth metatarsal on the lateral side, second cuneiform and second metatarsal on the medial side.

Ossification.—A single nucleus appears in the course of the first year.

FIG. 289.—THE LEFT THIRD CUNEIFORM BONE. (Lateral surface.)

THE CUBOID BONE

The **cuboid bone** [os cuboideum] (figs. 290–292), irregularly cubical in shape, is placed on the lateral aspect of the foot, forming a continuous line with the calcaneus and the fourth and fifth metatarsals.

Its **posterior surface** is somewhat quadrangular with rounded angles and presents a saddle-shaped articular surface for the calcaneus. Its lower and medial angle is somewhat prolonged backward (calcaneal process of the cuboid) beneath the projecting lip of the calcaneus which bears the anterior articular surface, by which the upward or outward movement of the bone is opposed. This process occasionally terminates in a rounded facet which plays on the head of the talus lateral to the facet for the plantar calcaneonavicular ligament. The **anterior surface** is smaller and divided by a vertical ridge into two articular facets, a lateral for the base of the fifth, and a medial for the base of the fourth metatarsal bone. The **superior surface** is rough

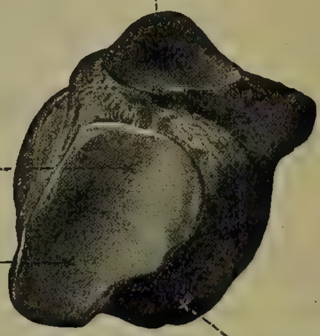


Fig. 290.—The Right Cuboid Bone. (Anterior view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

non-articular, and directed obliquely upward. The **inferior surface** presents a prominent ridge for the attachment of the long plantar ligament, in front of which is a deep groove—the **peroneal groove** [sulcus m. peronaei]—running obliquely forward and medially and lodging some connective tissue and fat. The ridge terminates laterally in an eminence, the **tuberosity of the cuboid bone** [tuberositas oss. cuboidei], on which there is usually a flat or convex cartilage covered facet for the passage of the tendon of the peroneus longus muscle. The part of the surface behind the ridge is rough for the attachment of the plantar calcaneocuboid ligament, a slip of the tibialis posterior, and a few fibers of the flexor hallucis brevis muscle.

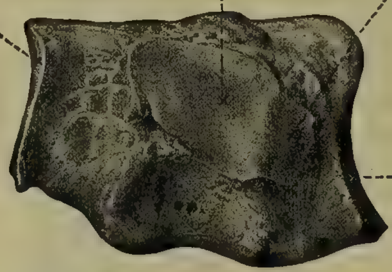


Fig. 291.—The Right Cuboid Bone. (Medial view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

The **medial surface** presents, near its middle and upper part, an oval facet for articulation with the third cuneiform bone (fig. 291); behind this, a second facet for the navicular is frequently seen. Generally the two facets are confluent and then form an elliptical surface. The remainder of this surface is rough for the attachment of strong interosseous ligaments.

The **lateral surface,** the smallest and narrowest of all surfaces, presents a deep notch which leads into the peroneal groove.

Articulations.—With the calcaneus behind, fourth and fifth metatarsals in front, third cuneiform and frequently the navicular on the medial side; occasionally also the talus.

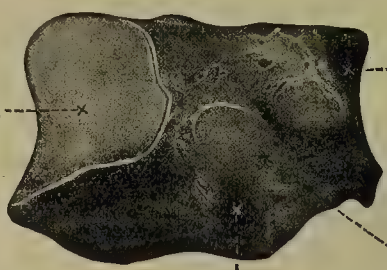


Fig. 292.—Right Cuboid Bone. (Plantar view.) (From Spalteholz 'Handatlas of Human Anatomy,' J. B. Lippincott Co.)

Ossification.—The cuboid is ossified from a single nucleus which appears about the time of birth.

Accessory tarsal elements (figs. 301–303).—As in the carpus, additional elements may occur in the tarsus. The most frequent of these is the **os trigonum,** which has already been noticed. Next in frequency is an additional first cuneiform, resulting from the ossification of the plantar half of that bone independently of the dorsal half, so that the bone is represented

by a plantar and a dorsal first cuneiform. Other additional elements may occasionally occur at the upper posterior angle of the sustentaculum tali; at the anterior superior angle of the calcaneus, between that bone and the navicular; in the angle between the first cuneiform and the first and second metatarsals; and in the lateral angle between the fifth metatarsal and the cuboid (**os Vesalianum**).

The lateral portion of the navicular is sometimes united to the cuboid and quite separate from the rest of the navicular, the cuboid in such cases articulating with the talus. This condition suggests the recognition of this portion of the navicular as a distinct accessory tarsal element, the *cuboides secundarium*, though it has not yet been observed as an independent bone in the human foot. An anterior calcanean peroneal facet on the lateral surface of the calcaneus anterior to the trochlear process was found by Edwards in 6.6 per cent. of cases.

THE METATARSUS

The **metatarsus** consists of a series of five somewhat cylindrical bones [ossa metatarsalia] (figs. 276, 277). Articulated with the tarsus behind, they extend forward, nearly parallel with each other, to their anterior extremities, which articulate with the phalanges. They are numbered according to their position from great toe to small toe. Like the corresponding bones in the hand, each presents a three-sided shaft, a proximal extremity termed the base, and a distal extremity or head. The shaft tapers gradually from the base to the head, and is slightly curved longitudinally so as to be convex on the dorsal and concave on the plantar aspect.

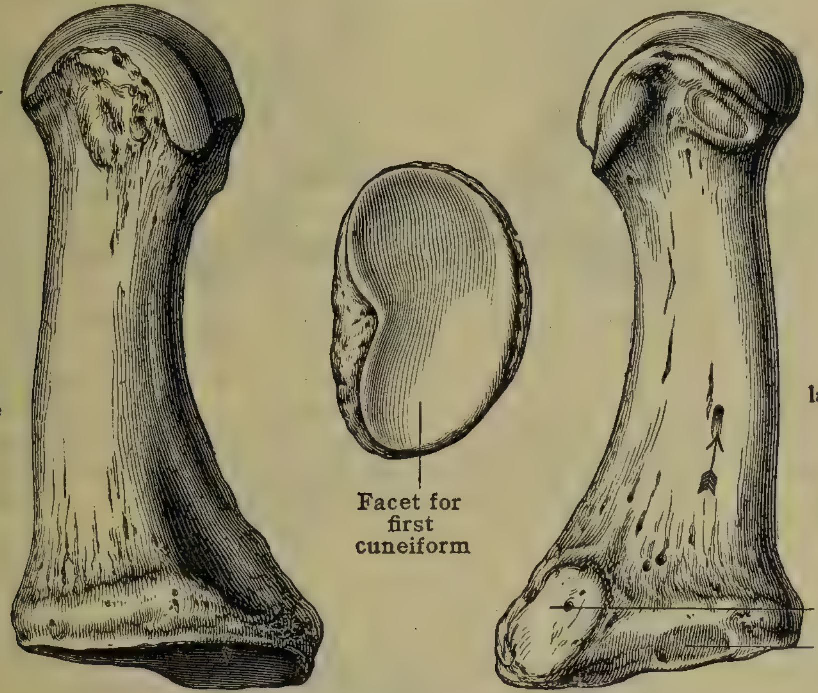


Fig. 293.—The First (Left) Metatarsal Bone.

A typical metatarsal bone.—The **shaft** [corpus] is compressed laterally and presents three borders and three surfaces. The two **borders**, distinguished as **medial** and **lateral**, are sharp and commence behind, one on each side of the dorsal aspect of the tarsal extremity, and, gradually approaching in the middle of the shaft, separate at the anterior end to terminate in the corresponding tubercles. The **inferior border** is thick and rounded and extends from the under aspect of the tarsal extremity to near the anterior end of the bone, where it bifurcates, the two divisions terminating in the articular eminences on the plantar aspect of the head. Of the three surfaces, the **dorsal** is narrow in the middle and wider at either end. It is directed upward and is in relation with the extensor tendons. The **medial** and **lateral surfaces**, more extensive than the dorsal, corresponding with the interosseous spaces, are separated above, but meet together at the inferior border; they afford origin to the interosseous muscles. The **base** [basis] is wedge-shaped, articulating by its terminal surface with the tarsus, and on each side with the adjacent metatarsal bones. The dorsal and plantar surfaces are rough for the attachment of ligaments. The **head** [capitulum] presents a semicircular articular surface for the base of the first phalanx, and on each side a depression, surmounted by a tubercle, for the attachment of the lateral ligaments of the metatarsophalangeal joint. The inferior surface of the head is grooved for the passage of the flexor tendons and is bounded by two eminences continuous with the terminal articular surface.

The several metatarsal bones possess distinctive characters by which they can readily be recognized.

The **first metatarsal bone** (fig. 293) is the most modified of all the metatarsal bones, and deviates widely from the general description given above. It is the shortest, the thickest, the strongest, and most massive of the series. The **base** presents a large reniform, slightly concave facet for the first cuneiform and projects downward into the sole to form the **tuberosity** [tuberositas oss. metatarsalis I], a rough eminence into which the peroneus longus and a slip of the tibialis anterior are inserted. A little above the tuberosity, on its lateral side, there is occasionally a shallow, but easily recognized facet, for articulation with the base of the second metatarsal. The **head** is marked on the plantar surface by two deep grooves, separated by a ridge, in which the two sesamoid bones of the flexor hallucis brevis glide. The **shaft** is markedly prismatic. The **dorsal surface** is smooth, broad, and convex, directed obliquely upward; the **plantar surface** is concave longitudinally and covered by the flexor hallucis longus and brevis, whilst the **lateral surface** is triangular in outline, almost vertical, and in relation with the first dorsal interosseous and adductor hallucis (oblique head). A few fibers of the medial head of the first dorsal interosseous occasionally arise from the hinder part of the surface adjoining the base, or from the border separating the lateral from the dorsal surface. Somewhere near

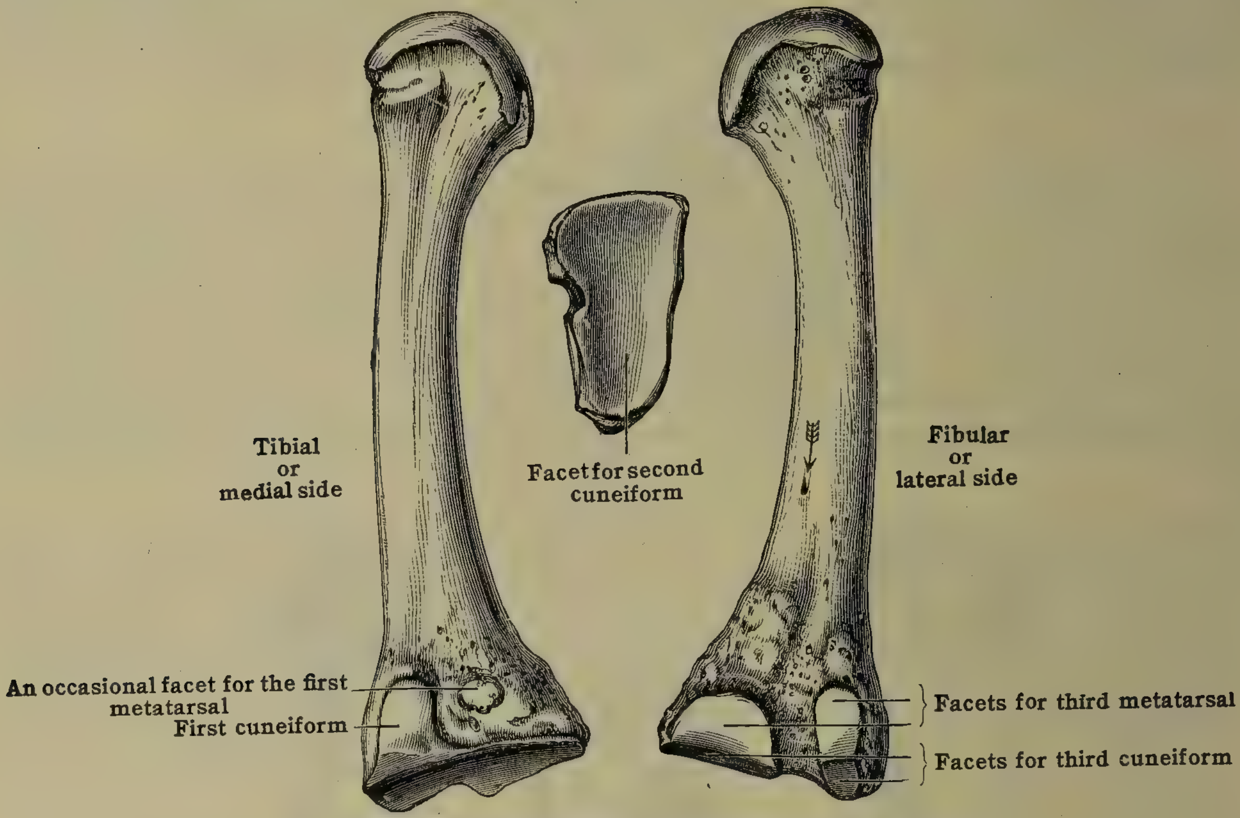


FIG. 294.—THE SECOND (LEFT) METATARSAL BONE.

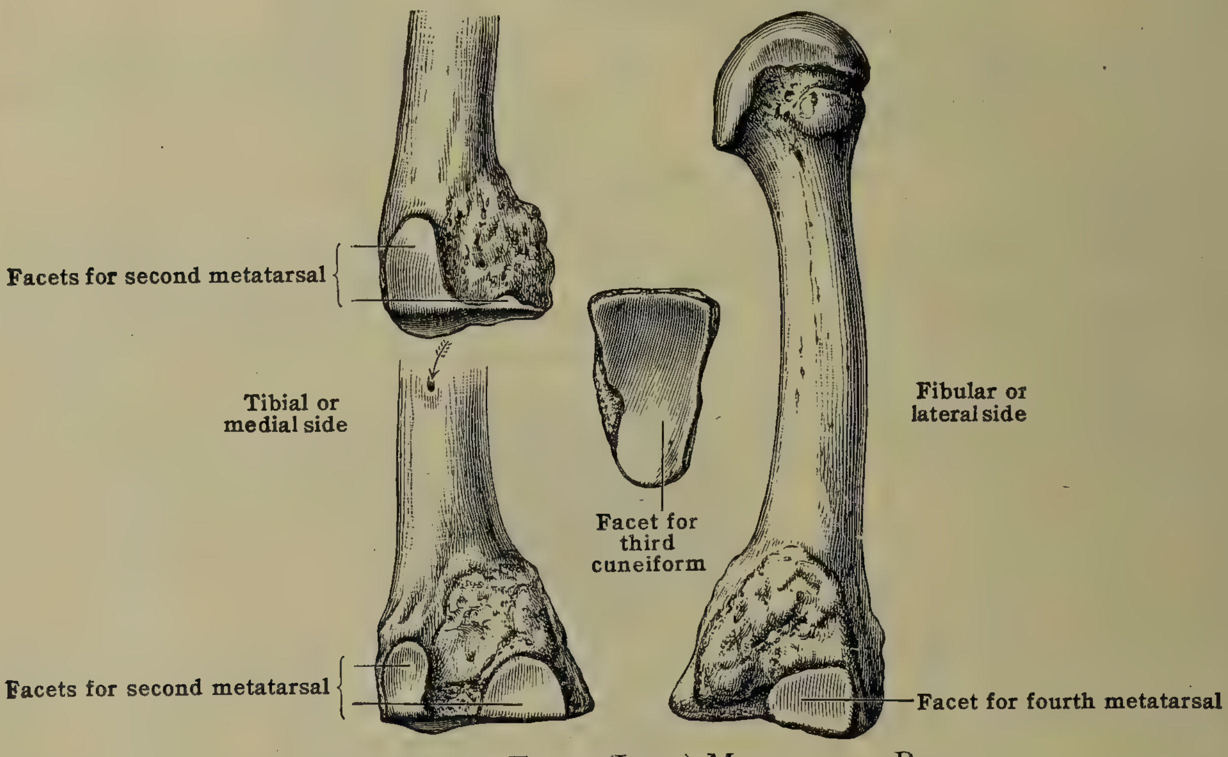


FIG. 295.—THE THIRD (LEFT) METATARSAL BONE.

the middle of the shaft, and on its fibular side, is the **nutrient foramen,** directed toward the head of the bone.

The second metatarsal bone (fig. 294) is the longest of the series. Its base is prolonged backward to occupy the space between the first and third cuneiform, and accordingly it is marked by facets for articulation with each of these bones. The tarsal surface is triangular in

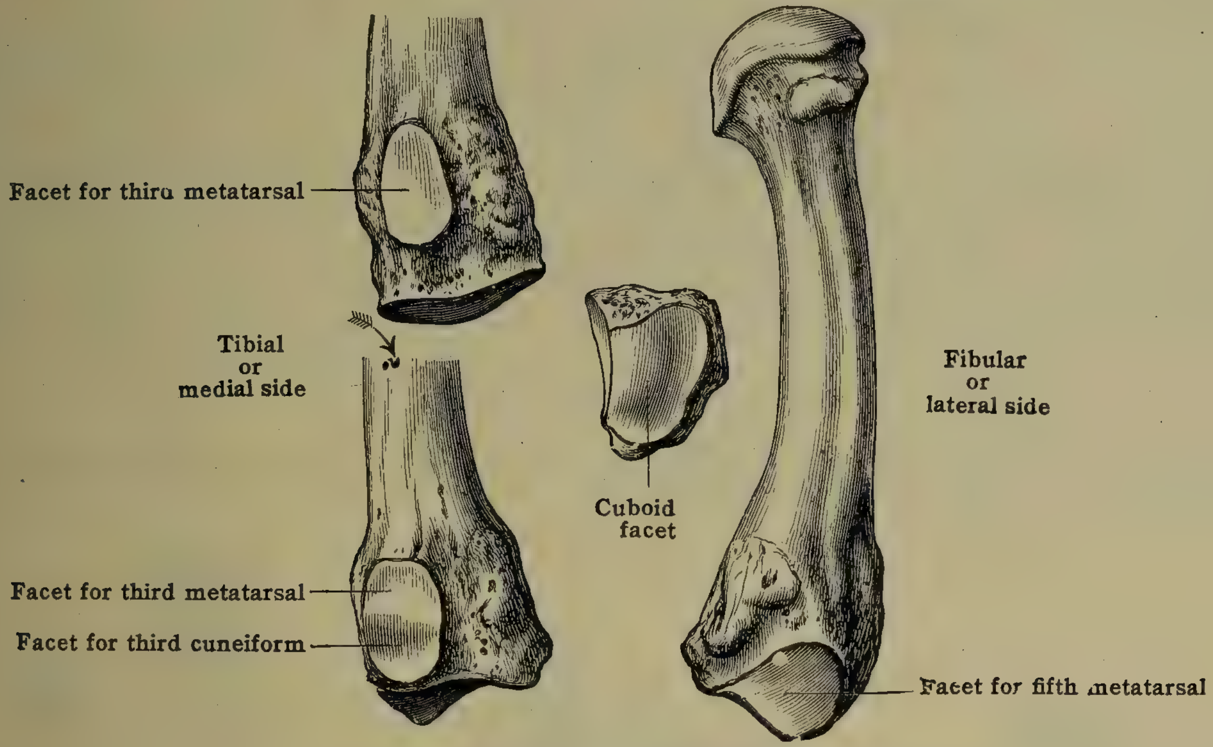


FIG. 296.—THE FOURTH (LEFT) METATARSAL BONE.

outline, with the base above and apex below, and articulates with the second cuneiform bone. On the tibial side of the base, near the upper angle, is a small facet for the first cuneiform, and occasionally another for the first metatarsal a little lower down. The fibular side of the base presents an upper and a lower facet, separated by a non-articular depression, and each facet is divided by a vertical ridge into two, thus making four in all. The two posterior facets articu-

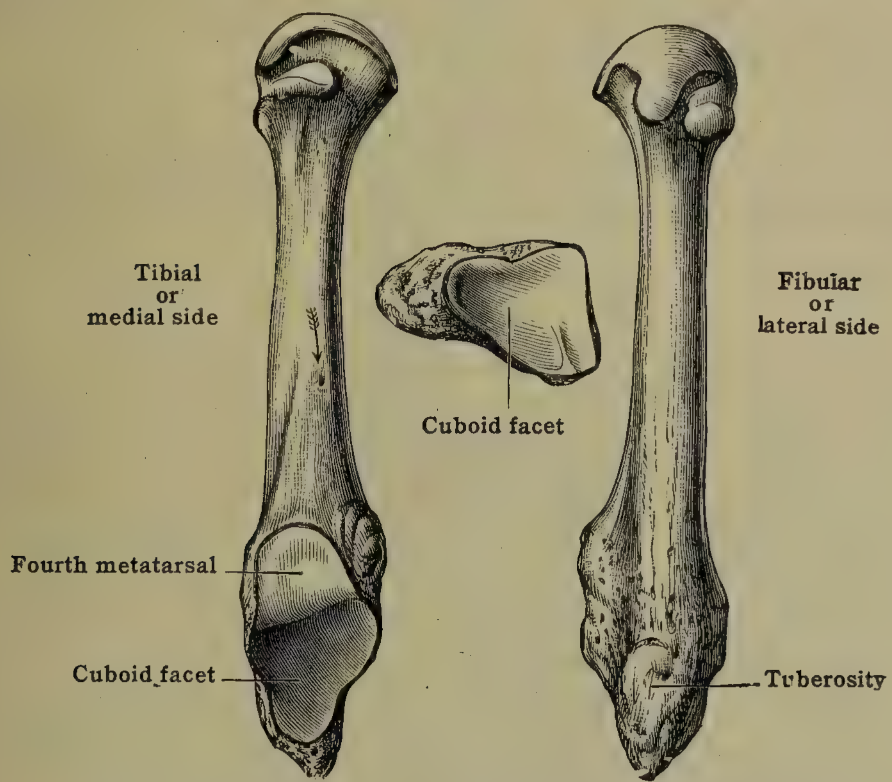


FIG. 297.—THE FIFTH (LEFT) METATARSAL BONE.

late with the third cuneiform and the two anterior with the third metatarsal. The base gives insertion to a slip of the tibialis posterior, while from the shaft the first and second dorsal interosseous muscles take origin. The nutrient foramen is situated on the fibular side of the shaft near the middle and is directed toward the base of the bone.

The **third metatarsal bone** (fig. 295), a little shorter than the second, articulates by the triangular surface of its base with the third cuneiform. On the medial side are two small facets, one below the other, for the second metatarsal, and on the lateral side, a single large facet for the fourth metatarsal. The base gives attachment to a slip of the tibialis posterior and the oblique head of the adductor hallucis and from the shaft three interosseous muscles take origin. The nutrient foramen is situated on the tibial side of the shaft and is directed toward the base.

The **fourth metatarsal bone** (fig. 296), smaller in size than the preceding, is distinguished by the quadrilateral facet on the base, for the cuboid. The medial side presents a large facet divided by a ridge into an anterior portion for articulation with the third metatarsal and a posterior portion for the third cuneiform. Occasionally the cuneiform part of the facet is wanting. On the lateral side of the base is a single facet for articulation with the fifth metatarsal.

The **fifth metatarsal bone** (fig. 297), is shorter than the fourth, but longer than the first. It is recognized by the large nipple-shaped process, known as the **tuberosity** [tuberositas oss. metatarsalis V], which projects on the lateral side of the base. It constitutes the hindmost part of the bone and gives insertion to the peroneus brevis on the dorsal aspect, and flexor brevis digiti quinti and the occasional abductor ossis metatarsi quinti on the plantar aspect. The fifth metatarsal articulates behind by an obliquely directed triangular facet with the cuboid, and on the medial side with the fourth metatarsal. The plantar aspect of the base is marked by a shallow groove which lodges the tendon of the abductor digiti quinti, and the dorsal surface, continuous with the superior surface of the shaft, receives the insertion of the peroneus tertius. The **head** is small and turned somewhat laterally in consequence of the curvature of the shaft in the same direction. The **shaft** differs from that of any of the other metatarsals in being compressed from above downward, instead of from side to side, so as to present superior, inferior, and medial surfaces. It gives origin to the lateral head of the fourth dorsal interosseous and the third plantar interosseous muscles. The nutrient foramen is situated on its tibial side and is directed toward the base.

Ossification.—Each metatarsal ossifies from two centers. The primary nucleus for the shaft appears in the eighth week of embryonic life in the middle of the cartilaginous metatarsal.

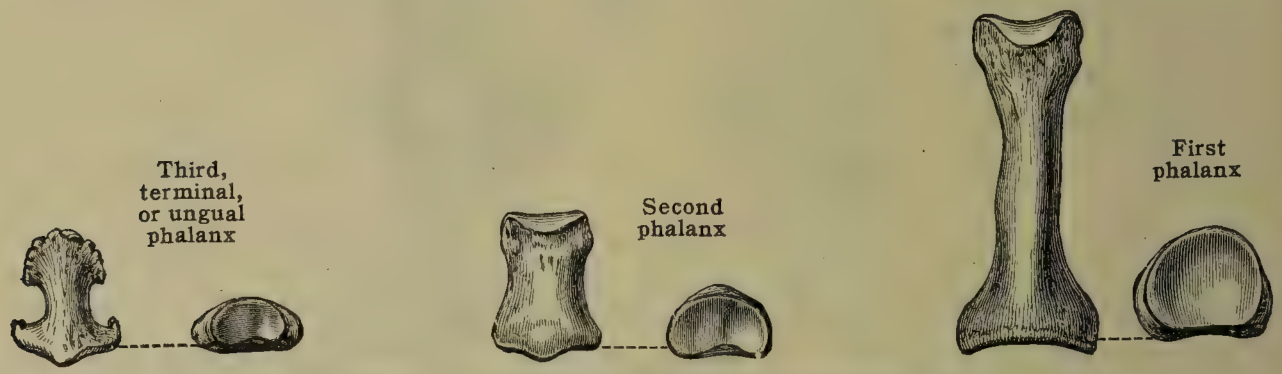


Fig. 298.—The Phalanges of the Middle Toe.

At birth, each extremity is represented by cartilage, and that at the proximal end is ossified by extension from the primary nucleus, except in the case of the first metatarsal. For this, a nucleus appears in the third year. A separate ossific center for the tuberosity of the fifth metatarsal is occasionally observed.

The distal ends of the four lateral metatarsals are ossified by secondary nuclei which make their appearance about the third year. Very frequently an epiphysis is found at the distal end of the first metatarsal as well as at its base. The shafts and epiphyses consolidate in a period extending from the fourteenth to twenty-first year; earlier in females, later in males. The sesamoids belonging to the flexor hallucis brevis begin to ossify between the eighth and eleventh years.

THE PHALANGES

The **phalanges of the toes** [phalanges digitorum pedis] (fig. 298) number in all fourteen. Excepting the hallux, there are in each toe three phalanges, distinguished as **first** [phalanx prima] (proximal), **second** [phalanx secunda] and **third** [phalanx tertia] (distal); in the great toe the second phalanx is absent. There is thus a similarity in regard to number and general arrangement to the phalanges of the fingers. With the exception of the phalanges of the great toe, which are larger than those of the thumb, the bones of the toes are smaller and more rudimentary than the corresponding bones of the fingers. In all the phalanges, the nutrient foramen is directed toward the distal extremity.

The phalanges of the **first row** are constricted in the middle and expanded at either extremity. The shafts are narrow and laterally compressed, rounded on the dorsal and concave on the plantar aspects. The base of each presents a single oval concave facet for the convex head of the corresponding metatarsal, whilst the head forms a pulley-like surface [trochlea phalangis], grooved in the center and elevated on each side for the second phalanx.

The phalanges of the **second row** are stunted, insignificant bones. Their shafts, besides being much shorter, are flatter than those of the first row. The **bases** have two depressions separated by a vertical ridge, and the heads present **trochlear** surfaces for the ungual phalanges.

The **third,** or **ungual** phalanges are easily recognized. The bases articulate with the second phalanges; the shafts are expanded, forming the **ungual tuberosities** [tuberositates unguiculares] which support the nails, and their plantar surfaces are rough where they come into relation with the pulp of the digits.

The muscles attached to the various phalanges may be tabulated thus:—

The **first phalanx of the hallux** gives insertion to the flexor hallucis brevis; abductor hallucis; adductor hallucis, transverse and oblique heads; extensor digitorum brevis.

The **first phalanx of second toe**: The first and second dorsal interosseous.

The **first phalanx of third toe**: Third dorsal interosseous; first plantar interosseous.

The **first phalanx of fourth toe**: Second plantar interosseous; fourth dorsal interosseous.

The **first phalanx of fifth toe**: Third plantar interosseous; flexor digiti quinti brevis; and abductor digiti quinti.

The **terminal phalanx of hallux**: Flexor hallucis longus; extensor hallucis longus.

The **second phalanges of the remaining toes**: Dorsal expansion of the extensor tendons, including extensor digitorum longus, extensor digitorum brevis (except in the case of the fifth toe), and expansions from the interossei and lumbricales.

The **third phalanges**: Flexor digitorum longus; dorsal expansion of the extensor tendon with the associated muscles.

Ossification.—Like the corresponding bones of the fingers, the phalanges of the toes ossify from a primary and a secondary nucleus. The centers for the shaft appear during the period extending between the eighth week and tenth month of prenatal life; those for the distal phalanges appear earliest; the middle appear last. The secondary center forms a scale-like epiphysis for the proximal end between the second and sixth years, and union takes place in the fourteenth to seventeenth year—i.e., earlier than the corresponding epiphyses in the fingers. The union occurs earlier in females than in males. The primary centers for the third phalanges appear at the distal extremities of the bones.

Sesamoid Bones

As previously mentioned, the patella is in reality a large sesamoid bone. In the foot a pair of sesamoid bones is constant over the metatarsophalangeal joint of the great toe in the tendons

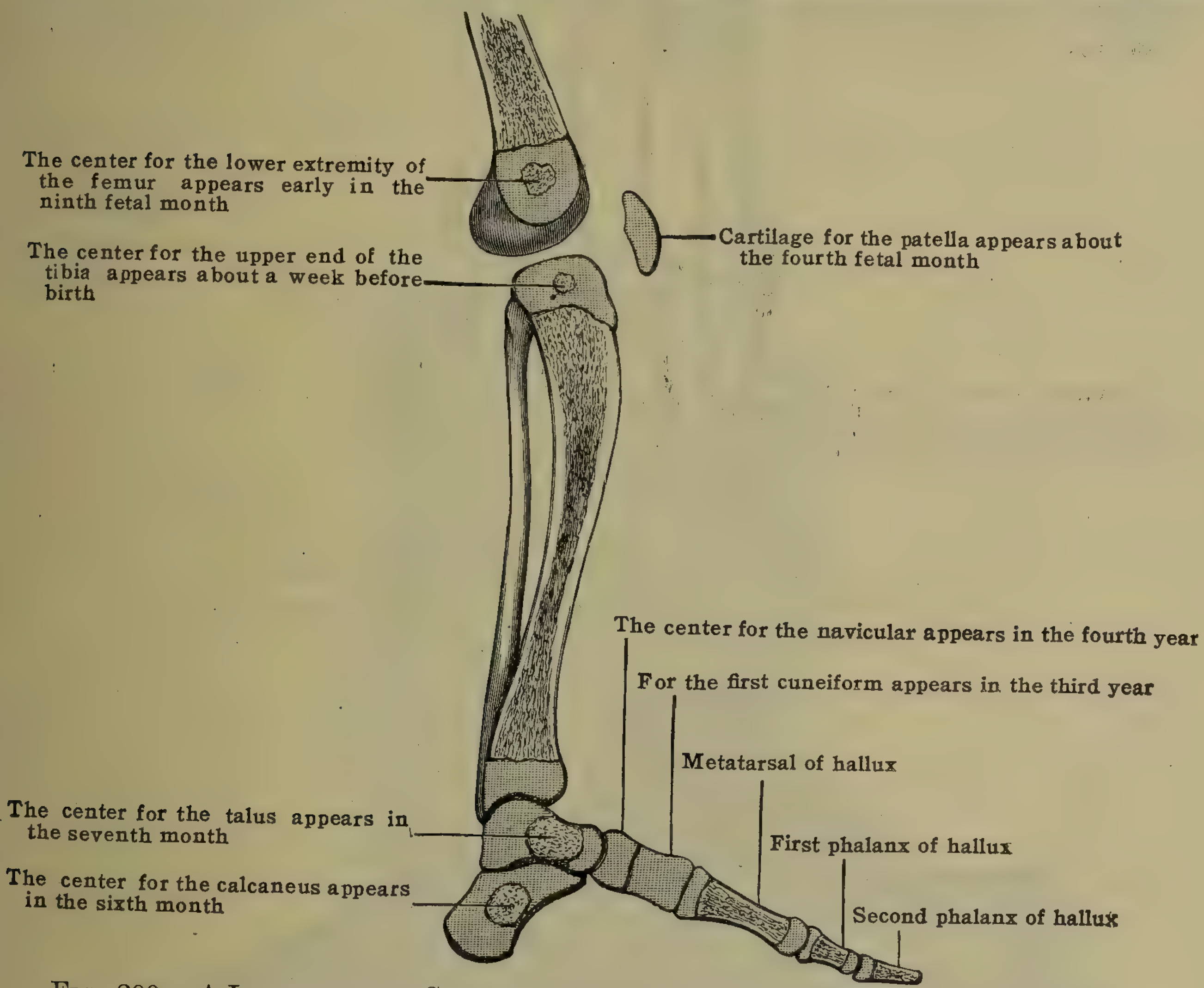


Fig. 299.—A Longitudinal Section of the Bones of the Lower Limb at Birth.

of the flexor hallucis brevis. One sometimes occurs over the interphalangeal joint of the same toe and over the metatarsophalangeal joints of the second and fifth and rarely of the third and fourth toes.

A sesamoid also occurs in the tendon of the peroneus longus, where it glides over the groove in the cuboid; another may be found, especially in later life, in the tendon of the tibialis anterior over the first cuneiform bone, and another in the tendon of the tibialis posterior over the medial surface of the head of the talus. Further a sesamoid, the *fabella*, sometimes occurs in the lateral head of the gastrocnemius (fig. 275), and another may be found in the tendon of the iliopsoas over the pubis.

Supernumerary bones of the foot have already been referred to; those most commonly observed are represented in figs. 301–303.

THE FOOT AS A WHOLE

Arches of the foot.—Although the foot is constructed on the same general plan as the hand, there is a marked difference in its architecture to qualify it for the

different functions which it is called upon to perform, standing and walking. When in the erect posture, the foot forms a firm basis of support for the rest of the body, and the bones are arranged in an elliptical arch, supported on two

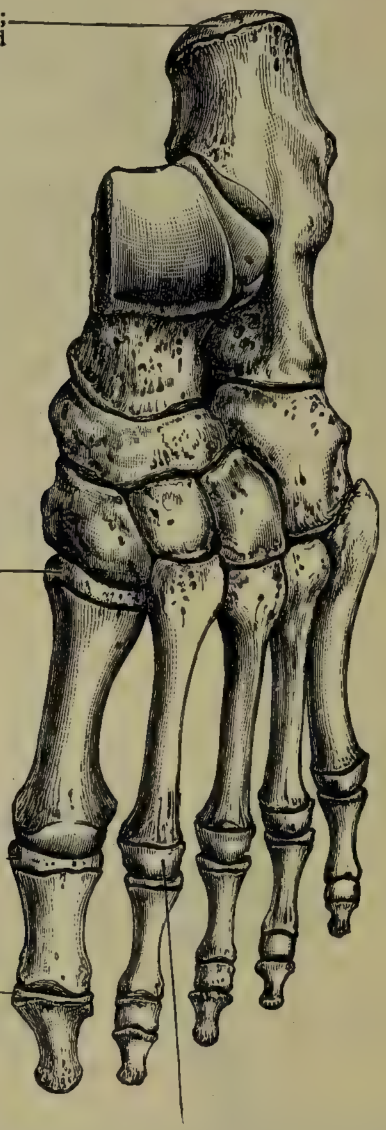


Fig. 300.—The Secondary Ossific Centers of the Foot.

Fig. 301.—Schema of Supernumerary Tarsal Bones. (Medial view.) (W. Pfitzner. From Rauber-Kopsch, Lehrbuch der Anatomie.)

1, Trigonum; 2, talus; 3, talus accessorius; 4, os sustentaculum; 5, calcaneus; 8, tibiale externum; 9, naviculare; 10, cuneiforme I plantare; 11, cuneiforme I dorsale.

pillars, a posterior or *calcaneal* pillar and an anterior or *metatarsal* pillar. The posterior pillar rests on the calcaneal tuberosity, the anterior on the heads of the metatarsal bones. It is convenient, however, to regard the anterior part of the

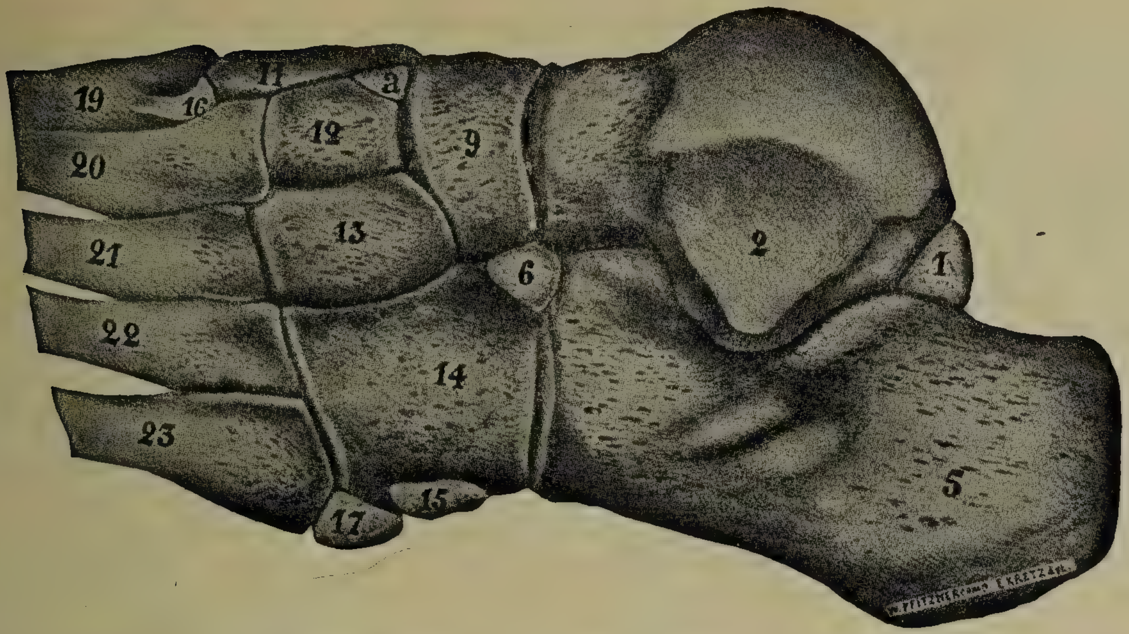


Fig. 302.—Schema of Supernumerary Tarsal Bones. (Lateral view.) (W. Pfitzner. From Rauber-Kopsch, Lehrbuch der Anatomie.)

1, Trigonum; 2, talus; 5, calcaneus; 6, calcaneus secondarius; 9, naviculare; 11, cuneiforme I dorsale; 12, cuneiforme II; 12a, intercuneiforme (Dwight); 13, cuneiforme III; 14, cuboides; 15, sesamum peronæum; 16, intermetatarseum; 17, os Vesalianum; 19–23, metatarsalia I–V.

Fig. 303.—Schema of Supernumerary Tarsal Bones. (Plantar view.) (W. Pfitzner From Rauber-Kopsch, Lehrbuch der Anatomie.)

5, Calcaneus; 7, cuboides secundarium; 8, tibiale externum; 9, naviculare; 10, cuneiforme I plantare; 12, cuneiforme II; 13*a*, intercuneiforme (Dwight); 13, cuneiforme III; 14, cuboides; 15, sesamum peronæum; 17, os Vesalianum; 18, pars peronæa metatarsalis I; 19–23, metatarsalia I–V.

arch as consisting of two segments, corresponding to the medial and lateral borders of the foot respectively. The medial segment is made up of the three metatarsal bones, the three cuneiform, the navicular, and talus; the lateral segment is made up of the fourth and fifth metatarsal bones, the cuboid, and the calcaneus, and both segments are supported behind on a common calcaneal pillar. The talus by its position, relations and mechanical functions is the keystone of the longitudinal arch. (Cf. figs. 299, 304.)

The division corresponds to a difference in function of the two *longitudinal arches*. Both are intimately concerned in ordinary locomotion. In addition, the medial, characterized by its great curvature and remarkable elasticity, sustains the more violent concussions in jumping and similar actions, whereas the lateral, less curved, more rigid, and less elastic arch forms, with the pillars in front and behind, a firm basis of support in the upright posture. The lateral longitudinal arch is the chief support in standing and walking in the anthropoid apes; the medial margin has been adapted to this function in man by the acquisition of the great toe, which has lost its opposibility and become almost rigidly fixed in the medial side of the foot.

Both arches are completed and maintained by strong ligaments and tendons, and sustained also by the action of both the intrinsic short muscles of the foot and by the dorsal long muscles of the leg. The weakest part is the joint between the talus and navicular bone, but this appears

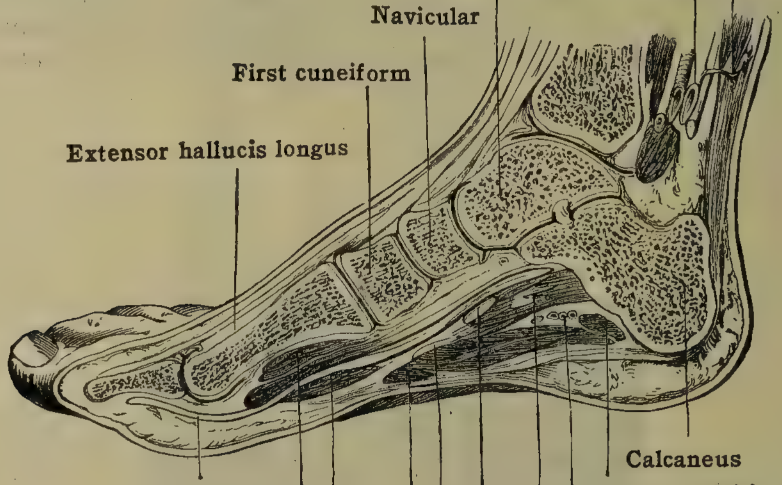


Fig. 304.—Longitudinal Section of the Foot. (× ⅓.) (Braune.)

to be strengthened by the plantar calcaneonavicular ligament, for the support of the head of the talus. This ligament is in turn supported by its union with the deltoid ligament of the ankle, and by the tendon of the tibialis posterior which passes beneath it to its insertion.

Besides being arched longitudinally, the foot presents a *transverse arch* formed by the metatarsal bones in front and the distal row of the tarsus behind (fig. 305). It is produced by an elevation of the central portion of the medial longitudinal arch above the ground, whereas the lateral longitudinal arch is much less raised, and at its anterior end becomes almost horizontal. The transverse arch is phylogenetically the older. Both the longitudinal and transverse arches serve the double purpose of increasing the strength and elasticity of the foot and of providing a hollow in which the muscles, nerves, and vessels of the sole may lie protected from pressure. For further consideration of the arches of the foot, see Section IV, Articulations.

Clinical Relations of the Foot

Bony landmarks.—The following are of great practical importance in operations on the foot.

(A) **Along the medial aspect of the foot.**—(1) Medial tubercle of the calcaneus; (2) medial malleolus; (3) 2.5 cm. (1 in.) below the malleolus, the sustentaculum tali; (4) about 2.5 cm. (in front of the medial malleolus, and a little lower, is the tuberosity of the navicular, the medial guide in Chopart's amputation; the gap between it and the sustentaculum being filled by the plantar calcaneonavicular ligament and the tendon of the tibialis posterior, in which there is often a sesamoid bone; (5) the first cuneiform; (6) the base of the first metatarsal; and (7) the head of the same bone, with its sesamoid bones below. (Holden).

(B) **Along the lateral aspect are:**—(1) The lateral tubercle of the calcaneus; (2) the lateral malleolus; (3) the trochlear process of the calcaneus (when present), 2.5 cm. (1 in.) below the malleolus, with the long peroneal tendon below it, and the short one above; (4) the projection

of the anterior end of the calcaneus, and the calcaneocuboid joint, midway between the tip of the lateral malleolus and the base of the fifth metatarsal bone; (5) the base of the fifth metatarsal bone; (6) the head of this bone.

Levels of joints and lines of operations.—The line of the ankle-joint is given at p. 372. That of the talocalcaneal joint—the limited lateral movements of the foot take place here and at the talocalcaneonavicular joint—corresponds, on the lateral side, to a point a little in front of the lateral malleolus and midway between it and the trochlear process; on the medial side, to one just above the sustentaculum tali. In **Syme's amputation** through the ankle-joint, the incision starts from the tip of the lateral malleolus, and is then carried, pointing a little backward toward the heel, across the sole to a point 1.2 cm. (½ in.) below the medial malleolus. The chief blood supply to the heel-flap is from the medial calcaneal. Care should be taken to divide the posterior tibial below its bifurcation and not to prick this vessel afterward.

In **Pirogoff's amputation** the incision begins and ends at the same points, but is carried straight across the sole. In each amputation the extremities of the above incision are joined by one going directly across the ankle-joint, which lies about 1.2 cm. (½ in.) above the tip of the medial malleolus.

In **Chopart's mediotarsal amputation,** which passes between the talus and the navicular on the medial side, and the calcaneus and the cuboid on the lateral, the line of the joints to be opened would be one drawn across the dorsum from a point just behind the tuberosity of the navicular to a point corresponding to the calcaneocuboid joint, just midway between the tip of the lateral malleolus and the base of the fifth metatarsal bone. The bifurcate ligament must be located and divided. The convexity of the plantar flap should reach to a point 2.5 cm. (1 in.)

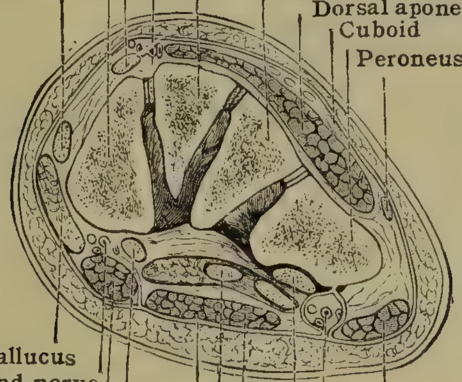


Fig. 305.—Vertical Section through the Cuneiform and Cuboid Bones. (× ½.)

behind the heads of the metatarsal bones. Owing to the tendency of the unbalanced action of the calf muscles to tilt up the calcaneus and thus throw the scar down into the line of pressure, the powerful tibialis anterior tendon and those of the extensors should be carefully stitched into the tissues of the sole flap.

In **Lisfranc's (Hey's)** or the **tarsometatarsal amputation,** the bases of the fifth and first metatarsals must be defined. The first of these can always be detected, even in a stout or swollen foot; on the medial side the joint between the first cuneiform and the first metatarsal bone lies 3.7 cm. (1½ in.) in front of the navicular tuberosity. In opening the joint between the second metatarsal and the middle cuneiform, its position (the base of the former bone projecting upward on to a level 6 or 8 mm. (¼ or ⅓ in.) above the others), and the way in which it is locked in between its fellows and the cuneiform bones, must be remembered. The convexity of the plantar flap here reaches the heads of the metatarsal bones.

These amputations are not employed as much as formerly. The introduction of the artificial limb has rendered them somewhat useless and unnecessary. They are of interest, however, in an anatomical and historical sense.

In marking out the flaps for the **amputation of the great toe,** the large size of the head of the first metatarsal, and the importance of leaving this so as not to diminish its supporting power and the treading width of the foot, and thus of marking out flaps sufficiently long and large, must be borne in mind. The dorsal incision should begin 3.7 cm. (1½ in.) above the web. The line of the joint is a little distal to the center of the ball of the toe (fig. 304). The sesamoid bones should be left, so as not to endanger the vitality of the flaps. In amputation of the other toes, the line of their metatarsophalangeal joints lies a full inch above the web.

Tarsal bones.—The chief surgical points about these are the frequency with which they are diseased and their changes in talipes. **Frequency of disease.**—This is explained, chiefly, by their delicate structure and the fact that on the aspect in which they are most exposed to injury the soft parts are scanty. Disease once started, often by slight injury, finds in the terminal circulation of the parts, and the frequent want of rest, other contributing causes. The numerous and complicated articular cavities mentioned above explain the extension of the disease. The calcaneus is the only bone in which mischief is likely to remain limited. The pres-

ence of an epiphysis on this bone appearing about the age of ten and joining at puberty is to be remembered as a starting-point of disease here. **Talipes.**—To take one instance, a case of talipes equinovarus, of congenital origin and confirmed degree, the following are the chief structural changes which should have been obviated and now have to be met, given briefly. *Calcaneus.*—This is elevated posteriorly, and rotated so that its long axis is directed obliquely medially. *Talus.*—The inclination of the neck medially is much increased, and the whole bone protruded from the ankle-joint. According to some, the neck is increased in length. *Navicular*—This is displaced medially so that it articulates with the medial side of the head of the talus and its tuberosity may form a facet on the medial malleolus. *Cuboid.*—The dorsal surface of this is displaced downward, and bears much of the pressure in walking. *Tendons.*—Those chiefly shortened are the tendo Achillis and those of the tibials and flexor digitorum longus. The tendo Achillis is displaced medially. *Ligaments.*—Those on the lateral side are stretched, those on the medial, especially the anterior part of the deltoid, the dorsal talonavicular and the plantar calcaneonavicular ligaments are shortened. The plantar fascia is also shortened, together with the abductor hallucis, which arises from it.

Homology of the Bones of the Extremities

That there is a general correspondence in the plan of construction of the two extremities is apparent to a superficial observer, and this becomes more marked when a detailed examination

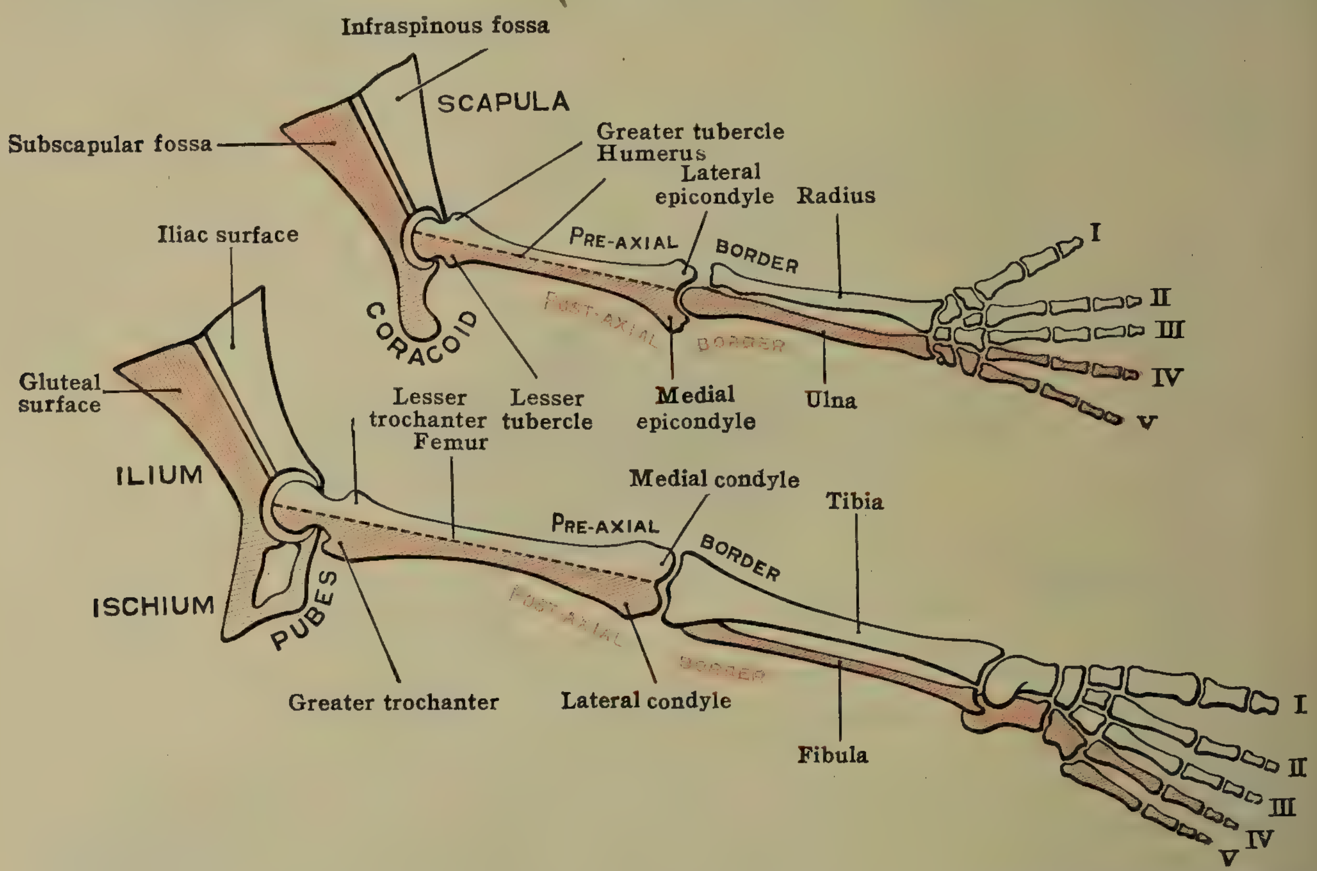


Fig. 306.—Diagrammatic Representation of the Bones of the Two Limbs, to Show Homologous Parts. (Modified from Flower.)

of the individual bones, their forms and relations, their embryonic and adult peculiarities, is systematically carried out. In each limb there are four segments, the shoulder girdle corresponding to the pelvic girdle, the arm to the thigh, the forearm to the leg, and the hand to the foot. These parts have been variously modified, in adaptation to the different functions of the two limbs, particularly in regard to the deviations or changes from what is considered as their primitive position, and as a knowledge of these changes is essential to a clear understanding of the homologies proposed, it will be advantageous to refer briefly to the relations of the limbs in the earliest stages of development.

The limbs first appear as flattened, bud-like outgrowths from the sides of the trunk. Each presents a *dorsal* or *extensor* surface, and a *ventral* or *flexor* surface, as well as two borders, an *anterior*, or *cephalic*, directed toward the head end of the embryo, and a *posterior* or *caudal*, directed toward the tail end. In reference to the axis of the limb itself, the borders have been called *preaxial* and *postaxial*, respectively. When, somewhat later, the various divisions of the limb make their appearance, it is seen that the greater tubercle, the lateral epicondyle, the radius, and the thumb lie on the preaxial border of the forelimb, and the lesser trochanter the medial condyle, the tibia, and the great toe on the preaxial border of the hind limb. Further, on the postaxial border of the forelimb are seen the lesser tubercle, the medial epicondyle, the ulna, and little finger, whilst on the corresponding border of the hind limb are the greater trochanter, the lateral condyle, the fibula, and the little toe. The parts enumerated on the corresponding borders of the two limbs have been regarded as serially homologous (fig. 306). The developmental flexures and rotation by which the limbs are shifted from their primitive embryonic to their adult positions have been mentioned (p. 20).

Furthermore, as shown in fig. 306, it is evident that the shoulder-girdle and the pelvic-girdle may be compared. The scapula may correspond to the ilium, and the coracoid process

to the ischium. The clavicle (corresponding to the reptilian precoracoid) may be the homolog of the pubis.

Bones of the hand and foot.—The carpus and tarsus, the metacarpus and metatarsus, and the various digits, commencing at the thumb, in the hand, and at the great toe, in the foot, are regarded as serially homologous. (Cf. terms recommended by the NK.)

In order to trace the correspondence between the various elements of the carpus and tarsus it is convenient to refer in the first place to a simple type of hand and foot as found in the water-tortoise and the lizard (fig. 307). In each segment nine elements may be recognized, arranged in a proximal row of three, named respectively *radiale* or *tibiale, intermedium,* and *ulnare,* or *fibulare,* a distal row of five *carpalia,* or *tarsalia,* numbered from one to five, commencing at the preaxial border, and between the two rows an *os centrale.*

In man the carpus may be compared with the simple type in the following manner: The radiale forms the navicular, intermedium the lunate, and ulnare, the triquetral; carpale I forms the greater multangular, carpale II the lesser multangular, carpale III the capitate, while carpalia IV and V coalesce to form the hamate. The os centrale is present in the human carpus at an early stage, but in the second month it joins the navicular. It is occasionally separate—a normal arrangement in most of the primates.

In the tarsus, the tibiale and intermedium coalesce to form the talus, and the fibulare becomes the calcaneus. It is interesting to note that although in the human subject there are three bones in the first row of the carpus and two in the first row of the tarsus, in carnivores the navicular and lunate are united to form a naviculo-lunate bone—the homologue of the talus. In the human tarsus the intermedium occasionally remains distinct as the *os trigonum.*

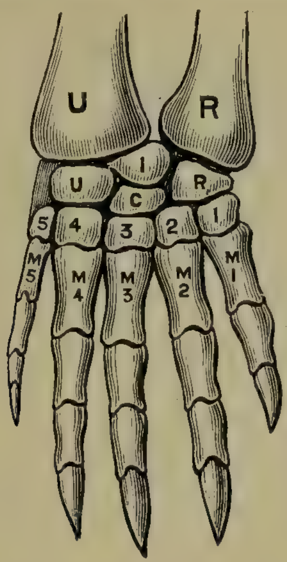


Fig. 307.—Dorsal Surface of the Right Manus of a Water-tortoise, *Chelydra serpentina.* (After Gegenbaur.)

Tarsale I forms the first cuneiform, tarsale II the second cuneiform, tarsale III the third cuneiform, and tarsale IV and V are joined to form the cuboid. The os centrale forms the navicular.

In addition to the carpal and tarsal elements enumerated above, brief mention must now be made of the sesamoid bones of the two segments, which are regarded by many anatomists as vestiges of the skeleton of suppressed digits. In the hand are the **ulnar** and **radial sesamoids,** the ulnar being represented by the pisiform and the radial probably by the tuberosity of the navicular. In the mole and other allied species with fossorial habits, the radial sesamoid is greatly developed to form a sickle-shaped bone which has received the name of *os falciforme.*

The corresponding structures in the foot are the **tibial** and **fibular sesamoids,** the tibial being most nearly represented by the tuberosity of the navicular and the fibular by the tuber of the calcaneus.

References.—For the *development* of the skeleton, consult the bibliography in Bardeen's article in Keibel and Mall's 'Human Embryology,' Vol. 1; for *ossification,* Mall, Am. Jour. of Anat., v. V, 1906; Pryor, Bull. State College, Kentucky, 1906 and 1908; Macewen, Growth of Bone, 1912. For further references concerning the *adult structure* and *morphology* of the skeleton, the sections on osteology in the larger works on human anatomy by Quain, Poirier-Charpy, von Bardeleben, etc., should be consulted. For *variation* (axial skeleton) LeDouble, 1903, 1906, 1912. On *anthropology,* Hrdlicka (*anthropometry*), 1920; Martin's Lehrbuch, 1929. For *Age Changes,* Todd, Am. Jour. Phys. Anthrop. v. 4, 1921. *Cranium,* Macklin, Am. Jour. Anat. v. 16, 1914; Noordenbos, in Petrus Camper, 1905; Shaeffer, Nose and Accessory Sinuses, 1920. References to the most recent literature may be found chiefly in the Anatomischer Anzeiger; Anatomischer Bericht; Biological Abstracts; Jour. Roy. Micros. Soc.; Quarterly Cumulative Index; Bibliographic cards of the Wistar Institute of Anatomy.

SECTION IV

THE ARTICULATIONS

BY ROBERT J. TERRY, A.B., M.D.

PROFESSOR OF ANATOMY IN WASHINGTON UNIVERSITY

THE parts of the skeleton described in the preceding section are bound together in special ways in the formation of the natural framework of the body. The intrinsic binding elements in these articulations are fibrous bands and capsules, cartilage and even bone itself. Support to these proper structures of the joint is given by certain extrinsic factors such as the integuments and fasciae, and especially by the tendons and muscles that cross a joint and which are often closely connected with the ligaments. The stability of articulations is still further secured by atmospheric pressure.

Structure of joints.—The study of the articulations, **arthrology,**[1] has shown the existence of two kinds, which structurally are quite different, one exhibiting unbroken binding substance between the skeletal parts, the other presenting a joint cavity within the binding substance and between the ends of the skeletal

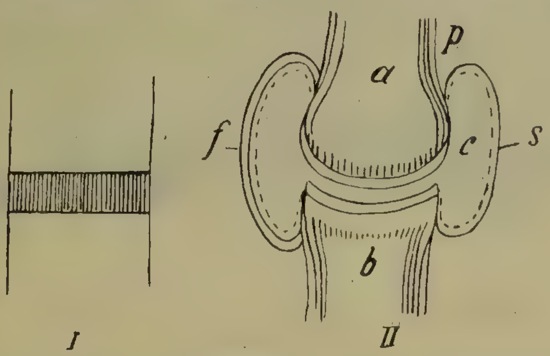


FIG. 308.—DIAGRAM OF JOINT STRUCTURE. I. SYNARTHROSIS. II. DIARTHROSIS. *a* and *b*, articular ends of two bones with articular cartilages; *p*, periosteum; *s*, synovial layer, and *f*, fibrous layer of the articular capsule; *c*, articular cavity. (Rauber-Kopsch, Lehrbuch der Anatomie.)

elements entering into this sort of articulation. The name **synarthrosis** has been given to the class of joints characterized by continuous union, **diarthrosis** (articulus NK) to the class distinguished by the presence of a joint cavity (fig. 308).

The simple synarthrodial joint is the more primitive considered both from the standpoint of development in the individual and from that of the distribution of kinds of joints in the vertebrate series. Diarthrodial joints reach their ultimate structural characteristics by developmental processes and by transformation from the original synarthrodial type of the embryo, and in the range of animals it is the synarthrosis that prevails in the lower forms, whereas the diarthrosis appears in ascending the series (see Section on Growth and Development).

I. SYNARTHROSIS

Synarthrosis consists of the union of skeletal elements by continuous intervening substance, it may be cartilage, fibrous tissue or bone. Several varieties of the class are recognized.

[1] Arthrology. Syndesmologia, the term adopted by the BNA for the heading of the section on joints, means the study of ligaments, and in the literal sense is a far less comprehensive term than arthrology which includes the consideration of all joint structures (and functions). Furthermore there are many diverse structures in the body named ligaments (lig. inguinale, lig. umbilicale laterale, lig. hepatogastricum, lig. vocale, lig. teres uteri, lig. denticulatum, etc., etc.) which are excluded from the category of syndesmologia. The usage of the term has age to recommend its continuance (Hippocrates, Aristotle, Galen), but it is lacking in the present day definition of what joint study involves. In the NK revision, the term *juncturæ ossium* is substituted.

(a) **Synchondrosis** (fig. 308(I)), the simplest form and the most primitive embryologically, is characterized by the union of the bones through intervening cartilage. This may be hyalin or fibrocartilage. Synchondroses involving hyalin cartilage are generally transitory joints, disappearing through replacement of the cartilage by bone (synostosis) whereby the originally separate skeletal elements of the joint are immovably united and only traces of the juncture are visible.

Examples of synchondrosis are the **epiphysial unions** [synchondrosis epiphyseos] (fig. 343) which go over into synostosis at definite ages, mostly under twenty two years, and those of the base of the skull, e.g., synchondrosis sphenoccipitalis, which persists until about the twentieth year before bony union intervenes. Other examples of synchondroses involving a hyalin cartilaginous bond are found in the Y-shaped joint in the acetabulum between the separate ilium, ischium and pubis of the young hip-bone; between the coracoid process and body of the scapula in the immature scapula. In all of these examples the cartilage uniting the parts is a vestige of and a derivative by proliferation of the original cartilaginous skeleton. This is true for all synchondroses.

The binding element in certain synchondroses is a disk of fibrocartilage which in its development has been differentiated from an original basis of hyalin cartilage. Examples of this variety of synchondrosis are the articulations between the bodies of vertebræ by means of the intervertebral fibrocartilages (fig. 319), the symphysis pubis and the symphysis sacrococcygea. Fibrocartilaginous synchondroses between the separate bodies of the immature sacrum are transformed normally into synostoses, thereby giving the single-piece bone of the adult.

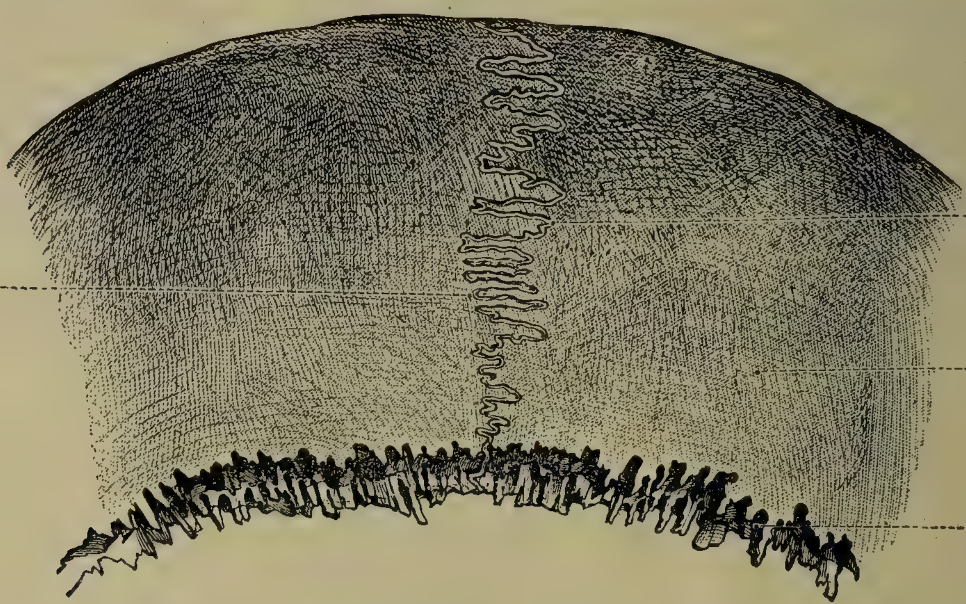


Fig. 309.—Serrated or Dentated Suture. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

In the fibrocartilaginous disk of the symphysis pubis a small cavity is constantly found. This has been taken as indication of a progressive development in this joint toward diarthrosis and the name *amphiarthrosis*[1] has sometimes been used to designate the structural state of the symphysis pubis as intermediate between true synarthrosis and diarthrosis (fig. 360).

(b) **Sutura.**—The variety of synarthrosis named **suture** is characterized by the presence of a thin layer of fibrous tissue uniting the apposed skeletal parts, which are generally the edges of flat bones or plates of bone. The appearance of most such articulations is seam-like; in distribution sutures are limited to the skull. In the case of the tabular bones, which are formed in membrane, the binding fibrous tissue layer is regarded as a derivative of this membrane.

At the time of birth most sutures are imperfectly formed, farther advanced in the face than in the cerebral cranium where, especially at the vertex and sides, the intervening membrane is extensive and the edges and angles of the tabular bones are separated by considerable intervals (the fontanelles). With the progress of ossification and growth the spaces are diminished, the edges of the bones are brought into very close approximation and the peculiar characteristic modifications of the bony margins appear which function in the locking and stability of the completed suture. As in the case of many of the synchondroses where the normal progress is toward eventual bony union, so also is the tendency present for the sutures to go over into synostosis. Some sutures are obliterated in infancy and early childhood, others do not begin to close until middle life, a few may remain open in old age.

[1] Amphiarthrosis. The term as used above connotes structure; the commonly accepted meaning is that of implying restricted motion. The diarthroses in which movement is slight are termed amphiarthroses.

The form of the apposed edges of the bones entering into sutures presents constant characteristics and on this basis varieties of suture have been distinguished. To those articulations in which the margins develop saw-toothed interlocking processes, the name **serrate suture** [sutura serrata] has been given (fig. 309). The processes may be simple irregular juttings of the edge, or elaborately branched extensions which are involved in complicated patterns of seam formation (sagittal and lambdoid sutures). The term **squamous suture** [sutura squamosa] (fig. 310) is applied to a synarthrodial joint in which the bevelled, sharp edge of one bone overlaps and is united to the reciprocally bevelled edge of a subjacent bone (squamoparietal suture). In **harmonic suture** [sutura harmonia] (fig. 136) the even, regular edges of the apposing bones are brought into union by the fibrous tissue layer (lacrimoethmoidal suture). The union of the roots of the teeth with the walls of the dental alveoli is recognized as a form of suture to which the name *gomphosis* is given.

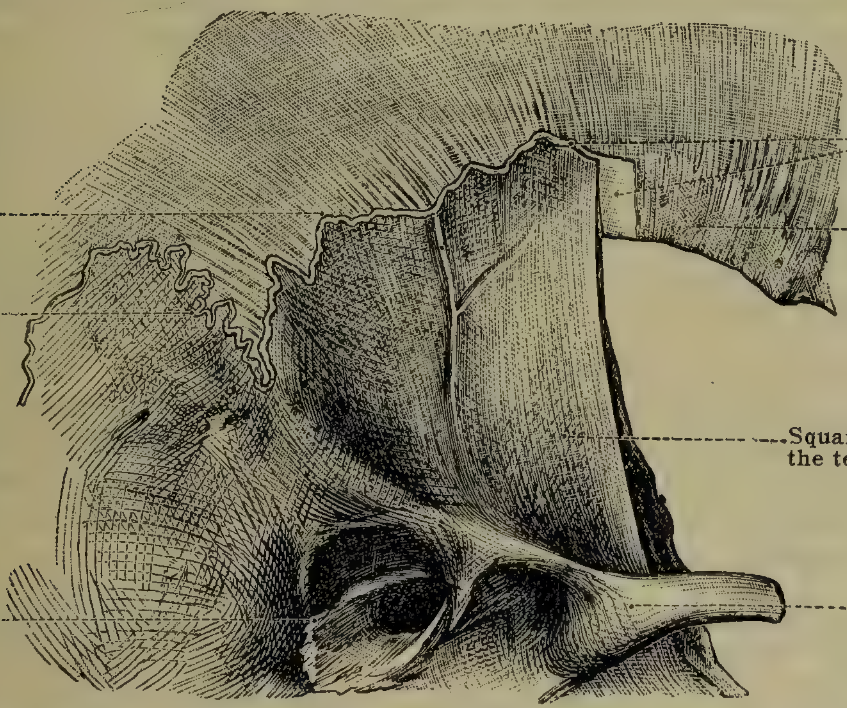


FIG. 310.—SQUAMOUS SUTURE. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

(c) **Syndesmosis** (fig. 337).—In this form of synarthrosis, the skeletal parts, close together or far apart, are united by bands of white fibrous or yellow elastic tissue. The distinctive feature of this synarthrosis is the form differentiation of the binding substance in the shape of **ligaments.**

Whereas the typical form of the ligament is strap-shaped or cord-like, composed of parallel bundles of fibers, a considerable range of forms exists in the articular structures to which the term ligament has been applied. Among the syndesmoses the stylohyoid ligament (fig. 317) exemplifies the cord-form, the coracoacromial ligament is band-formed, the costoclavicular ligament (fig. 336) is flattened and rhomboid in outline, the forms of the parts of the coracoclavicular ligament (fig. 337) are expressed in their names, conoid and trapezoid, the antibrachial interosseous membrane is a broad fibrous sheet. All of these are examples of union by white fibrous tissue. Union by yellow elastic tissue bands is of less frequent occurrence, the principal representatives of this variety being the yellow ligaments connecting the arches of the vertebræ (fig. 326).

Although the distinction between white fibrous and elastic ligaments is justified it must be remembered that delicate elastic fibers are present in the white fibrous bands.

As to the genesis of the bands present in the syndesmosis our knowledge is very incomplete. There is evidence that some of them represent metamorphosed muscle tendons and fasciæ, and vestiges of the primordial skeleton; others are developed in situ from the preexisting mesenchyma. The tendency to give way to synostosis is not normal in syndesmosis, as it is in many synchondroses and sutures.

II. DIARTHROSIS

The characteristic structural feature of the class of articulations called diarthroses has already been pointed out, viz., the presence of an articular cavity within the capsule of the joint and separating the bony elements (fig. 308). The joints of this class are more highly organized than synarthroses by the added number and complexity of parts. There are in the class, variations in form and degree of differentiation that make necessary further division into sub-

classes. It is in order, therefore, first to define and describe the several structures composing the diarthrosis.

The **articular surface** [facies articularis] (fig. 343). In the section on Osteology descriptions of the articular surfaces of the bones have been given and it is necessary at this point only to recall the essential features of these parts which enter into the formation of diarthrodial joints. The articular surface is smooth in adaptation to its coating of articular cartilage, and it is conformed in relation to other contiguous skeletal parts and articular structures. It is generally sharply limited at its periphery toward the adjacent non-articular part of the bone. In this region a groove, slight or deep, may be present affording attachment to the articular capsule. Articular surfaces are formed on compact bone overlying spongy tissue which in the articular parts of bones is abundant.

The **articular cartilage** [cartilago articularis] (fig. 340) covers the articular surface and presents a free smooth glistening surface toward the articular cavity, which comes into contact with the free surface of the opposite articular cartilage. The attached surface of the articular cartilage is firmly adherent to the whole articular surface of the bone.

Generally the cartilage is hyalin, but in certain joints white fibrocartilage replaces it wholly or in part. The posterior part of the mandibular fossa is covered by white fibrous tissue. It has been observed that the part of the articular cartilage next the bone is calcified.

The articular cartilages vary in thickness in different joints and the thickness of a given cartilage varies in its different regions; the range seems to be from 0.5 mm. to 6 mm. Flexibility and elasticity are properties of articular cartilages and it has been shown that they are under tension in definite directions.

The **articular capsule** [capsula articularis] (fig. 340). In its simplest form the articular capsule is a sack-like envelope for the diarthrosis, attaching itself to both bones usually near the periphery of the articular surfaces, closing the articular cavity within. It may be ample or restricted in size, usually pliant and often strengthened by accessory bands. Its wall consists of two layers, an outer **fibrous layer** and an inner **synovial layer.**

The **fibrous layer** [stratum fibrosum] (fig. 308) is composed of white fibrous tissue with which elastic elements are intermixed. The greater number of fibers have a parallel arrangement, generally in the axis of the bones that are joined. The attachment of the fibrous layer to the bone is through the intermediation of the periosteum with which the capsule blends. The attachment may be linear at the level of the edge of the articular surface, in a groove, or it may be broad and spread over the surface of bone adjacent to the articular surface, or the level of the connection with the bone may be removed some distance from the articular surface.

The fibrous capsule commonly shows variations in thickness and consequently in strength in different places; openings are present in certain joints admitting the entrance of a tendon or giving communication with a neighboring bursa.

The fibrous layer of the capsule is in many instances strengthened by accessions of fiber bundles in definite regions, as for example, the iliofemoral ligament of the articular capsule of the hip-joint (fig. 364). The capsule is strengthened and supported in a number of joints by the incorporation of the tendons of muscles (shoulder joint).

The **synovial layer** [stratum synoviale] (fig. 308) is present in all diarthroses, as the deeper stratum of the articular capsule, its free surface looking into the articular cavity. It is composed of loose connective tissue with elastic fibers and fat in varying amount. The free surface is smooth, but often presents **folds** [plicæ synoviales], some of large size containing fat (alar folds of the knee-joint, fig. 379), or providing for the course of vessels; in places the surface shows slender projections, **synovial villi** [villi synoviales] which may give the velvety appearance suggestive of the inner surface of the small intestine. Villi commonly occur in the regions of attachment of the capsule. The stratum synoviale is co-extensive with the stratum fibrosum, and is always limited at the free margins of the articular cartilages, never extending upon them in the fully developed diarthrosis. In those joints in which the attachment of the capsule is displaced away from the margin of the articular cartilage, the synovial layer is reflected from the line of attachment and covers the interval up to the articular cartilage. Extensions of the synovial layer beyond the fibrous layer of the capsule, occur not only as folds but frequently as pouches into which the articular cavity is expanded.

The **articular cavity** [cavum articulare] (fig. 350) is the capillary space enclosed by the synovial layer and articular cartilages. It is occupied by the synovial fluid. On opening a complicated diarthrosis such as the knee-joint, the articular cavity appears to be of greater capacity than is shown in frozen sections, resulting from the falling away of the articular capsule and displacement of synovial folds, which in the intact joint are closely pressed against the articular ends of the bones and into interstices resulting from incongruent articular surfaces and the presence of interarticular structures. In many joints the cavity stands in communication with the cavities of bursae associated with tendons.

The **synovial fluid** [synovia] is a watery fluid, clear, somewhat stringy, containing salts, mucin, albumin, fat droplets and cellular detritus, probably derived by rubbing, from the articular cartilages and synovial layer. The origin of synovia is as yet unknown.

In many diarthroses structures are found which are to some extent independent of the capsule and articular cartilages but in their development, structural relations and function are to be regarded as parts of the articulation: ligaments, interarticular disks and crescents, glenoid lips, bursae and sesamoid bones.

Extra-articular ligaments quite distinct from the capsule are present in many diarthroses (fibular collateral ligament of the knee, sphenomandibular ligament) (figs. 315, 373); they are of diverse origins and vary in functional significance, some essential to the mechanism of the joint, others of no apparent use. Many instances of **intra-articular ligaments** occur (cruciate ligaments of the knee, interosseous ligaments of the carpus and tarsus) (figs. 350, 380), apparently within the capsule, but always excluded from the joint cavity by reflexions of the synovial layer. **Articular disks** [disci articulares] and **articular crescents** [menisci articulares] composed of dense fibrous tissue or of fibrocartilage enter into the structure of certain diarthroses (discus articularis of the mandibular joint fig. 316; menisci of the knee-joint fig. 377). They are attached by their margins to the articular capsule and in certain instances to the articular surface of the bone, extend into the joint between the bones and have their free surfaces covered by reflexions of the synovial layer from the capsule. An inter-articular disk may completely subdivide the joint cavity into two separate spaces, and the two additional articular surfaces thus given have important functions in the mechanism of the articulation. The meniscus is a three sided prism bent into a crescent, attached by its convex border to the articular capsule, the two other sides in contact with the apposing bones in the joint. The presence of the meniscus contributes a raised margin to an otherwise flat or shallow articular surface. Being movable, it differs from the **glenoid lip** [labrum glenoidale] (fig. 368) which, also composed of dense fibrous tissue (some cartilage cells), is firmly fixed in the form of a ring to the margins of the articular surface of certain joints. The two free surfaces meeting in an acute angle are covered with the synovial layer.

The form of articular surfaces.—The surfaces and edges of the bones entering into a synarthrosis are occupied by the attachment of the binding element to which their contours are chiefly adapted; movement in this class of joints is nearly excluded or slight and adaptation of the bone to mobility is correspondingly low. In the diarthroses, however, in which movement is generally freely permitted, the bony surfaces engaged in the joint are obviously specially adapted to contribute to the freedom of movement and to the perfection of definite kinds of movement.

The skeletal elements entering into a diarthrosis may be two in number and such a joint is known as a **simple articulation** [articulatio simplex] (fig. 368), or there may be more than two bones involved, constituting the **compound articulation** [articulatio composita] (fig. 350). In attempting to classify diarthrodial joints all the articular surfaces in the combination of bones must be considered.

Articular surfaces are generally curved, and can be described as parts of the surfaces of spheres, ovals, cones, cylinders and of combinations of these forms. If the radius of the curve is long enough the articular surface appears flat and on this basis it is customary to recognize flat articular surfaces. Two or more apposing surfaces may differ in form or present curves of unequal radii resulting in imperfect fitting; this condition is described by the term **incongruity** (fig. 336). Joints are **congruent** where the surfaces respond in form and curvature (fig. 371). One of the functions of synovial folds, articular disks and menisci is to diminish or correct incoegruity.

Kinds of diarthroses.—Employing as the basis of classification the forms of articular surfaces encountered, the kinds of diarthroses recognized are the following: (a) **Spheroidal articulation** [articulatio spheroidea] (fig. 350), a rounded head received in a concave surface (e.g., metacarpophalangeal joints of the fingers); **enarthrosis** is a special form of spheroidal articulation where the head is locked within a socket comprising more than a hemisphere (e.g., head of femur in the acetabulum and glenoid lip); (b) **hinge-joint** [ginglymus] (fig. 355), a convex cylindrical surface, grooved at right angles to the axis of the cylinder (trochlea), meeting a concave cylindrical surface, ridged to fit the trochlea (e.g., interphalangeal joints); (c) **screw-joint** [articulatio cochlearis], hinge-joint in which the groove of the trochlea is in a plane not at right angles with the axis, and the hinge movement is consequently accompanied by progression at right angles to the hinge plane (e.g. atlantoepistropheal joint (fig. 318)); (d) **ellipsoidal joint** [articulatio ellipsoidea] (fig. 350), articular surfaces ellipsoidal, a convex surface received in a concave surface (e.g., radiocarpal articulation); (e) **trochoidal**

joint [articulatio trochoidea] (fig. 347), the articular surface of one bone is the edge of a disk gliding in a corresponding concave articular surface of the other bone (e.g., superior and inferior radioulnar articulations); (f) **saddle-joint** [articulatio sellaris]; in one bone the articular surface is concave in one direction and convex in a direction at right angles to the first: the surfaces of the other bone reciprocally convex and concave (e.g. metacarpophalangeal joint of the thumb) (fig. 311); (g) **irregular joint,** surfaces irregular, flat or slightly curved, small (e.g., some of the intercarpal and intertarsal joints).

Vascular and nerve supply of articulations. Neither nerves nor blood-vessels have been found in cartilage. Articular vessels approach closely the margins of the articular cartilages and the diaphyseal surface of the epiphyseal cartilage. Articular disks and menisci receive vessels and nerves at their margins and are penetrated for short distances by them in a sparse distribution. Ligaments and articular capsules are well supplied by nerves and blood-vessels (fig. 575). Branches of arteries contribute **networks** (retia articularia) specially rich about the capsules of diarthroses supplying the fibrous layer and sending branches to the synovial stratum and to the ends of the bones. The synovial layer is furnished with rich networks of fine vessels. Articular veins drain the structures supplied by the articular arteries (fig. 619). Lymph vessels form networks in the articular capsules. Nerves to the ligaments, especially abundant in articular capsules, are generally recorded ending in Pacinian corpuscles, the distribution in the synovial layer being extensive. These nerves are in part vasomotor, but chiefly proprioceptive fibers of afferent elements. It has been observed that the trunk of a nerve, sending branches to a given muscle, supplies branches to the joint moved by the muscle and to the area of skin over the insertion of the muscle (Hilton's law).

Fig. 311.—Saddle-joint (Carpometacarpal Joint of the Thumb). (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

Mechanics of Joints

Contour of the bones.—Of the structural differences between synarthrosis and diarthrosis, the contour of the parts of the bones concerned in the joint presents in each class characteristics peculiar to it.

Synarthrosis.—As already mentioned the skeletal parts brought into these joints are occupied by the binding elements and are adapted to their firm fixation. Hence one finds uneven areas, eminences and depressions of various forms affording attachment to cartilages and bands of fibrous or elastic tissue. Among the recognized forms of the contour at the sites of synarthrodial union are spines, ridges, margins, tubercles, rough areas, elevated or depressed, sometimes fossæ or grooves.

Diarthrosis.—In contrast to the uneven contour of the bones in synarthroses are the smooth articular surfaces (facies articulares) of diarthroses. Instead of serving for the attachment of the binding elements they are occupied by articular cartilages, acting as cushions and rubbing surfaces for the ends of the apposed bones. The forms of the articular surfaces vary and are adapted to the special functions of the different articulations.

Analysis of these articular surfaces has shown that there exists in nature the geometrical shapes familiar in the science of mechanics (see above). It should be explained that the bony articular surface perhaps never exemplifies the perfect geometrical figure, but the discrepancy is compensated for in the movements of the joint by the articular cartilage, in part by its coating and in part by its compressibility and elasticity.

Agents operating in the union of the bony elements.—Ligaments and cartilages are sufficient to bind bones together. The ligaments in some of the diarthroses are tightened in certain contact positions of the joint surfaces, relaxed in other states of the joint, an indication that other factors are in operation to hold the bones together.

One of these factors is the *pull of muscles* in tonic contraction, operating across the joint, and of great influence, the strong tug of muscles in active contraction, tending to draw the joint surfaces together, by direct traction or by pressure of tendons upon the articular ends of bones. The *skin, subcutaneous tissue and fascia* must be included among the more obvious agents in helping to retain joint surfaces in relation, especially so for the joints of the limbs. Also the *pressure exerted by superimposed weight*, as in the case of the head resting on the neck compressing the occipital condyles upon the superior articular surfaces of the atlas, and in the ankle joint where the weight of the body drives the tibiæ upon the tali. On the other hand the weight of the hanging arm must react unfavorably to the maintenance of apposition of humeral head and scapula; in this case the support given by the shoulder muscles crossing the joint is obvious.

Less apparent in their effects in holding bony surfaces together, but yet of much importance, are *adhesion and atmospheric pressure.* The resistance to separation of two smooth moist surfaces placed in apposition is familiar and the principle finds its application in mechanics. This resistance, as is well known, is less when the surfaces are slipped from one another than it is when the attempt is made to separate them in a direction at right angles to the surfaces. The smooth, moist surfaces of the articular cartilages in congruent joints offer the conditions necessary for the operation of adhesive force, and if it is considered that through the presence of articular cartilages and synovial folds all diarthroses have congruent surfaces, adhesion is operative in all of them.

The classical experiment of the Weber brothers (1838) drew attention to the influence of atmospheric pressure in maintaining the apposition of bones in a diarthrodial joint. After severing all the muscles and other soft structures which connect the thigh with the trunk and girdling the articular capsule of the hip joint through to the neck of the femur, dislocation did not occur in the upright body even with the full weight of the limb dragging upon the femoral head in the acetabulum. When, by drilling a small hole through the bottom of the acetabulum from within the pelvis, air was admitted, the head of the femur at once dropped away from the socket.

In regard to friction produced in the rubbing of articular surfaces, apparently this reaction is exceedingly slight. The mirror-smooth surfaces of the articular cartilages, kept moistened by synovia tends to reduce friction to zero.

Mechanical properties of joint surfaces. Bone.—The physical attributes of strength and elasticity of bone have been briefly considered in the Section on Osteology. It will be recalled that following the differences in function of the bony contours concerned in synostoses and diarthroses, those of the former will be subjected in general to traction, pull, whereas the articular surfaces of diarthroses will be under the influence of pressure and rubbing; in the immediate region of articular surfaces, where capsular ligament and accessory bands are attached, the bone is also subjected to pull.

Cartilage.—Cartilage, under the influence of pressure, pull, shoving and torsion, by its elasticity reacts like a piece of rubber, undergoing changes in shape during joint activity and returning to its original form in the quiescent state. Although cartilage is weaker, less resistant than bone, it is nevertheless admirably adapted to perform its functions in the joint and to sustain its integrity under all normal stresses and strains.

Ligaments.—H. von Meyer found the iliofemoral ligament to withstand a resistance of five times the weight of the trunk. Henry Bigelow stated, concerning this same accessory band of the hip-joint:—"this ligament required for its rupture the attachment of weights—varying in the several cases from two hundred and fifty to seven hundred and fifty pounds." A slight amount of elasticity is offered by the white fibrous ligaments, varying with age and, it has been claimed, with sex, the elasticity being less in the aged and in the female.

Movements

The study of the movements permitted by joints has been naturally divided into the consideration of (a) the movements at the joint and between its parts; (b) movements of parts of the body upon one another.

Movements at the joint.—One finds in descriptions of joints the statement often made that the synarthroses are immovable joints, the diarthroses joints permitting free movement. This statement is far from accurate, for some synarthroses allow a considerable range of movement (syndesmosis stylohyoidea), most of them permit some motion; and a few are fixed. In many diarthroses the range of movement is extremely limited (some of the carpometacarpal joints, the superior tibiofibular articulation). The kind of movement is generally less easily defined in synarthroses than in diarthroses, chiefly because of the absence of fitting articular surfaces.

Synarthroses. Slight movements are permitted in synchondroses because of the elastic nature of the cartilaginous bond between the bones. The epiphysis, united to the body of the bone, is in certain joints subjected to the pressure of superimposed weight (epiphyses of tibia) which may be lessened or augmented by changes in posture or by impact (jumping), resulting in slight movements of the epiphysis as the cartilage is compressed or relieved of pressure. Many epiphyses give attachment to the tendons of muscles and are subjected to strain by muscle pull. In the rough treatment sustained by the joints in childhood (learning to walk) and in youth (sports), the epiphyses must inevitably undergo slight movements. The chief functions of epiphyseal cartilages seem to be in the provision for growth and in serving as cushions or buffers, but that they function as joint elements is quite evident. With the replacement of the cartilage by bone and the completion of synostosis movement ceases to be possible.

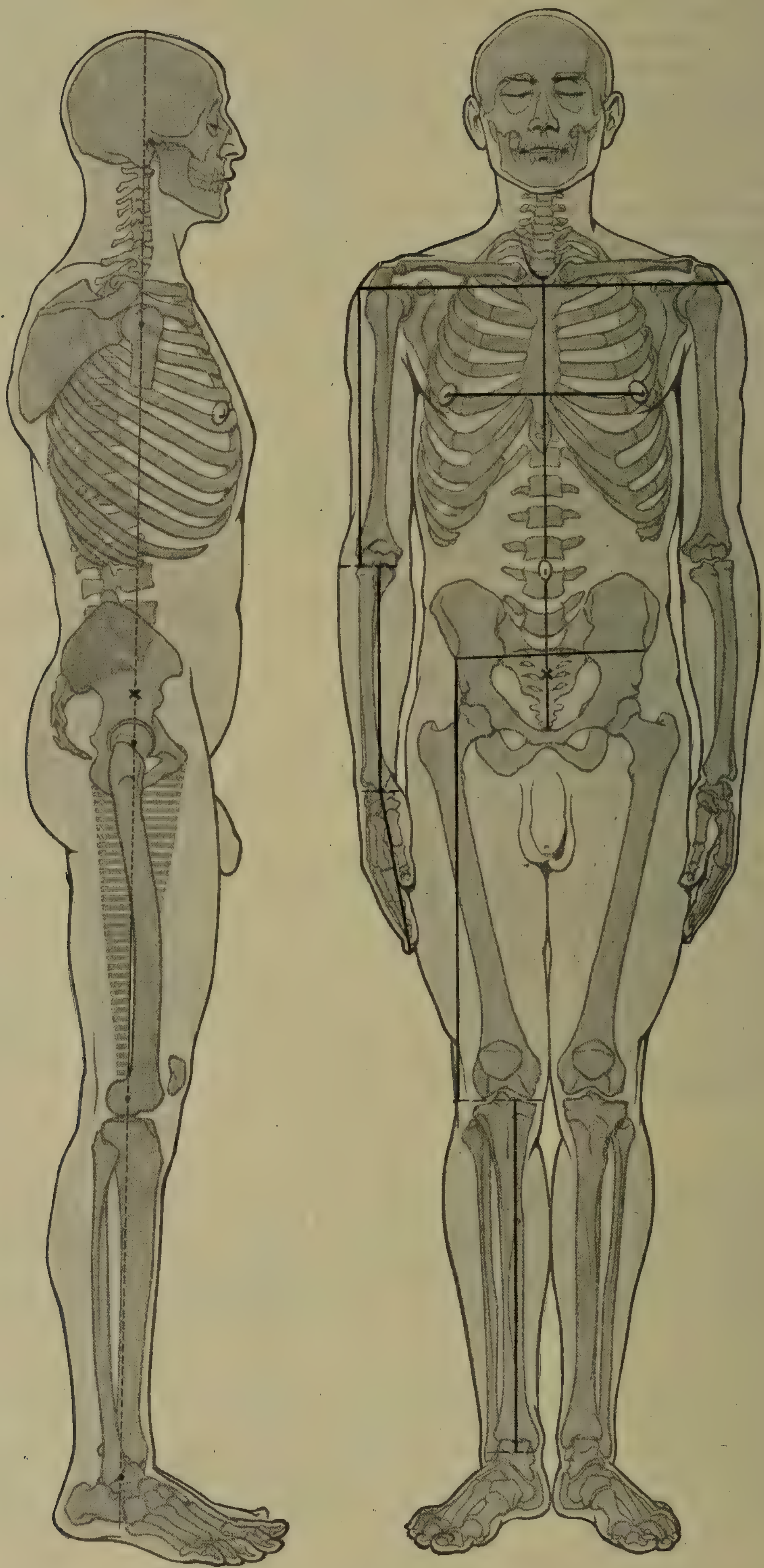


FIG. 312.—VIEW OF A STRONG MAN WITH THE SKELETON DRAWN IN (A) FROM THE SIDE; (B) FROM IN FRONT. (Braus.)

In fig. A, the center of gravity of the body (x) and the vertical for the normal posture are shown (according to Braune and Fischer). The triangular shaded area corresponds to the adductor mass of the thigh. In fig. B, osteometric points are indicated (See Martin, Lehrbuch der Anthropologie). Pelvis and thorax show normal asymmetry. x, center of gravity.

Whereas movement in the sutures is denied, it must be remembered that the jagged edges of the bones are not actually in contact, but are separated by membrane, very slight in the adult it is true. In the unperfected sutures of the newborn very considerable movement can take place, and during birth displacement of the bones by marginal overlapping is essential to successful passage of the head (figs. 194, 195). It has been maintained that the presence of the intervening membrane of the suture serves to break the shock received at a place away from the suture and to lessen the force transmitted to adjacent bones. There is some implication here of movement of the bone first subjected to the impact. Syndesmosis permits movements in various directions, generally slight if the ligament is short, free when the band is long. The ligamenta flava react like rubber bands, permitting separation and approximation of the vertebral arches.

Diarthroses.—Movement at the diarthrodial joint is generally more definite and constant in kind and usually more free than that permitted in synarthroses. The following kinds have been recognized as taking place between articular surfaces: (1) gliding or slipping, (2) rolling, (3) mixed gliding and rolling, (4) rotatory, (5) mixed gliding, rolling and rotatory movement.

In gliding movements different points of congruent articular surfaces come into contact during the action of the joint. The movement may take place in straight lines, or be in the form of rotation between apposed flat surfaces, or in a curved path over spherical, cylindrical or other form of curved articular surface. Another form of gliding or slipping occurs when the margin of a wheel-form articular surface turning on a fixed axis, slips upon the concave articular surface receiving it (superior radioulnar joint), or the reciprocal of this relation of curved surfaces (inferior radioulnar joint). Rolling is illustrated by the relation to the road of the tire of a wheel of a moving motor car, which presents a new point of contact to a new point in the road as the car progresses. The pure wheel movement is not encountered in organic joints, but is combined with gliding, resulting in the third type. The most familiar example of mixed rolling and gliding is in the path taken by the femoral condyles rolling and at the same time slipping upon the superior articular surface of the tibia in bending and straightening the knee. Pure rotatory movement, which demands that a circular movement take place between two surfaces at only one point of contact, is never found in the animal body. The contact site is a spot or surface on each apposed bone resulting from the compression of the curved surfaces of the articular cartilages. The term rotation is applied to the revolving movement of a limb or segment around its long axis which is drawn through the center of the articular surfaces. Rotation in the joint is ideal, not real; it is the gliding of one curved surface upon a fixed curved surface, resulting in the turning of a segment of the body on its long axis. The movement of gliding, rolling and rotation in combination occurs between certain articular surfaces, e.g., in the knee at the completion of extension.

The kind of movement occurring in a given joint is correlated chiefly with the shape of the articular surfaces, but to some extent also by the influence of ligaments and articular disks. In the diarthrosis, ligaments serve not only to help in binding the bones together but also to limit the range of movement (check ligaments), or modify the movement or to influence the direction of the movement (guide ligaments). The collateral ligaments and cruciate ligaments of the knee combine all of these functions. Articular disks may participate in providing for a combination of movements within the joint, as in the case of the mandibular articulation, where surfaces for gliding and rolling are offered by the articular disk.

Movements of parts of the body.—It has been observed that the movements of the limbs or of other parts of the body are the results chiefly of revolving of joint surfaces (to a less extent of movement on parallel planes) and that definite paths are followed. The revolving takes place around mathematical axes which are located in or near the joint. In rotation in one plane, the axis stands at right angles to the plane of rotation. Thus in the bending of a phalanx, revolving takes place in an interphalangeal joint around an axis passing transversely, determining the movement in a sagittal plane. If the finger be moved away from or toward the mid-plane of the hand it is following a path in a frontal plane, determined by an axis passing in a sagittal direction. When rotation of the lower limb occurs, the turning takes place around a longitudinal axis traversing the limb and the head of the femur in the acetabulum; these movements of the limb are in a plane at right angles to the axis of rotation. The terms **flexion** and **extension** are used for the movements of bending and straightening parts of the body in a sagittal plane. **Abduction** and **adduction** signify the movement of parts away from or toward the mid-plane of the body (in the case of the digits, the plane of the middle finger and that of the second toe) and the path is in a frontal plane (fig. 312B). When all of these angular movements are combined in succession so that the limb revolves upon a point in the proximal joint, the end of the limb describes a circle and the shaft of the limb the surface of a cone, the term **circumduction** is given the movement. **Rotation** is the name given for the revolving movements of a part around the longitudinal axis of the part (fig. 312A).

When a part moves upon one axis its path is restricted to one plane, to one dimension of space. Such a part is said to possess one degree of freedom. Among uniaxial joints are the interphalangeal and radioulnar, (figs. 355). A part which enters into biaxial articulation can move in two planes at right angles to each other and possesses two degrees of freedom; for example the radius in (a) flexion and extension, and (b) rotation on the capitulum of the humerus (fig. 313). Parts having three degrees of freedom move in three dimensions of space, upon tri-axial joints: the femur moving at the hip-joint (fig. 369). Three axes of movement are all that one joint can possess. A part of the body can, however, enjoy more than three degrees of freedom, by participating in the constitution of a several-jointed structure. The knee-joint theoretically possesses four degrees of freedom by the combination of its uniaxial hinge movement with the triaxial angular and rotatory movements of the hip-joint. Five degrees of freedom are given the ulna by the triaxial shoulder joint and the biaxial humeroulnar joint (hinge and screw). Absolute freedom is found in six degrees obtained by a series of parts including joints of one, two and three axes (combination of the joints of both upper limbs, the hands joined). (Fick.)

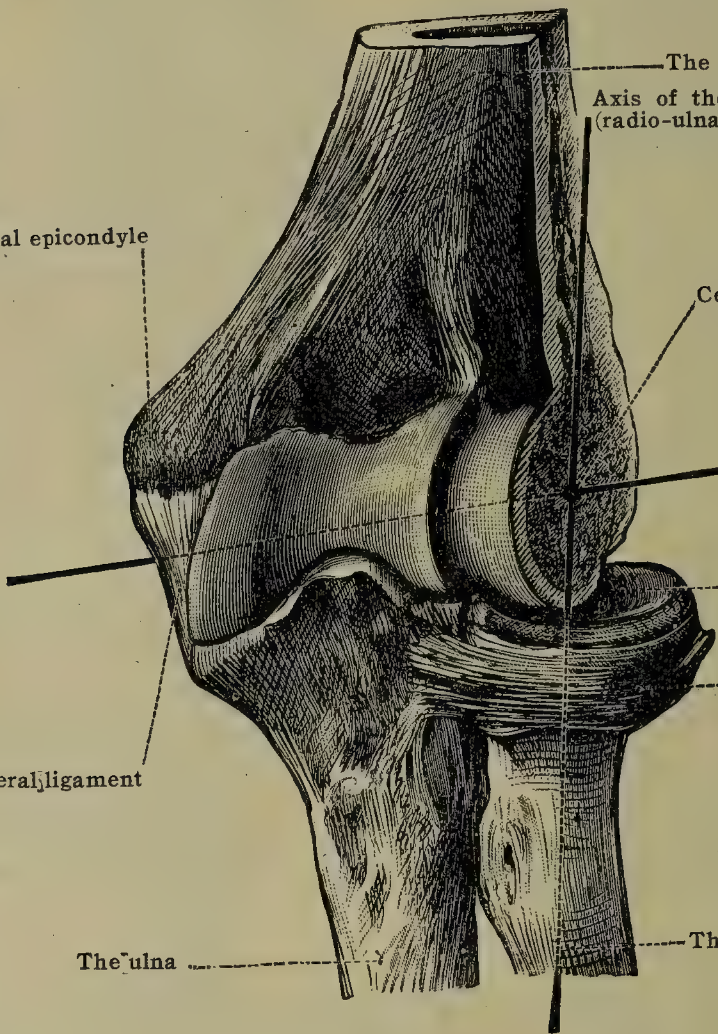


Fig. 313.—Trochoid or Pivot-joint, and Ginglymus or Hinge-joint. (Volar aspect of the Elbow-joint.)

The radial half of the capitulum of the humerus has been removed by a sagittal section passing through its center of curvature. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

Series of joints in a limb skeleton or in certain parts of the axial skeleton may be called upon to act in coordination and therefore on both structural and functional attributes may be considered in the light of joint chains. Joint chains are closed when a ring is formed by the members; open, when no ring is formed. The closed joint rings, less numerous than open, are represented in man by such series of articulations as that uniting the bones to form the pelvic girdle, and by the ring made by the articulations of a pair of ribs with the vertebral column and sternum. The cranium presents chains in the sagittal, transverse and frontal planes and because of the relatively loose connections of the bones in the fetal skull, the sum of all movements is considerable and confers that mobility which enables the head to model and adapt its form to the dimensions and shape of the pelvic canal during labor. The bony walls of the canal itself participate in a closed joint ring. The mechanical demands for complete freedom in space seem to be met by the cranial bones of the full time fetus, the actual range of movement being limited. Open joint chains are seen in the series of intervertebral joints and in the series of joints in a limb. The possibilities of freedom of motion are increased by the building of joint chains as will be readily understood. The examination of a joint chain shows it to contain articulations differing by the number of axes, by the orientation of axes of movement and by an advantageous order of these different joints in the chain. A cumulative result in freedom in space follows from the possession of two pairs of five digited limbs in the vertebrate organism.

For references to the structure and movements of joints the student should consult the monumental work of Rudolf Fick—Handbuch der Anatomie und Mechanik der Gelenke, 1904–1911, Jena, which has been drawn upon in the above presentation of joint structure in general.

The articulations may be divided for convenience of description into those: (1) of the SKULL; (2) of the TRUNK; (3) of the UPPER LIMB; and (4) of the LOWER LIMB.

THE ARTICULATIONS OF THE SKULL

The articulations of the skull comprise (1) the mandibular; (2) those between the skull and the vertebral column, namely between the occiput and atlas in connection with which it will be convenient to describe the joints between the atlas and epistropheus (axis); (3) the articulations between the ossicles of the ear; (4) the syndesmosis with the hyoid bone; (5) the sutures and synchondroses. The articulations of the ear ossicles are described in Section IX, The Sense Organs. The form of the sutures and syndesmoses will be found described in Section III, OSTEOLOGY.

THE MANDIBULAR ARTICULATION

The articular surfaces entering into the formation of the **mandibular joint** [articulatio mandibularis] (figs. 314–317) are offered by:—the mandibular fossa

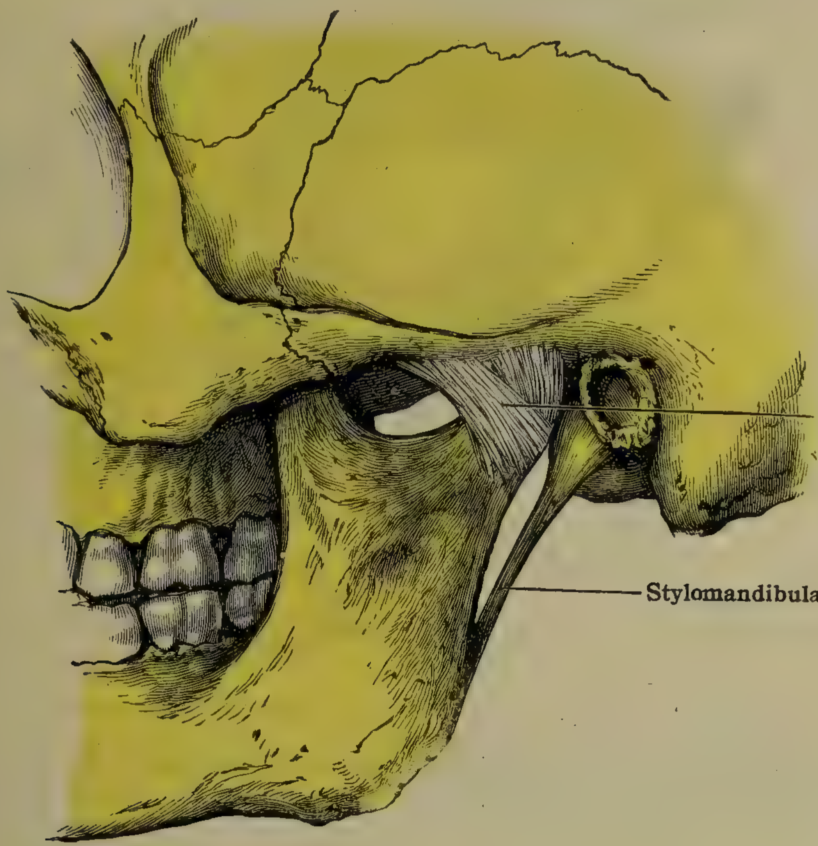


FIG. 314.—LATERAL VIEW OF THE MANDIBULAR JOINT.

and articular tubercle constituting the articular surface of the temporal bone above, and the condyle of the lower jaw below (See pp. 149, 174). Both are covered with fibrocartilage, which approximates pure fibrous tissue on the back of the fossa and of the capitulum. The ligament which unites the bones is the articular capsule, with which are associated the temporomandibular, sphenomandibular and stylomandibular ligaments, and the articular disk.

The **articular capsule** [capsula articularis], a loose sack, is attached above to the zygomatic process of the temporal bone, to the anterior margin of the articular tubercle, to the medial edge of the mandibular fossa and angular spine of the sphenoid and to the posterior edge of the mandibular fossa in front of the petrotympanic (Glaserian) fissure. Below, it finds attachment to the neck of the condyle, extending posteriorly upon the ramus. Part of the tendon of insertion of the external pterygoid muscle penetrates the capsule in front to be fixed into the articular disk.

The **articular disk** [discus articularis] (fig. 316) is an oval plate of fibrocartilage interposed between and adapted to the two articular surfaces. It is thinner at the center than at the circumference, and is thicker behind, where it covers the thin bone at the bottom of the mandibular fossa which separates it from the dura mater, than in front, where it covers the articular tubercle.

Its *inferior surface* is concave and fits on to the condyle of the lower jaw; while its *superior surface* is concavoconvex from before backward, and is in contact with the articular surface of the temporal bone. It divides the joint into two separate synovial cavities, but is occasionally perforated in the center, and thus allows them to communicate. It is connected with the articular capsule at its circumference, and has some fibers of the external pterygoid muscle inserted into its anterior margin.

There are usually two articular cavities and two **synovial membranes** (fig. 316), the superior being the larger and looser, passing down from the margin of the articular surface above, to the upper surface of the articular disk below; the lower and smaller one passes from the articular disk above to the condyle of the jaw below, extending somewhat further down behind than in front. When the disk is perforated, the two sacs communicate.

The **temporomandibular ligament** [lig. temporomandibulare] (fig. 314) is added to the lateral part of the capsule. It is broader above, where it is attached to the lower edge of the zygoma, as well as to the tubercle at the point where the two roots of the zygoma meet. It is inclined downward and backward, to be inserted into the condyle and neck of the mandible laterally. Its fibers diminsh in obliquity and strength from before backward, those coming from the tubercle being short and nearly vertical.

Fig. 315.—Medial View of the Mandibular Joint.

The **sphenomandibular ligament** [lig. sphenomandibulare] (fig. 315) is a thin, loose band, situated some little distance from the joint. It is attached above to the angular spine of the sphenoid and from the region of the petrotympanic fissure, and below to the lingula of the lower jaw.

It covers the upper end of the mylohyoid groove, and is here pierced by the mylohyoid nerve. Its origin is a little medial to, and immediately behind, the origin of the medial portion of the capsule. It is separated from the joint and ramus of the jaw by the internal maxillary artery and vein, the inferior alveolar nerve and artery, the auriculotemporal nerve, and the middle meningeal artery. It is the fibrous remnant of a part of the mandibular (Meckelian) bar.

The **stylomandibular ligament** [lig. stylomandibulare] (figs. 315, 316) is a process of the deep cervical fascia (buccopharyngeal fascia) extending from near the tip of the styloid process to the angle and posterior border of the ramus of the jaw, between the masseter and internal pterygoid muscles. It separates the parotid from the submaxillary gland, and gives origin to some fibers of the styloglossus muscle.

The **arterial supply** of the mandibular joint is derived from the middle temporal, middle meningeal, anterior tympanic and ascending pharyngeal arteries, and from the latter by its branches to the Eustachian tube. **Lymphatic vessels** drain chiefly to the parotid nodes.

The **nerves** are derived from the masseteric and auriculotemporal.

Movements.—The mandibular articulation is a combination of four joints, or a pair of double joints made between the mandibular fossa and capitulum separated by the articular disk. They constitute moreover a closed joint ring and the movements permitted are mixed gliding and rolling. (1) The chief movement of this joint is of a **ginglymoid or hinge character,** accompanied by a slight gliding action, as in opening or shutting the mouth. In the opening movement the condyle turns like a hinge on the articular disk, while at the same time the articular disk, together with the condyle, glides forward so as to rise upon the tuberculum articulare, reaching as far as the anterior edge of the tubercle; but the condyle never reaches quite so far as the summit of the tubercle. In the shutting movement the condyle revolves back again, and the articular disk glides back, carrying the condyle with it. This combination of the hinge and gliding motions gives a tearing as well as a cutting action to the incisor teeth, without any extra muscular exertion.

There is (2) a **horizontal gliding action** in an anteroposterior direction, by which the lower teeth are thrust forward and drawn back again: this takes place almost entirely in the upper compartment, because of the closer connection of the articular disk with the condyle than with the squamosal bone, and also because of the insertion of the external pterygoid into both bone and cartilage. In these two sets of movements the joints of both sides are simultaneously and similarly engaged.

(3) The form of movement called the **oblique rotatory** is that by which the grinding and chewing actions are performed. It consists in a rotation of the condyle about the vertical axis of its neck in the lower compartment, while the articular disk glides obliquely forward and inward on one side, and backward and inward on the other, upon the articular surface of the squamosal

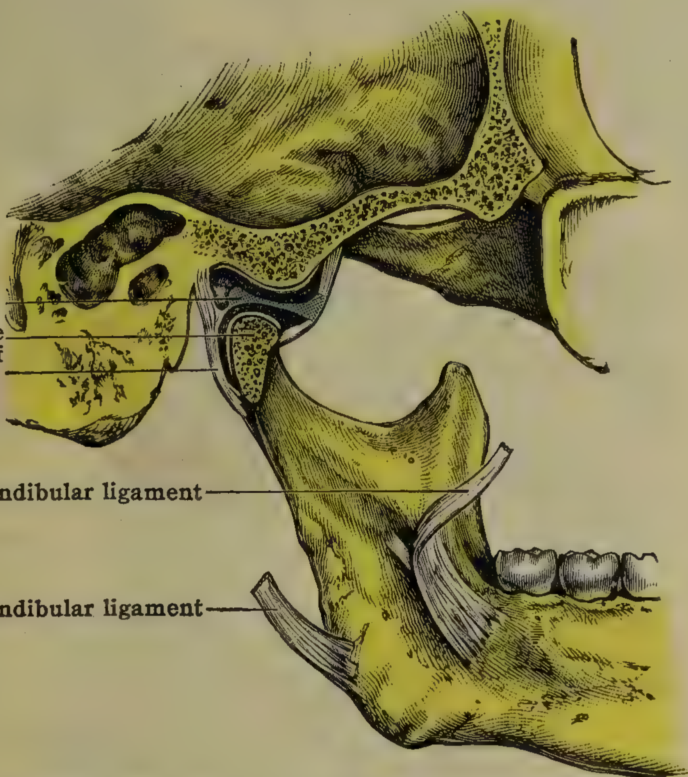


FIG. 316.—SAGITTAL SECTION THROUGH THE CONDYLE OF JAW TO SHOW THE TWO ARTICULAR CAVITIES AND THE ARTICULAR DISK.

bones, each side acting alternately. If the symphysis of the jaw be simply moved from the center to one side and back again, and not from side to side as in grinding, the condyle of that side moves round the vertical axis of its neck, and the opposite condyle and cartilage glide forward and inward upon the mandibular fossa. But in the ordinary grinding movement, one condyle advances and the other recedes, and then the first recedes while the other advances, slight rotation taking place in each joint meanwhile.

Four degrees of freedom of movement are given by the mandibular joint: (a) in a sagittal plane, (b) in a frontal plane, (c) parallel gliding in a horizontal (transverse) plane, (d) rotation around vertical axes. For further details on the movements of the mandibular joint see p. 570.

Functions of the ligaments.—The articular disk compensates for the incongruity of the articular surfaces of the mandibular fossa, articular eminence and capitulum and offers the articular surface for the capitulum. Its thick posterior margin protects the thin layer of bone forming the floor of the mandibular fossa. The anterior bundles of the temporomandibular ligament are put upon the stretch in the backward excursion of the capitulum and the posterior fibers limit the anterior movement of the condyle. There is no apparent function performed by the sphenomandibular ligament or by the stylomandibular ligament.

Relations.—The chief relations are: Behind, and overlapping the lateral side, the parotid gland. Laterally, the superficial temporal artery. Medially, the internal maxillary artery and auriculotemporal nerve. In front, the nerve to the masseter muscle.

Muscles acting on the joint (cf. also p. 570).—*Elevators of the mandible.*—Temporals, masseters, internal pterygoids.

Depressors.—Mylohyoid, digastric, geniohyoid, muscles connecting the hyoid bone to lower points. The weight of the jaw.

Protractors.—External pterygoids, superficial layer of masseter.
Retractors.—Posterior fibers of temporal, slightly by the deep layer of the masseters.

Practical considerations.—Should the condyle, by excessive movement (as in a convulsive yawn), glide over the summit of the articular tubercle, it slips into the zygomatic fossa, the mandible is dislocated, and the posterior portion of the capsule is torn.

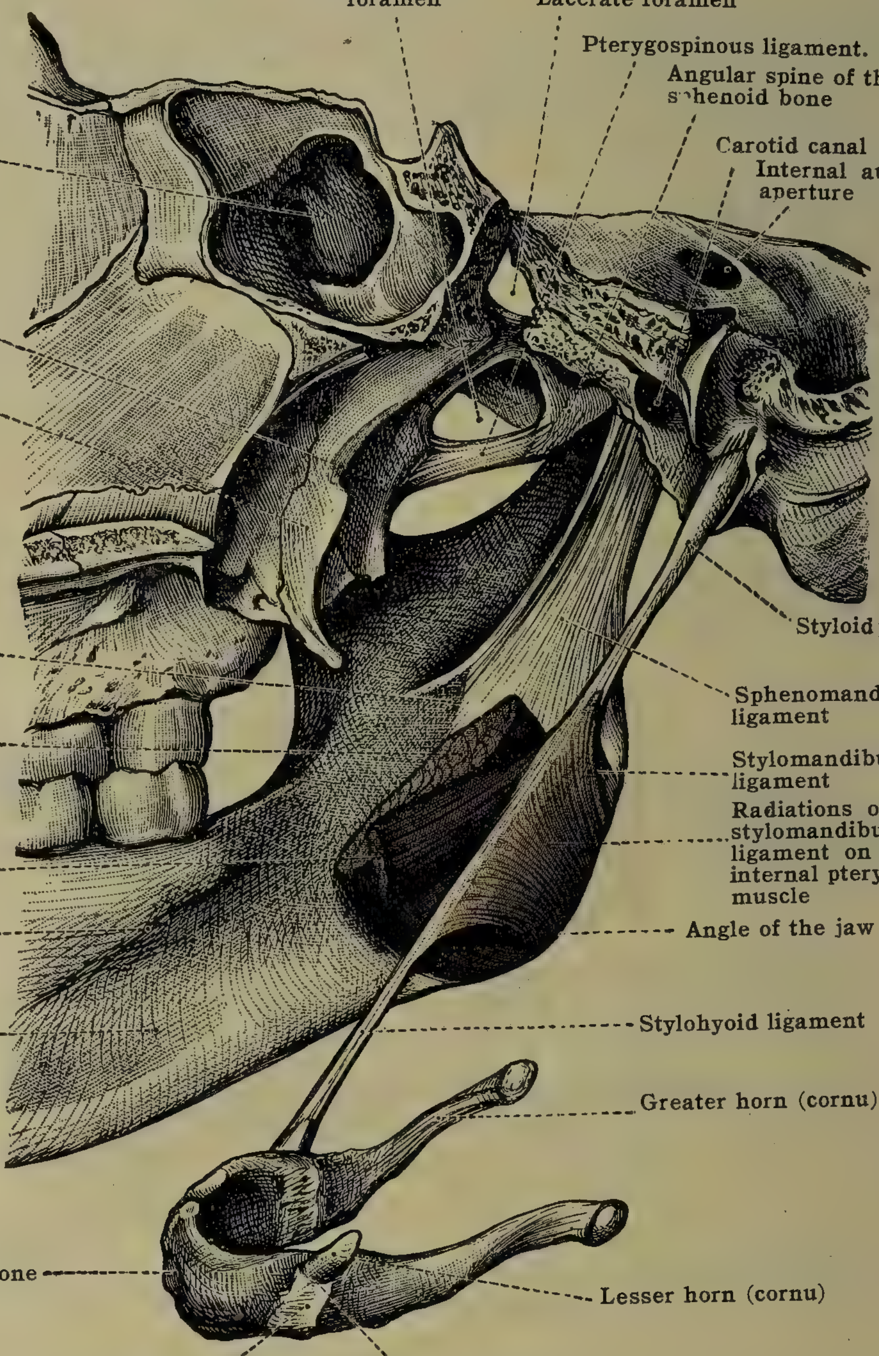


Fig. 317.—Ligaments of the Mandibular Articulation and of the Hyoid Bone.
The posterior part of the facial portion of the skull with the adjoining portion of the base of the skull divided sagitally somewhat to the left of the median plane. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

LIGAMENTS OF THE HYOID BONE

The hyoid bone, standing between the root of the tongue and the larynx, gives attachment to many muscles, by which its position is chiefly maintained, and is connected with the skull and with the thyroid cartilage by ligaments. A slender fibrous band, the **stylohyoid ligament** [lig. stylohyoideum] (fig. 317), extends from the extremity of the styloid process of the temporal bone to the lesser horn of the hyoid. It is sometimes ossified at its upper or its lower part; (for the connection of the hyoid with the larynx, see Section XI, The Respiratory System). The lesser horns are united by an articular capsule with the base of the greater horn; with the body of the hyoid by fibrous tissue. Union of the greater horns with the body is by synchondrosis.

THE LIGAMENTS AND JOINTS BETWEEN THE SKULL AND VERTEBRAL COLUMN, AND BETWEEN THE ATLAS AND EPISTROPHEUS

(a) The Atlanto-occipital Articulation

This articulation [articulatio atlantooccipitalis] consists of a pair of joints symmetrically situated on either side of the middle line. The parts entering into their formation are the two cup-shaped superior articular pits of the atlas and the two condyles of the occipital bone (See pp. 120, 133). They are united by the following ligaments: two articular capsules, anterior atlanto-occipital, and posterior atlanto-occipital.

The **atlantooccipital articular capsules** (figs. 318 and 319) are very distinct and strongly marked, except on the medial side, where they are thin and formed only of short membranous fibers. They are lax, and do not add much to the security of the joint.

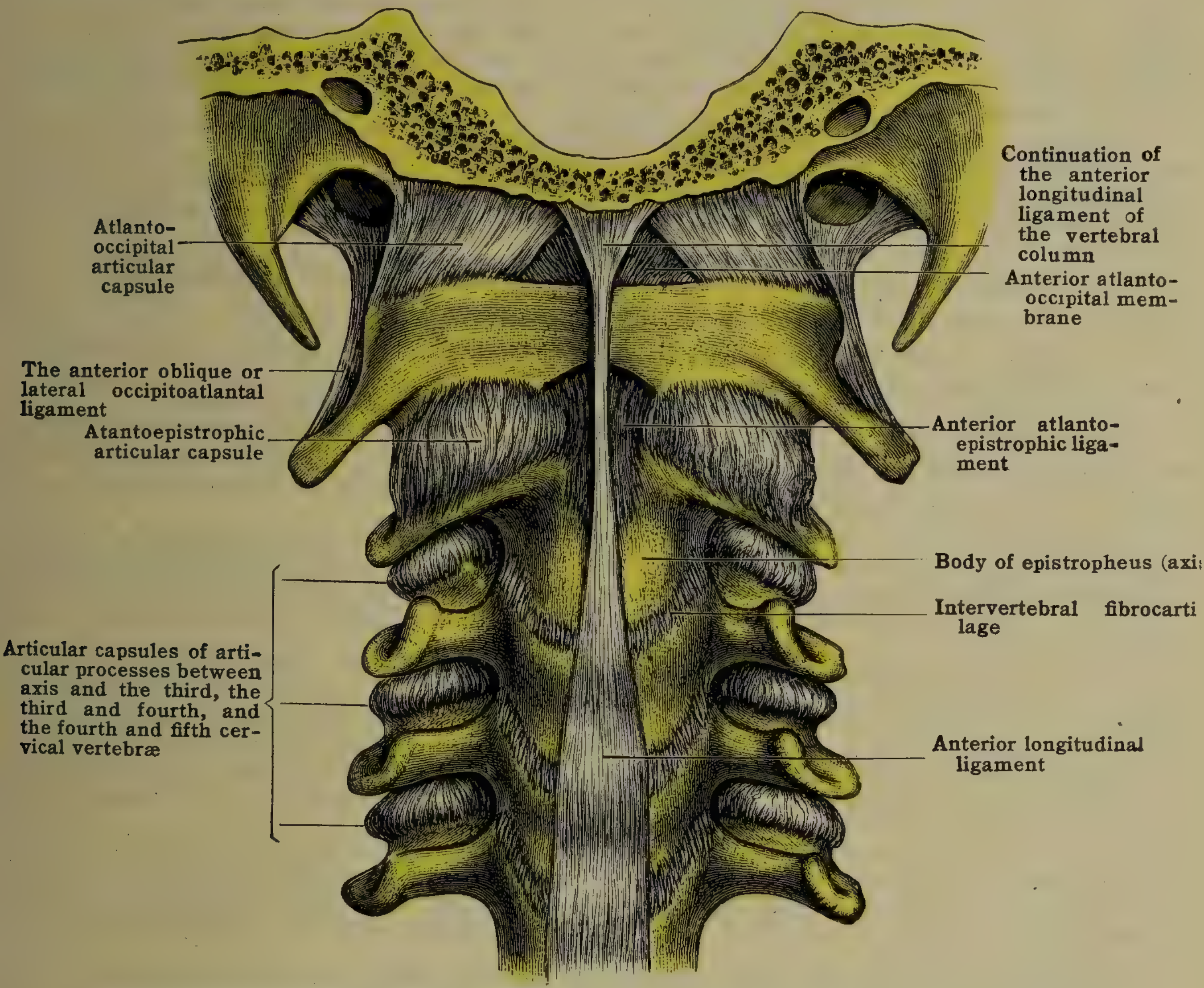


Fig. 318.—Anterior View of the Upper End of the Vertebral Column.

In front, the capsule descends upon the atlas, to be attached, some distance below the articular margin, to the front surface of the lateral mass and to the base of the transverse process; these fibers take an oblique course upward and medialward, overlapping the anterior atlantooccipital membrane. At the sides and behind, the capsule is attached above to the margins of the occipital condyles; below, it skirts the medial edge of the foramen for the vertebral artery, and behind is attached to the prominent tubercle overhanging the groove for that vessel; these latter fibers are strengthened by a band running obliquely upward and medialward to the posterior margin of the foramen magnum.

The **anterior atlanto-occipital membrane** [membrana atlantooccipitalis anterior] (fig. 318) is about 2 cm. wide, and is composed of densely woven fibers most of which radiate slightly lateralward as they ascend from the front surface and upper margin of the anterior arch of the atlas to the anterior border of the foramen magnum and inferior surface of the basilar part of the occipital bone; it is continuous at the sides with the articular capsules, the fibers of which overlap its edges, and take an opposite direction medially and upward.

The central fibers ascend vertically from the anterior tubercle of the atlas to the pharyngeal tubercle on the occipital bone; they are thicker than the lateral fibers, and are continuous below with the superficial part of the anterior atlantoepistrophic ligament, and through it with the anterior longitudinal ligament of the vertebral column. The lateral fibers are connected with the fibrocartilage of the petrooccipital synchondrosis. It is in relation, in front, with the mm. recti capitis anteriores; and behind, with the apical dental ligament.

The **posterior atlantooccipital membrane** [membrana atlantooccipitalis posterior] (fig. 319) is broader, more membranous, and not so strong as the anterior. It extends from the posterior surface and upper border of the posterior arch of the atlas to the posterior margin of the foramen magnum from condyle to condyle; bridging over the groove for the vertebral artery on either side and converting it into a tunnel for the passage of that artery into, and of the suboccipital nerve out of, the vertebral canal. It is somewhat thickened in the middle line by fibers, which pass from the posterior tubercle of the atlas to the lower end of the occipital crest.

It is not tightly stretched between the bones, nor does it limit their movements; it corresponds with the position of the ligamenta flava, but has no elastic tissue in its composition. It is in relation in front with the dura mater, which is firmly attached to it; and behind with the mm. recti capitis posteriores minores and enters into the floor of the suboccipital triangle. Its lateral margins are the so-called *oblique ligaments of the atlas* and they form the posterior boundaries of the apertures through which the vertebral arteries enter and the suboccipital nerves leave the vertebral canal.

The **anterior oblique or lateral atlanto-occipital ligament** is an accessory band which strengthens the capsule laterally (fig. 318). It is an oblique, thick band of fibers, sometimes quite separate and distinct from the rest, passing upward and medialward from the upper surface of the transverse process beyond the transverse foramen to the jugular process of the occipital bone.

The **articular cavities** of these joints occasionally communicate with that between the dens (odontoid process) and the transverse ligament.

The **arterial** supply is derived from twigs of the vertebral, and occasionally from twigs from the meningeal branches of the ascending pharyngeal.

The **nerve-supply** comes from the anterior division of the suboccipital nerve.

Movements (Cf. p. 571).—By the symmetrical and bilateral arrangement of these joints, security and strength are gained at the expense of a very small amount of actual articular surface; the basis of support and the area of action being equal to the width between the most distant borders of the joint.

The principal movement permitted at these joints is of a ginglymoid character, producing flexion and extension upon a transverse axis drawn at about the level of the jugular processes opposite the slightly constricted parts of the condyles. In flexion, the forehead and chin drop, and what is called the nodding movement is made; in extension, the chin is elevated and the forehead recedes.

There is also a slight amount of gliding movement, which may be directly lateral, the lateral edge of one condyle sinking a little within the lateral edge of the socket of the atlas, and that of the opposite condyle projecting to a corresponding degree. This slight abduction and adduction takes place on a median sagittal axis somewhat higher than the axis of nodding movements. The head is thus tilted to one side, and it is even possible that the weight of the skull may be borne almost entirely on one joint, the articular surfaces of the other being thrown partly out of contact.

Or the movement may be obliquely lateral, when the lower side of the head will be a trifle in advance of the elevated side. In this motion, which takes place on the anteroposterior axis, one condyle advances slightly and approaches the middle line, while the other recedes. This is of the nature of rotation, though there is no true rotation round a vertical axis possible between the occiput and atlas.

These lateral movements are checked by the alar ligaments and the lateral part of the capsules; extension is checked by the anterior atlantooccipital and anterior oblique ligaments, and flexion by the posterior part of the capsule and the tectorial membrane.

Muscles acting upon the atlanto-occipital joint (Cf. p. 571).—Flexion whereby the chin is approximated toward the sternum is produced by the weight of the anterior part of the head and by all muscles which are attached to the hyoid bone or to the bones of the skull in front of a transverse axis between the two condyles. These muscles take their fixed point below either from the vertebral column, the sternum, or the bones of the shoulder girdle. Before those connected with the mandible can act that bone must be fixed by the muscles of mastication which, therefore, also take part in the movements.

Extension is due to the action of muscles or portions of muscles inserted into the skull behind the transverse axis above mentioned, and connected below either with the vertebral column, shoulder girdle, or sternum. The sternomastoid muscles are chiefly extensors, although their most anterior portions may serve as flexors of the joint.

Lateral movement is produced by the anterior and posterior groups of muscles on the same side acting simultaneously and aided by the rectus capitis lateralis of that side.

(*b*) The Atlantoepistrophic Articulation

1. The Two Lateral Atlantoepistrophic Joints.
2. The Two Central Atlantoepistrophic or the Atlantodental Joints.

The bones that enter into the formation of these joints [articulatio atlanto-epistrophica] are the atlas and epistropheus. The articular surfaces of the lateral joints are the two inferior articular surfaces of the atlas and the two anterior surfaces of the epistropheus (axis); the articular surfaces of the central joint are the two facets of the dens (odontoid process), one articulating in front with the facet on the anterior arch of the atlas, and one behind articulating with the transverse ligament (see pp. 92, 94).

The ligaments which unite the epistropheus, atlas, and occipital bone are two articular capsules (for lateral joints), two atlantodental articular capsules, the anterior atlantoepistrophic, the posterior atlantoepistrophic, and the transverse ligament of the atlas, two alar ligaments, the apical dental ligament, the cruciate ligament of the atlas, the tectorial membrane.

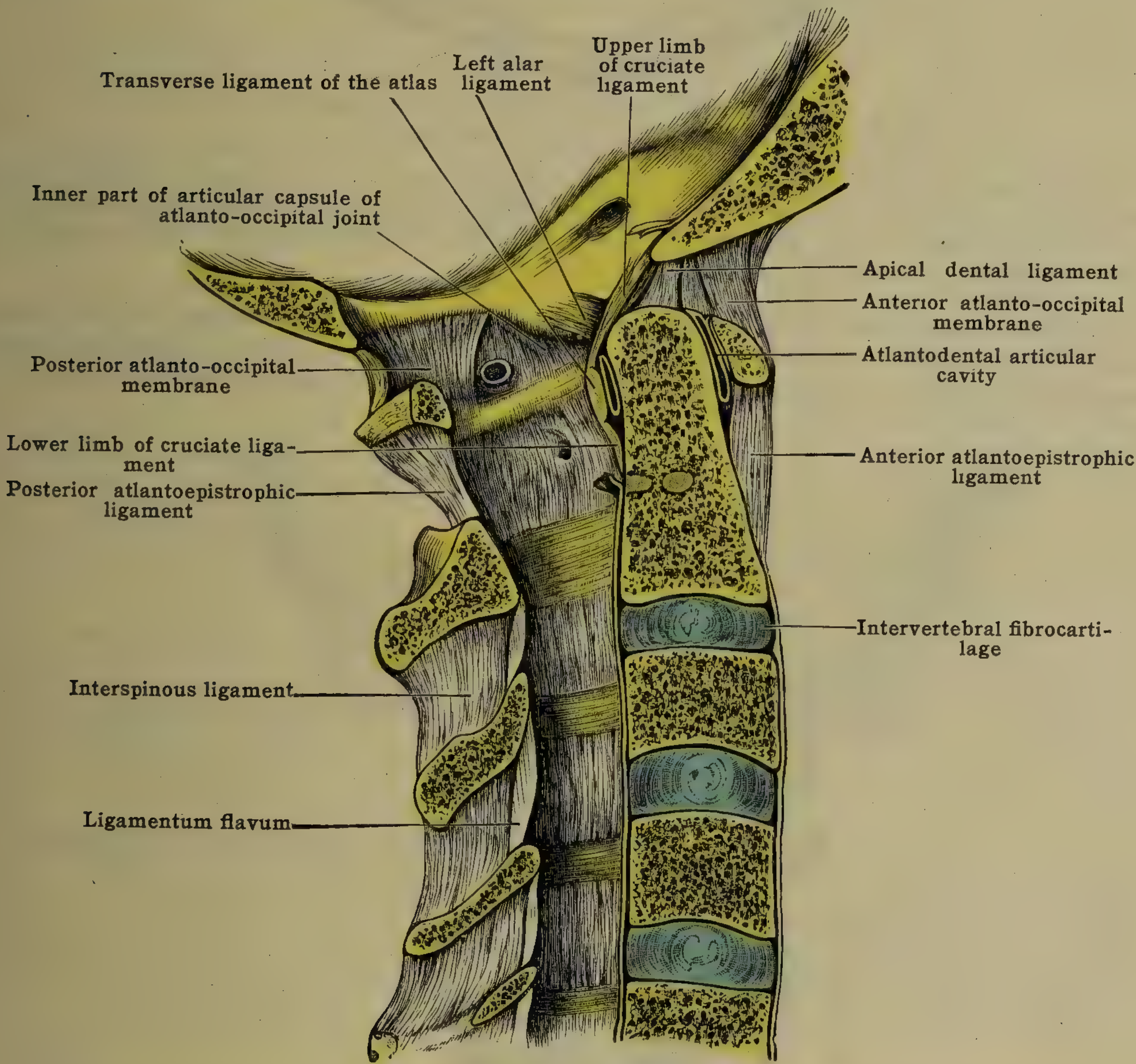


FIG. 319.—MEDIAN SAGITTAL SECTION OF VERTEBRAL COLUMN SHOWING LIGAMENTS.

The **anterior atlantoepistrophic ligament** (figs. 318, 319) is a narrow but strong membrane filling up the interval between the lateral joints. It is attached above to the front surface and lower border of the anterior arch of the atlas, and below to the transverse ridge on the front of the body of the epistropheus. Its fibers are vertical, and are thickened in the median line by a dense band which is a continuation upward of the anterior longitudinal ligament of the vertebral column.

This band is fixed above to the anterior tubercle of the atlas, where it becomes continuous with the central part of the anterior atlantooccipital membrane (fig. 318); it is sometimes separated by an interval from the deeper ligament, and is often described as the superficial atlanto-epistrophic ligament. It is in relation with the longus colli muscle.

The **posterior atlantoepistrophic ligament** (fig. 319) is a deeper, but thinner and looser membrane than the anterior. It extends from the posterior root of the transverse process of one side to that of the other, projecting laterally beyond the posterior part of the capsules which are connected with it. It is attached

above to the posterior surface and lower edge of the posterior arch of the atlas, and below to the superior edge of the arch of the epistropheus on its dorsal aspect.

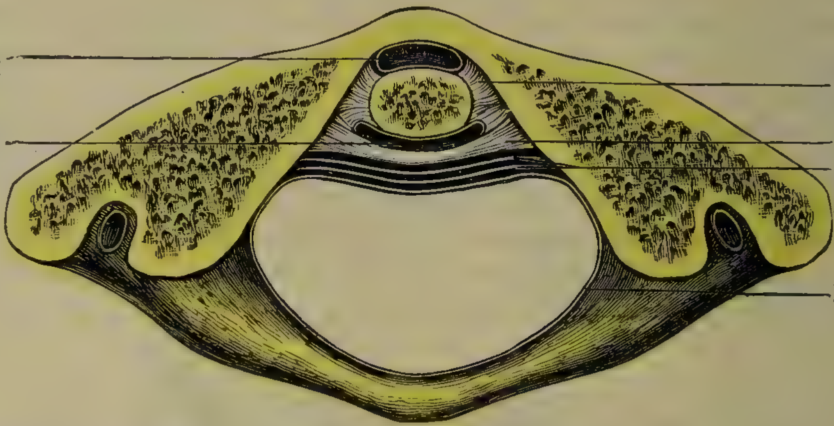


FIG. 320.—HORIZONTAL SECTION THROUGH THE LATERAL MASSES OF THE ATLAS AND THE TOP OF THE DENS (ODONTOID PROCESS).

It is denser and stronger in the median line, and has a layer of elastic tissue on its anterior surface like the ligamenta flava, to which it corresponds in position. It is connected in front with the dura mater; behind, it is in relation with the inferior oblique muscles, and is perforated at each side by the second cervical nerve.

1. THE LATERAL ATLANTOEPISTROPHIC JOINTS are provided with short, ligamentous fibers, forming **articular capsules** (fig. 318), which completely surround the articular surfaces. Lateral to the vertebral canal they are attached

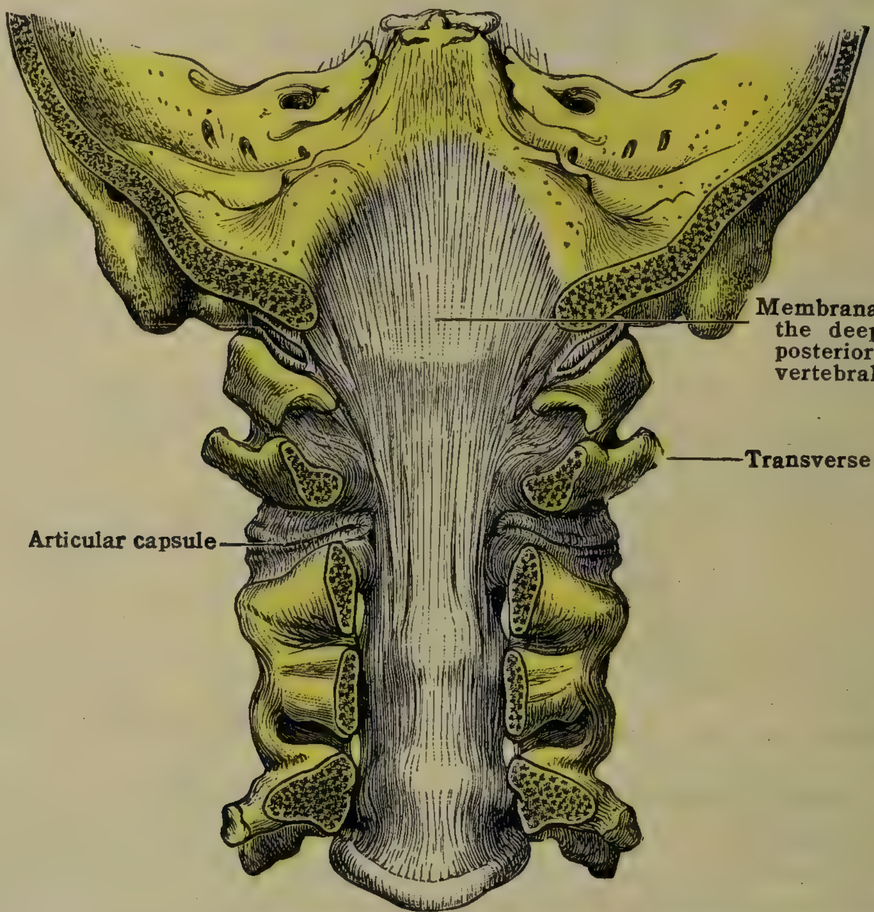


FIG. 321.—THE TECTORIAL MEMBRANE. DEEP STRATUM OF THE POSTERIOR LONGITUDINAL VERTEBRAL LIGAMENT. SUPERFICIAL LAYER REMOVED. POSTERIOR VIEW.

some little distance from the articular margins, extending along the roots of the transverse processes of the epistropheus nearly to the tips, but between the roots they skirt the medial edge of the transverse foramina. They are strengthened in front and behind by the atlantoepistrophic ligaments. There is a **synovial membrane** for each joint.

Medially each capsule is thinner, and attached close to the articular margins, being strengthened behind by a strong band of slightly oblique fibers passing upward along the lateral edge of the tectorial membrane from the body of the epistropheus to the lateral mass of the atlas behind the transverse ligament; some of these fibers pass on, thickening and blending with the atlanto-

occipital capsule, to be inserted into the margin of the foramen magnum. This band is sometimes called the **accessory band** (fig. 322).

2. The Central Atlantoepistrophic Joint, although usually described as one, is composed of two articulations, which are quite separate from each other: an anterior between the dens and the arch of the atlas, and a posterior between the dens and the transverse ligament. The articular surfaces of the dens and atlas arch (see pp. 92, 94) are covered by fibrocartilage.

The **transverse ligament of the atlas** [lig. transversum atlantis] (figs. 319, 320, 322) is one of the most important structures in the body, for on its integrity and that of the alar ligaments our lives largely depend. It is a thick and very strong band, as dense and closely woven as fibrocartilage, about 6 mm. deep at the sides, and somewhat more in the midline. Attached at each end to a tubercle on the inner side of the lateral mass of the atlas, it crosses the ring of this bone in a curved manner, so as to have the concavity forward; thus dividing the ring into a smaller anterior portion for the dens and a larger posterior part for the spinal cord and its membranes, and the accessory nerves.

It is flattened from before backward, being smooth in front, and presents a fibrocartilaginous surface allowing it to glide freely over the posterior facet of the dens. Where it is attached to the atlas it is smooth and well rounded off, providing an easy floor of communication between the transversodental and occipitoatlantal joints.

To its posterior surface is added, in the midline, a strong fasciculus of vertical fibers (superior crus), passing upward from the root of the dens to the basilar border of the foramen magnum on its cranial aspect. Some of these fibers are derived from the transverse ligament. A smaller band (inferior crus) extends downward to an attachment on the back of the body of the epistropheus. These vertical fibers give the transverse ligament a cruciform appearance, hence the name, the **cruciate ligament of the atlas** [lig. cruciatum atlantis] (figs. 319 and 322) applied to the whole.

The **atlantodental articular capsule** (fig. 320) is a tough, loose membrane, completely surrounding the apposed articular surfaces of the atlas and dens.

At the dens it blends above with the front of the alar ligament and arises also along the sides of the articular facet as far as the neck of the dens; the fibers are thick, and blend with the capsules of the lateral joint. At the atlas they are attached to the nonarticular part of the anterior arch in front of the tubercles for the transverse ligament, blending, above and below the borders of the bone, with the anterior atlanto-occipital and atlantoepistrophic ligaments, as well as with the medial portion of the articular capsules. It holds the dens to the anterior arch of the atlas after all the other ligaments have been divided.

The **synovial membranes** (figs. 319, 320) are two in number:—one for the joint between the dens and atlas; and another (transversodental) for that between the transverse ligament and the dens. This last often communicates with the atlanto-occipital articulations; it is closed in by membranous tissue between the borders of the transverse ligament and the margin of the facet on the dens, and is separated from the anterior sac by the atlantodental articular capsule.

(c) Ligaments Uniting the Occipital Bone and Epistropheus

The following ligaments unite bones not in contact, and are to be seen from the interior of the vertebral canal after removing the posterior arches of the epistrospheus and atlas and posterior boundary of the foramen magnum: the tectorial membrane, the cruciate ligament, two alar (or check) ligaments, the apical dental ligament.

The **tectorial membrane** [membrana tectoria] (figs. 321, 322) consists of a very strong band of fibers, connected below to the upper part of the body of the third vertebra and lower part of the body of the epistropheus as far as the root of the dens. It is narrow below, but widens out as it ascends, to be fastened to the clivus of the basilar part of the occipital bone. Laterally, it is connected with the accessory fibers of the atlantoepistrophic capsule. It is really only the upward prolongation of the deep stratum of the posterior longitudinal ligament, the superficial fibers of which run on to the occipital bone without touching the epistropheus, thus giving rise to two strata. It is in relation in front with the cruciate ligament.

The **cruciate ligament** was described above.

The **alar** (or check) **ligaments** [ligg. alaria] (figs. 319, 322) are two strong rounded cords, which extend from the sides of the apex of the dens, transversely lateralward to the medial edge of the anterior portion of the occipital condyles.

They are to be seen immediately above the upper border of the transverse ligament, which they cross obliquely owing to its forward curve at its attachments to the atlas. Some of their fibers occasionally run across the middle line from one alar ligament to the other. At the dens they are connected with the atlantodental capsule, and at the condyles they strengthen the atlanto-occipital articular capsule.

The **apical dental** (or suspensory) **ligament** [lig. apicis dentis] (figs. 319, 322) consists of a slender band of fibers ascending from the summit of the dens to the lower surface of the occipital bone, close to the foramen magnum. It is best seen from the front after removing the anterior atlanto-occipital ligament, or from behind by drawing aside the cruciate ligament.

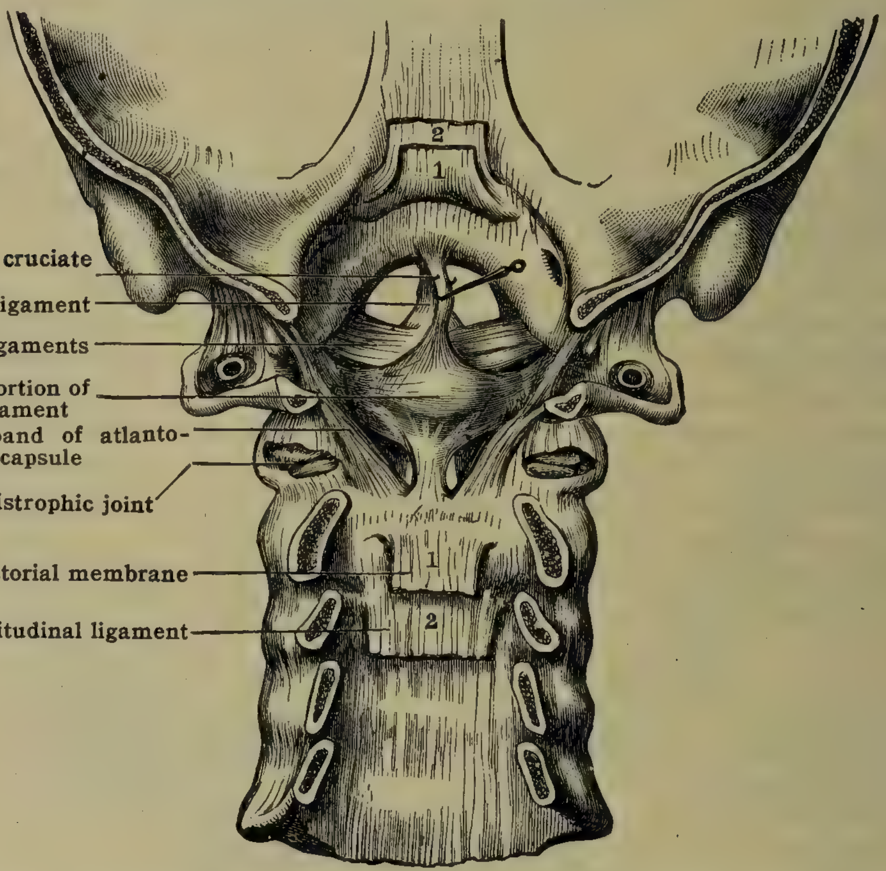


Fig. 322.—Coronal Section of the Vertebral Column and the Occipital Bone to Show Ligaments.
The tectorial membrane (1), though shown as a distinct stratum, is really the deeper part of the posterior longitudinal ligament (2). The upper ends have been reflected upward, the lower downward. (Viewed from behind.)

The apical ligament is tightened by extension and relaxed by flexion or nodding; the alar ligaments not only limit the rotatory movements of the head and atlas upon the epistropheus, but by binding the occiput to the pivot, round which rotation occurs, they steady the head and prevent its undue lateral inclination upon the vertebral column. (See Transverse Ligament, p. 291.)

The **arterial supply** of the atlantoepistrophic joints is from the vertebral artery, and the **nerve-supply** from the loop between the first and second cervical nerves.

Movements (Cf. p. 571).—The chief and characteristic movement at these joints is the rotation, in a nearly horizontal plane, of the collar formed by the atlas and transverse ligament, round the dens as a pivot, which is extensive enough to allow of an all-round view without twisting the trunk. Partly on account of its ligamentous attachments, and partly on account of the shape of the articular surfaces, the cranium must be carried with the atlas in these movements. The rotation is checked by the ligaments passing from the dens to the occiput (alar ligaments), and also by the atlantoepistrophic. Owing to the fact that the articular facets of the epistropheus, which enter into the formation of the lateral atlantoepistrophic articulations, are convex from before backward, and have the articular cartilage thicker in the center than at the circumference, the motion is not quite horizontal but slightly curvilinear. In the erect position, with the face looking directly forward, the most convex portions of the articular surfaces are alone in contact, there being a considerable interval between the edges; during rotation, therefore, the articular surfaces of the atlas descend upon those of the epistropheus, diminishing the space between the bones, slackening the ligaments, and thus increasing the amount of rotation, without sacrificing the security of the joint in the central position. The axis of movement in the atlantoepistropheal articulations is a vertical one through the dens and the several articular surfaces; if extended so as to be continuous, it would form the mantles of concentric cones. Since the rotation of one on the other is affected by the incongruent lateral articular surfaces

the path followed is not pure rotation in one plane, but the path of a screw. Because of this, the joint combination has been classified as a screw-joint.

Besides rotation, forward and backward movements and some lateral flexion are permitted between the atlas and epistropheus, even to a greater extent than in most of the other vertebral joints.

The muscles acting upon the atlantoepistrophic joints (Cf. p. 571).—The muscles capable of producing rotation at the atlantoepistrophic joints are those which take origin from near the mesial plane, either in front or behind and which are attached above either to the atlas or the skull, lateral to the atlantoepistrophic joints. When the muscles which lie at the back of the joint on one side act they will turn the head to the same side and will be aided by the muscles in front on the opposite side. If the muscles in front and behind on the same side act simultaneously, they will pull down the head to that side and will be aided by muscles which pass more or less vertically from the transverse process of the atlas to points below.

By experiments, it has been proved that the head, when placed so that the orbits look a little upward, is poised upon the occipital condyles in a line drawn a little in front of their middle; the amount of elevation varies slightly in different cases, but the balance is always to be obtained in the human body—it is one of the characteristics of the human posture. It serves to maintain the head erect without undue muscular effort, by a strong ligamentum nuchæ

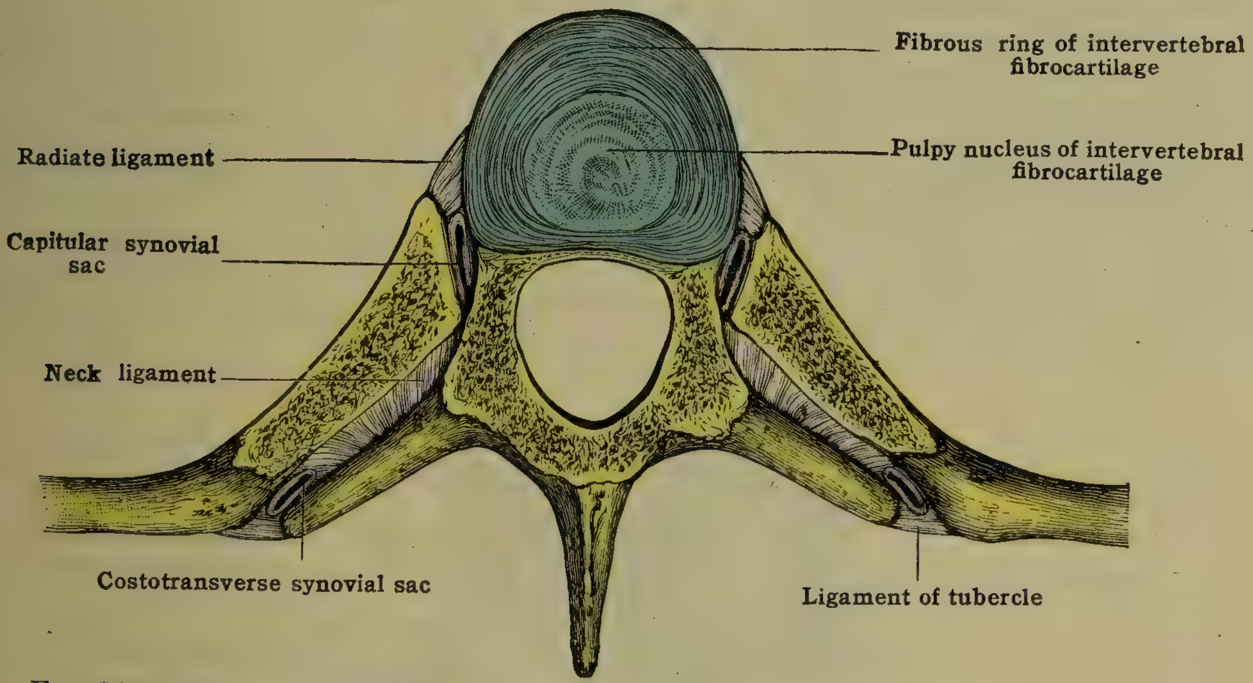


FIG. 323.—HORIZONTAL SECTION THROUGH AN INTERVERTEBRAL FIBROCARTILAGE.

attached to dorsal spines such as are seen in the lower animals. Disturb this balance, and let the muscles cease to act, the head will either drop forward or backward according as the center of gravity is in front or behind the balance line. The ligaments which pass over the dens to the occiput are not quite tight when the head is erect, and only become so when the head is flexed; if this were not so, no flexion would be allowed; thus, muscular action, and not ligamentous tension is employed to steady the head in the erect position. It is through the combination of the joints of the atlas and epistropheus, and occipital and atlas (consisting of two pairs of joints placed symmetrically on either side of the median line, while through the median line there passes a pivot, also with a pair of joints), that the head enjoys such freedom and celerity of action, remarkable strength, and almost absolute security against violence, which could only be obtained by a ball-and-socket joint; but the ordinary ball-and-socket joints are too prone to dislocations by even moderate twists to be reliable enough when the life of the individual depends on the perfection of the articulation: hence the importance of this combination of joints.

THE ARTICULATIONS OF THE VERTEBRAL COLUMN

There are two distinct sets of articulations in the vertebral column: (*a*) those between the bodies, which form synchondroses; (*b*) those between the articular processes, which form diarthroidal joints.

The ligaments which unite the various parts may also be divided into two sets, viz.—**immediate**, or those that bind together parts which are in contact; and **intermediate**, or those that bind together parts which are not in contact.

(*a*) THE ARTICULATIONS OF THE BODIES OF THE VERTEBRÆ

The ligaments which unite the bodies of the vertebræ are the intervertebral fibrocartilages, short lateral ligaments, anterior longitudinal, and posterior longitudinal.

The **intervertebral fibrocartilages** [fibrocartilagines intervertebrales] (disci intervertebrales NK) (figs. 319, 323) are tough, but elastic and compressible disks of composite structure, which serve as the chief bond of union between the vertebræ. They are twenty-three in number, and are interposed between the bodies of all the vertebræ from the epistropheus to the sacrum (figs. 324, 327, 328). Similar disks are found between the segments of the sacrum and coccyx in the younger stages of life, but they undergo ossification at their surfaces and eventually throughout their whole extent. The joint between the sacrum and coccyx is known as the **symphysis sacrococcygea.**

Each disk is composed of two portions—a circumferential laminar, and a central pulpy portion; the former tightly surrounds and braces in the latter, and forms somewhat more than half the disk (fig. 323). The **fibrous ring** [annulus fibrosus] or laminar portion consists of fibrous tissue and fibrocartilage; the component fibers of these layers are firmly connected with two vertebræ, those of one passing obliquely down and to the right, those of the next down and to the left, making an X-shaped arrangement of the alternate layers. A few of the superficial lamellæ project beyond the edges of the bodies, their fibers being connected with the edges of the anterior and lateral surfaces; and some do not completely surround the rest, but terminate at the intervertebral foramina, so that on horizontal section the circumferential portion is seen to be thinner posteriorly. The more central lamellæ are incomplete, less firm, and not so distinct as the rest; and as they near the pulp they gradually assume its characters, becoming more fibrocartilaginous and less fibrous, and having cartilage cells in their structure.

The **pulpy nucleus** [nucleus pulposus] or central portion is situated somewhat behind the center of the disk, forming a ball of very elastic and tightly compressed material, which bulges freely when the confining pressure of the laminar portion is removed by either horizontal or vertical section. Thus, it has a constant tendency to spring out of its confinement in the direction of least resistance, and constitutes a pivot round which the bodies of the vertebræ can twist, tilt, or incline. It is yellowish in color, and is composed of fine white and elastic fibers amidst which are ordinary connective-tissue cells, and peculiar cells of various sizes which

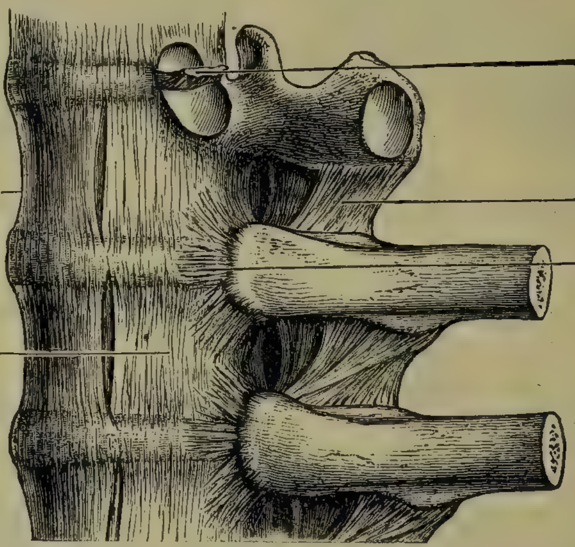


Fig. 324.—Anterior Longitudinal Ligament, and the Connection of the Ribs with the Vertebræ.

contain one or more nuclei. Together with the most central laminæ, it is separated from immediate contact with the bone by a thin plate of articular cartilage. The central pulp of the intervertebral substance has been regarded as the persistent part of the notochord.

The intervertebral substances vary in shape with the bodies of the vertebræ they unite, and are widest and thickest in the lumbar region. In the cervical and lumbar regions they are thicker in front than behind, thus causing the convexity forward of the cervical, and increasing that of the lumbar region. The curve in the thoracic region, almost entirely due to the shape of the bodies, is, however, somewhat increased by the disks. Without the disks the column loses a quarter of its length, and assumes a curve with the concavity forward, most marked a little below the midthoracic region. Such is the curve of old age, which is due to the shrinking and drying up of the intervertebral substances. The disk between the epistropheus and third cervical is the thinnest of all (fig. 327); that between the fifth lumbar and sacrum is the thickest, and is much thicker in front than behind (fig. 362). The intervertebral disks are in relation, in front with the anterior longitudinal ligament; behind, with the posterior longitudinal ligament; laterally, with the short lateral; and in the thoracic region, with the interarticular and radiate ligaments.

In the cervical region lateral diarthrodial joints are placed one on each side of the intervertebral disks. They are of small extent and are confined to the intervals between the prominent lateral lips of the upper surface of the body below and the bevelled lateral edges of the lower surface of the body above.

The **anterior longitudinal ligament** (figs. 318, 324) commences as a narrow band attached to the inferior surface of the occipital bone in the median line,

just in front of the atlanto-occipital ligament, of which it forms the thickened central portion. Attached firmly to the tubercle of the atlas, it passes down as the central portion of the atlantoepistrophic ligament, in the midline, to the front of the body of the epistropheus. It now begins to widen out as it descends, until it is nearly 5 cm. wide in the lumbar region. Below, it is fixed to the upper segment of the sacrum, becoming lost in periosteum about the middle of that bone; but is again distinguishable in front of the sacrococcygeal joint, as the **anterior sacrococcygeal ligament** [lig. sacrococcygeum anterius].

Its structure is bright, pearly-white, and glistening. Its lateral borders are separated from the short lateral bands by clefts through which blood-vessels pass; they are frequently indistinct and are best marked in the thoracic region. It is thickest in the thoracic region, and thicker in the lumbar than in the cervical. It is firmly connected with the bodies of the vertebræ, and is composed of longitudinal fibers, of which the superficial extend over several, while the deeper pass over only two or three vertebræ. It is connected with the tendinous expansion of the prevertebral muscles in the cervical, and with the crura of the diaphragm in the lumbar region.

The **posterior longitudinal ligament** (figs. 322, 325, 329) extends from the occipital bone to the coccyx. It is wider above than below, and commences by a broad attachment to the cranial surface of the basilar part of the occipital bone. In the cervical region it is of nearly uniform width, and extends completely across the bodies of the vertebræ, upon which it rests quite flat. It does, however,

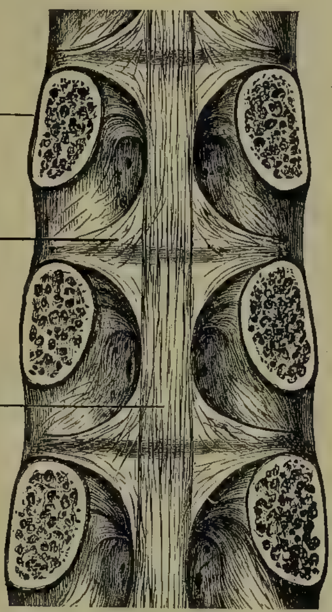


Fig. 325.—Posterior Longitudinal Ligament. (Thoracic region.) (Roots cut through, and posterior arches of vertebræ removed.)

extend slightly further laterally on each side opposite the intervertebral disks. In the thoracic and lumbar regions it is distinctly dentated, being broader over the intervertebral substances and the edges of the bones than over the middle of the bodies, where it is a narrow band stretched over the bones without resting on them, the anterior internal vertebral venous plexus being interposed. The narrow median portion consists of longitudinal fibers, some of which are superficial and pass over several vertebræ; others are deeper, and extend only from one vertebra to the next but one below.

The last well-marked expansion is situated between the first two segments of the sacrum: below this, the ligament becomes a delicate central band with rudimentary expansions, being more pronounced again over the sacrococcygeal joint, and losing itself in the ligamentous tissue at the back of the coccyx. The dura mater is tightly attached to it at the margin of the foramen magnum and behind the bodies of the upper cervical vertebræ, but is separated from it in the rest of its extent by loose cellular tissue which becomes condensed in the sacral region to form the sacrodural ligament. The filum terminale becomes blended with it at the lower part of the sacrum and back of the coccyx.

The **lateral** (or short) **vertebral ligaments** (fig. 324) consist of numerous short fibers situated between the anterior and posterior longitudinal ligaments, and passing from one vertebra over the intervertebral disk, to which they are firmly adherent, to the next vertebra below.

(b) The Articulations between the Articular Processes

The ligaments associated with these articulations include those connecting (1) the articular processes, (2) the laminæ, (3) the spinous processes, and (4) the transverse processes of the vertebræ.

The **articular capsules** (fig. 326) which unite the articular processes are composed partly of yellow elastic tissue and partly of white fibrous tissue. In the cervical region only the medial side of the capsule is formed by the ligamenta flava, which in the thoracic and lumbar regions, however, extend anteriorly to the margins of the intervertebral foramina.

The articular capsules in the cervical region are the most lax, those in the lumbar region are rather tighter and those in the thoracic region are the tightest.

There is one **synovial membrane** to each capsule.

The **yellow ligaments** [ligamenta flava] (fig. 326) are thick plates of closely woven yellow elastic tissue, interposed between the laminæ of two adjacent vertebræ, constituting a series of elastic syndesmoses. The first connects the epistropheus with the third cervical, and the last the fifth lumbar with the sacrum. Each ligament extends from the medial and posterior edge of the intervertebral foramen on one side to a corresponding point on the other; above, it is attached close to the inner margin of the inferior articular process and to a

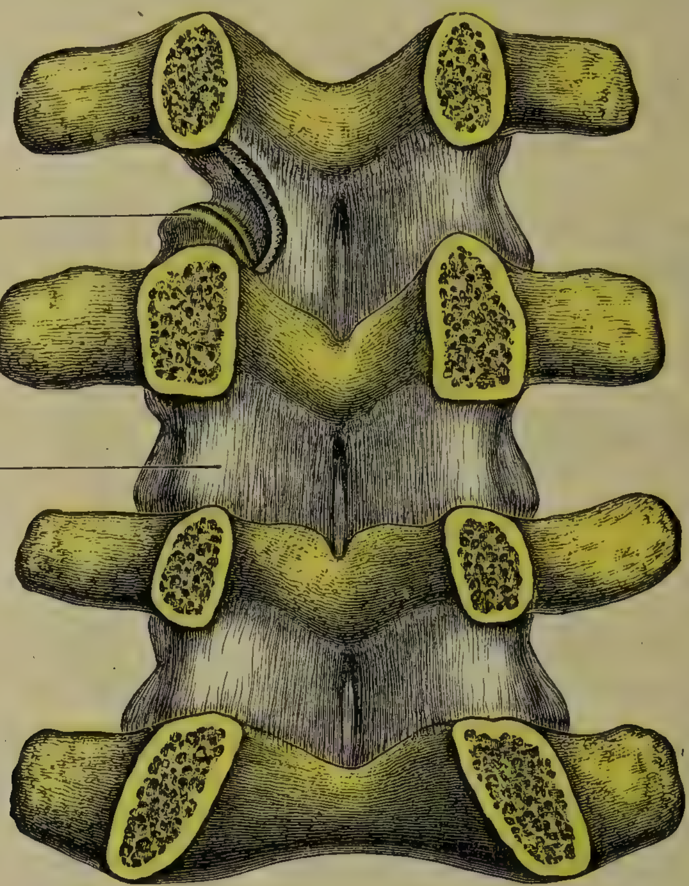


Fig. 326.—Ligamenta Flava in the Lumbar Region Seen from Within the Vertebral Canal.

well-marked ridge on the inner surface of the lamina as far as the root of the spine; below, it is fixed close to the inner margin of the superior articular process and to the dorsal aspect of the upper edge of the lamina.

Thus each yellow ligament, besides filling up the interlaminar space, enters into the formation of two articular capsules; they do so to a greater extent in the thoracic and lumbar regions than in the cervical, where the articular processes are placed wider apart. When seen from the front after removing the bodies of the vertebræ, they are concave from side to side, but convex from above downward; they make a more decided transverse curve than the arches between which they are placed. This concavity is more marked in the thoracic, and still more in the lumbar region than in the cervical; in the lumbar region the yellow ligaments extend a short distance between the roots of the spinous process, blending with the interspinous ligament, and making a median sulcus when seen from the front; there is, however, no separation between the two parts. In the cervical region, where the spines are bifid, there is a median fissure in the yellow tissue which is filled up by fibroareolar tissue. The ligaments are thickest and strongest in the lumbar region; narrow but strong in the thoracic; thinner, broader, and more membranous in the cervical region.

The **ligaments connecting the spinous processes** include the supraspinous ligament, interspinous ligaments, and the ligamentum nuchæ.

The **supraspinous ligament** [lig. supraspinale] (fig. 328) extends without interruption as a well-marked band of longitudinal fibers along the tips of the spines of the vertebræ from that of the seventh cervical downward till it ends on the median sacral crest.

Its more superficial fibers are much longer than the deep. The deeper fibers pass over adjacent spines only, while the superficial overlie several. It is connected laterally with the aponeurotic structures of the back; indeed, in the lumbar region, where it is well marked, it appears to result from the interweaving of the tendinous fibers of the several muscles which are attached to the tips of the spinous processes. In the thoracic region it is a round slender cord which is put on the stretch in flexion and relaxed in extension of the back.

The **ligamentum nuchæ**, or the posterior cervical ligament (fig. 327), is the continuation in the neck of the supraspinous ligament, from which, however, it differs considerably. It is a slender vertical septum of an elongated triangular form, extending from the seventh cervical vertebra to the external protuberance and the crest of the occipital bone. Its anterior border is firmly attached to the

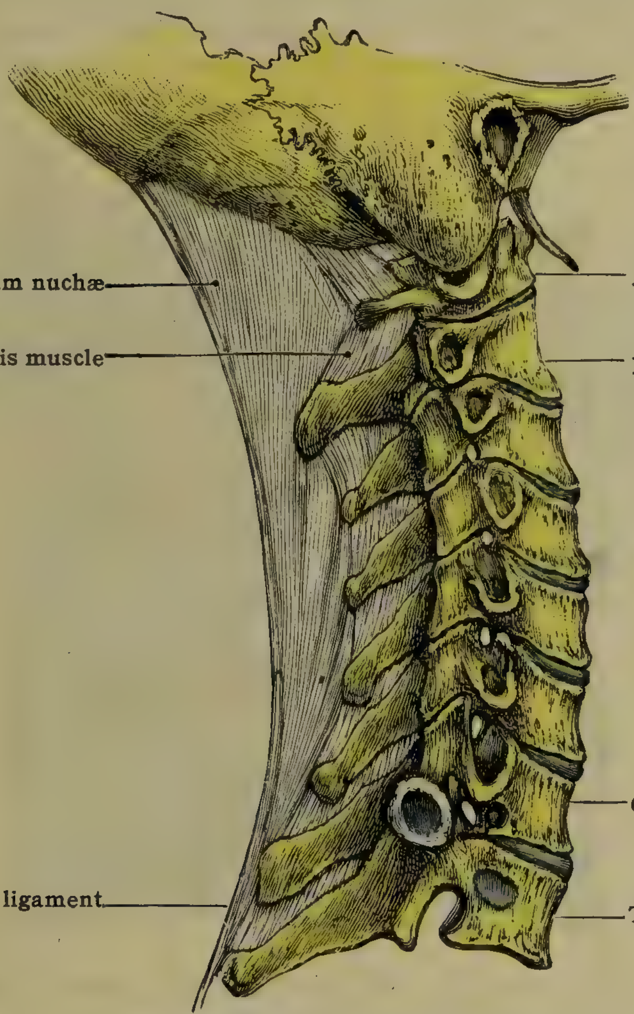


Fig. 327.—Side View of Ligamentum Nuchæ.

tips of the spines of all the cervical vertebræ, including the posterior tubercle of the atlas, as well as to the occiput. Its posterior border gives origin to the trapezii, with the tendinous fibers of which muscles it blends. Its lateral, triangular surfaces afford numerous points of attachment for the posterior muscles of the head and neck.

In man it is rudimentary, and consists of elastic and white fibrous tissues. As seen in the horse, elephant, ox, for example, it constitutes a great and important elastic ligament, which even reaches along the thoracic part of the spinal column. In these animals it serves to support the head and neck, which otherwise from their own weight would hang down. Its rudimentary state in man is probably correlated with his erect position.

The **interspinous ligaments** [ligg. interspinalia] (fig. 328) are thin membranous structures which extend between the spines, and are connected with the yellow ligaments in front, and the supraspinous ligament behind.

The fibers pass obliquely from the root of one spine to the tip of the next; they thus decussate. They are best marked in the lumbar region, and are replaced by the well-developed interspinales muscles in the cervical region.

The **intertransverse ligaments** [ligg. intertransversaria] are but poorly developed.

In the thoracic region they form small rounded bundles, and in the lumbar they are flat membranous bands, unimportant as bonds of union. They consist of fibers passing between the apices of the transverse processes. In the cervical region they are replaced by the intertransversarii muscles.

The Sacrococcygeal Symphysis

The last piece of the sacrum and first piece of the coccyx enter into this union [symphysis sacrococcygea] and are bound together by the following ligaments: anterior sacrococcygeal, superficial posterior sacrococcygeal, deep posterior sacrococcygeal, lateral sacrococcygeal, and intervertebral fibrocartilage.

The **intervertebral fibrocartilage** is a small oval disk, about 2 cm. wide, and a little less from before backward, closely connected with the surrounding ligaments. It resembles the other disks in structure, but is softer and more jelly-like, though the laminæ of the fibrous portion are well marked.

The **anterior sacrococcygeal ligament** [lig. sacrococcygeum anterius] is a prolongation of the glistening fibrous structure on the front of the sacrum. It is really the lower extremity of the anterior longitudinal ligament, which is thicker over this joint than over the central part of either of the bones.

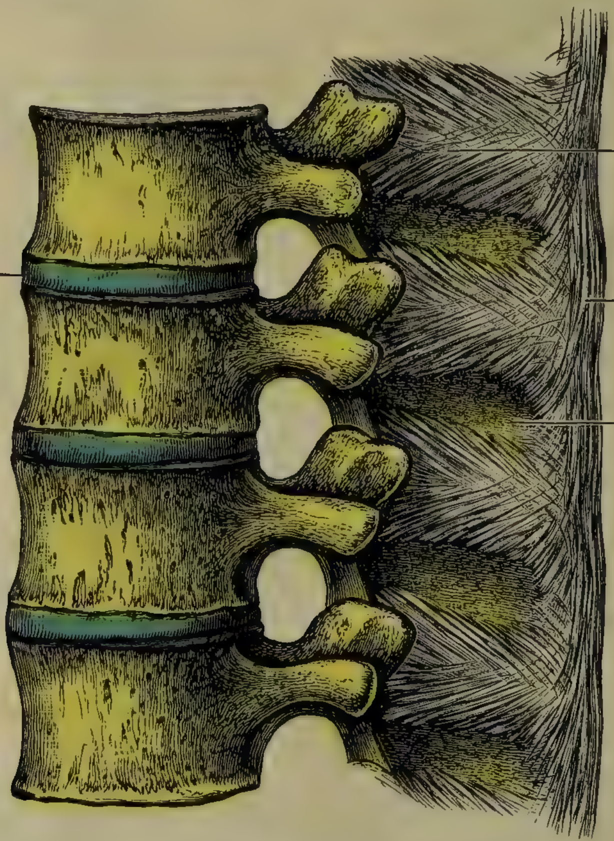


Fig. 328.—The Interspinous and Supraspinous Ligaments in the Lumbar Region.

The **posterior sacrococcygeal ligament** (fig. 329) is divided into two layers of which one (the **deep**) [lig. sacrococcygeum posterius profundum] is a direct continuation of the posterior longitudinal ligament of the column, consisting of a narrow band of closely packed fibers, which become blended at the lower border of the first segment of the coccyx with the filum terminale and deep posterior ligament.

The **superficial posterior sacrococcygeal ligament** [lig. sacrococcygeum superficiale], (fig. 329) is the prolongation of the supraspinous which becomes inseparably blended with the aponeurosis of the sacrospinalis (erector spinæ) muscle opposite the laminæ of the third sacral vertebra, and is thus prolonged downward upon the back of the coccyx, passing over and roofing in the lower end of the spinal canal where the laminæ are deficient.

The median fibers (the **supraspinous ligament**) extend over the back of the coccyx to its tip, blending with the deep fibers of the posterior sacrococcygeal ligament and filum terminale; the deeper fibers run across from the stunted laminæ on one side to the next below on the opposite side, and from the sacral cornu on one side to the coccygeal on the opposite, some passing between the two cornua of the same side, and bridging the aperture through which the fifth sacral nerve passes. Its posterior surface gives origin to the gluteus maximus muscle.

The **lateral sacrococcygeal** (or **intertransverse**) **ligament** [lig. sacrococcygeum laterale] (fig. 329) is merely a quantity of fibrous tissue which passes from the transverse process of the coccyx to the lateral edge of the sacrum below its angle, completing with the two bones the boundaries of a foramen through which passes the anterior division of the fifth sacral nerve. It is connected with the sacrosciatic ligaments at their attachments, and is perforated by twigs from the lateral sacral artery and the coccygeal nerve.

A fiber bundle, the **lig. caudatum,** extends from the last coccygeal vertebra to the integuments, not infrequently causing a dimple, the **foveola coccygea.**

Intercoccygeal Joints

The several segments of the coccyx are held together by the anterior and posterior longitudinal ligaments, which completely cover the bony nodules on their anterior and posterior aspects. Laterally, the sacrosciatic ligaments, being attached to nearly the whole length of the coccyx, serve to connect them. Between the first and second pieces of the coccyx there is a well-marked intervertebral fibrocartilage.

In middle age the lower three pieces of the coccyx are united by synostosis; in advanced age the sacrococcygeal symphysis has passed into bony union, the rest of the coccyx having joined with the first piece. The sacrococcygeal synostosis usually includes the lateral sacrococcygeal ligament. The bony union occurs earlier in men than in women.

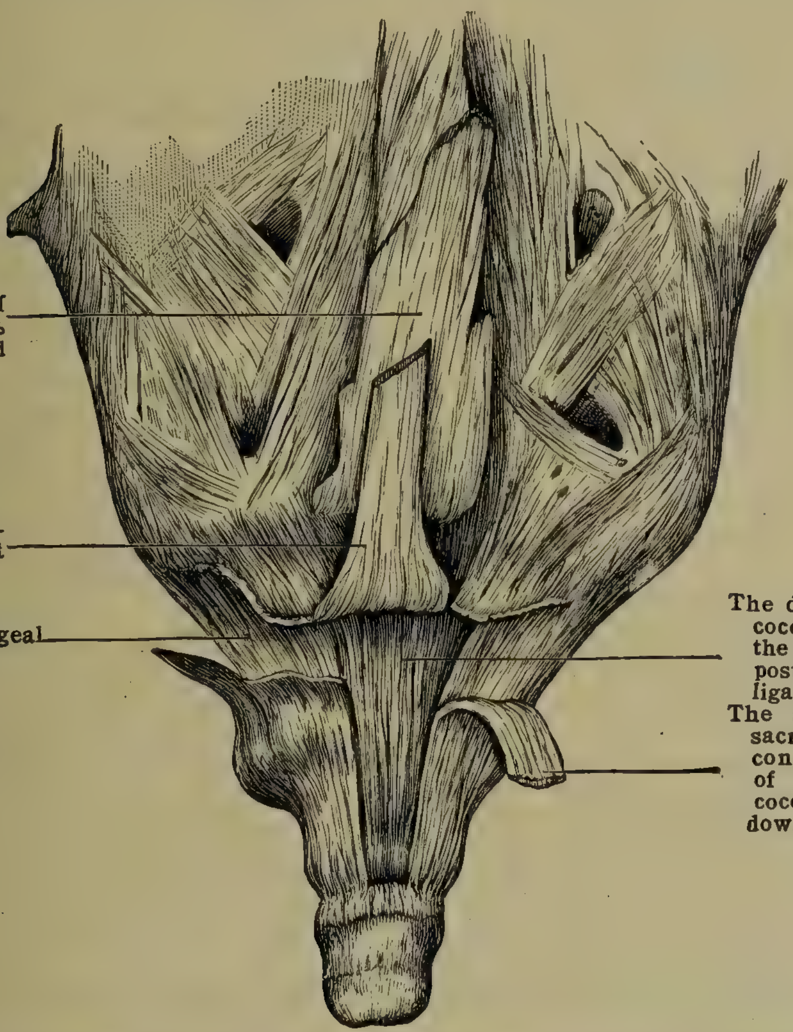


Fig. 329.—Ligaments Connecting Sacrum and Coccyx Posteriorly.

Vessels, Nerves and Movements of the Vertebral Articulations

The **arterial supply** for the articulations of the vertebral column comes from twigs of the vertebral, ascending pharyngeal, ascending cervical, superior and aortic intercostals, lumbar, iliolumbar, and lateral and middle sacral.

The **nerve-supply** comes from the spinal nerves of each region.

Movements (Cf. p. 572).—The vertebral column is so formed of a number of bones and intervertebral disks as to serve many purposes. It is the axis of the skeleton; upon it the skull is supported; and with it the walls and viscera of the trunk and the limbs are connected. As a fixed column it is capable of bearing great weight, and, through the elastic intervertebral substances, of resisting and breaking the transmission of shocks. Moreover, it is flexible. Whereas the movements between any two vertebræ are slight, the range of movements for the column as a whole is very considerable.

Before considering the movements which the vertebral column undergoes in life, a careful review should be made of the structure of the types of vertebræ which are found in it, with special attention to the forms of the bodies and of the articular processes; for the function of weight bearing is served by the one, and the direction and limitation of movement largely deter-

mined by the other. The form of the column as a whole and of its natural curves should be clearly understood. (See pp. 103, 104).

The *kinds of movement* permitted in the vertebral column are: (1) in the median plane, flexion and extension; (2) in a frontal plane, lateral flexion or abduction and adduction; combination of all angular movements in all intermediate planes; (3) torsion; (4) bending on vertical axis to increase or lessen the natural curves.

The *amount of motion* is everywhere limited by the common vertebral ligaments, but depends partly upon the width of the bodies of the vertebræ, and partly upon the depth of the disks, so that in the loins, where the bodies are large and wide, and the disks very thick, free motion is permitted; in the cervical region, though the disks are thinner, yet, as the bodies are smaller, the greatest freedom of motion is allowed. The influence of the articular processes in limiting the direction of inclination will appear from a study of the movements in the three regions of the spine. Were it not for these processes, the column, instead of being steady, endowed with the capacity of movement by muscular agency, would be tottering, requiring muscles to steady it.

In the **neck** all movements are permitted and are free, except between the second and third cervical vertebræ, where they are slight, owing to the shallow intervertebral disk and the great prolongation of the anterior lip of the inferior surface of the body of the epistropheus, which checks forward flexion considerably. Extension is free whilst flexion is more extensive than in any other region. The axis of these movements passes transversely, not through the intervertebral fibrocartilage, but through the body of the vertebra. Rotatory movements are also free (90° according to Fick) but take place, on account of the position and inclination of the articular facets, not, as in the thoracic region, round a vertical axis, but round an oblique axis, in the median plane at right angles to the articular surfaces, the articular process of one side gliding upward and forward and that of the opposite side downward and backward. The cervical spine bearing the weight of the head is bent with its convexity forward; this curve may be reversed in extreme flexion of the neck.

In the **thoracic region,** especially near its middle, anteroposterior flexion and extension are very slight; and, as the concavity of the curve here is forward, the flat and nearly vertical surfaces of the articular processes prevent anything like sliding in a curvilinear manner of the one set of processes over the sharp upper edges of the other, which would be necessary for forward flexion. The transverse axis of flexion and extension lies in the intervertebral fibrocartilage. A fair amount of lateral inclination (median plane axis through fibrocartilage) would be permitted but for the impediment offered by the ribs; while the position and direction of the articular processes allows rotation round a vertical axis which passes in front of the bodies of the vertebræ. This rotation is not very great, and is freer in the upper than in the lower part of the thoracic region.

In the **lumbar region,** extension and flexion are very free (transverse axis in the fibrocartilage) especially between the third and fourth and fourth and fifth vertebræ, where the lumbar curve is sharpest; lateral inclination is also very free (median plane axis in the fibrocartilage) between these same vertebræ. The freedom of angular movement permits circumductory movements of the upper part of the trunk. It has been stated that the shape and position of the articular processes of the lumbar and the lower two or three thoracic are such as to prevent any rotation in these regions; but, owing to the fact that the inferior articular processes are not tightly embraced by the superior, so that the two sets of articular processes are not in contact on both sides of the bodies at the same time, there is always some space in which horizontal motion can occur round a vertical axis lying behind the vertebra, but it is very slight. Thus, the motions are most free in those regions of the column where the amount of fibrocartilage is large in proportion to the length of the division of the column, which have a convex curve forward, due to the shape of the intervertebral disks, where there are no bony walls surrounding solid viscera, where the spinal canal is largest and its contents are less firmly attached, and where the pedicles and articular processes are more nearly on a transverse level with the posterior surface of the bodies of the vertebræ.

The *movements* permitted at the sacrovertebral and intercoccygeal joints are of a simple forward and backward, or hinge-like character. In the act of defecation, the coccyx is pushed back by the fecal mass, and, in parturition, by the fetus; but this backward movement is controlled by the upward and forward pull of the levator ani and coccygeus. The external sphincter also tends to pull the coccyx forward.

Extent of movement of each section of the vertebral column as determined on the cadaver (Fick).

	Cervical	Thoracic	Lumbar
Flexion	about 90°	about 90°	about 23°
Extension	about 90°	about 40°	about 90°
Lateral inclination	about 30°	about 100°	about 35°
Rotation	about 45°	about 80° (entire)	about 5° (to each side)
Inclination and rotation	about 90°	about 120° (entire)	about 40° (to each side)

Nor must the functions of the *ligamenta flava* be forgotten. These useful structures—(1) complete the roofing-in of the vertebral canal, and yet at the same time permit an ever-changing variation in the width of the interlaminar spaces in flexion and extension; (2) they also restore the articulating surfaces to their normal position with regard to each other after movements of the column; (3) and by forming the medial portion of each articular capsule, they take the place of muscle in preventing it from being nipped between the articular surfaces during movement.

Muscles which take part in the movements of the vertebral column (Cf. p. 572).—**Flexors**: When acting with their fellows of the opposite side. Rectus abdominis, infrahyoid muscles (slightly), sternomastoid, external oblique, internal oblique, scalenus anterior, psoas major and minor, longus colli, longus capitis (rectus capitis anterior major).

Extensors: When acting with their fellows of the opposite side. Sacrospinalis, quadratus lumborum, semispinalis, longissimus dorsi, multifidus, rotatores, interspinales, the splenius, and with the scapula fixed, the levator scapulæ and the upper fibers of the trapezius.

Muscles which help to incline the column to their own side.—Sacrospinalis, quadratus lumborum, semispinalis, multifidus, the intercostals helping to fix the ribs, the external and internal oblique muscles, levatores costarum, the scalenes, splenius cervicis, sternocleidomastoid, longus colli (oblique part), rotatores, intertransversales, psoas, and with the scapula fixed the levator scapulæ and the upper and lower fibers of the trapezius.

Muscles which rotate the column and turn the body to their own side.—Splenius cervicis and capitis, iliocostalis cervicis, longissimus capitis and cervicis, internal oblique (the ribs being fixed), serratus posterior inferior, and with the scapula fixed, the lower fibers of the trapezius.

Muscles which rotate the column and turn the body to the opposite side.—Multifidus, semispinalis, rotatores, scaleni, external oblique, the lower oblique fibers of the longus colli, sternocleidomastoid, and with the scapula and humerus fixed the latissimus dorsi and trapezius.

Line of gravity.—It will be recalled (see p. 103) that the thoracic spine presents a wide sagittal curve, concave forward and a slight lateral curve concave to the left. The center of gravity of the body lies in the body of the ninth thoracic vertebra and so the weight of the upper half of the trunk with the upper limbs bears down upon and operates to maintain the thoracic curve in the erect posture. The lumbar spine is curved with the convexity forward, the line of gravity falling well behind it and still farther behind the lumbosacral angle. It strikes the spine at the third sacral, at the level of the lower part of the sacroiliac joint. (See fig. 312.)

THE COSTOVERTEBRAL ARTICULATIONS

The **costovertebral articulations** [articulationes costovertebrales] consist of two sets, viz.:—

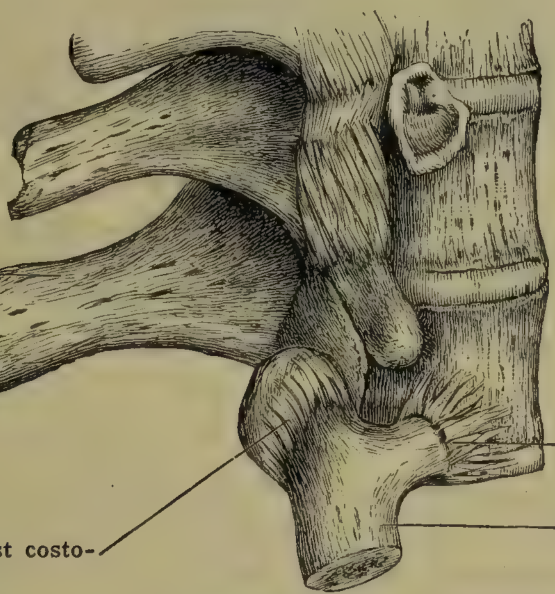


Fig. 330.—The Capsular Ligaments of the Costovertebral Joints.

(*a*) The **capitular** (costocentral): i. e., the articulation of the head of the rib with the vertebræ.

(*b*) The **costotransverse,** or the articulation of the tubercle (of each of the first ten ribs) with the transverse process of the lower of the two vertebræ, with which the head of the rib articulates: i. e., the one bearing its own number, as the first rib with the first thoracic vertebra, the second rib with the second thoracic vertebra, and so on.

(*a*) The Capitular Articulation

The **capitular articulation** [articulatio capituli] is a very perfect joint, into the formation of which enter the articular surface of the head of the rib and the costal pits of two vertebræ, with the intervertebral fibrocartilage between them. The articular surfaces of the bones (see p. 183) are covered with fibrocartilage. In the case of the first, tenth, eleventh, and twelfth ribs, the capitular joint is formed by the head of the rib articulating with a single vertebra.

The ligaments are the articular capsule, radiate ligament of the head of the rib, and interarticular ligament of the head of the rib.

The **articular capsule** (fig. 330) consists of short, strong fibers, completely surrounding the joint, which are attached to the bones and intervertebral disks, a little beyond their articular margins.

At its upper part it reaches through the intervertebral foramen toward the back of the bodies of the vertebræ, being strengthened here by fibers which at intervals connect the anterior with the posterior longitudinal ligaments. The lower fibers extend downward nearly to the costal pit of the rib below; behind, it is continuous with the neck ligament, and in front is overlaid by the radiate ligament of the head. Capsules of the first, eleventh and twelfth capitular joints are lax.

The **radiate ligament** [lig. capituli costæ radiatum], a thickening of the anterior part of the capsule (figs. 324, 331), is the most striking of all, and consists of bright, pearly-white fibers attached to the anterior surface, and upper and lower borders of the neck of the rib, a little way beyond the articular facet; from this they radiate upward, forward, and downward, so as to form a continuous layer of distinct and sharply defined fibers.

The middle fibers run straight forward to be attached to the intervertebral fibrocartilage, the upper ascend to the lower half of the lateral surface of the vertebra above, and the lower descend to the upper half of the vertebra below. The radiate ligament is overlapped on the vertebral bodies by the lateral (short) vertebral ligaments.

In the case of the first, tenth, eleventh, and twelfth ribs, each of which articulates with one vertebra, the ligament is not quite so distinctly radiate, but even in these the ascending fibers reach the vertebra above that with which the rib articulates.

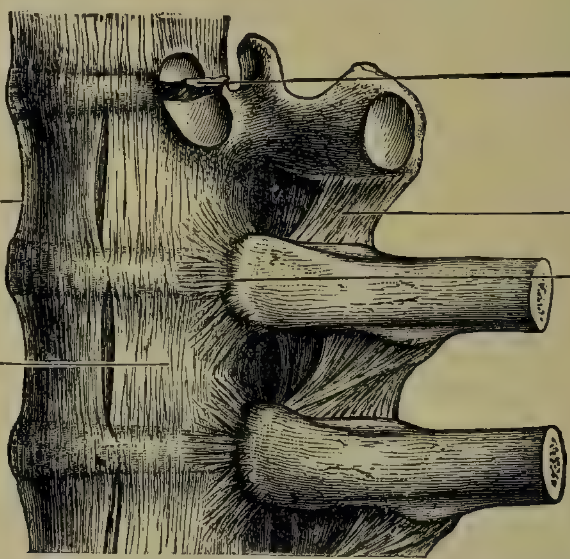


FIG. 331.—ANTERIOR LONGITUDINAL LIGAMENT, AND THE CONNECTION OF THE RIBS WITH THE VERTEBRÆ

The **interarticular ligament** [lig. capituli costæ interarticulare] (fig. 331) consists of short, strong fibers, closely interwoven with the outermost ring of the intervertebral fibrocartilage, and attached to the transverse ridge separating the articular facets on the head of the rib. It completely divides the articulation into two parts, but does not brace the rib tightly to the spine, being loose enough to allow a moderate amount of rotation on its own axis. There is no interarticular ligament in the costovertebral joints of the first, tenth, eleventh, and twelfth ribs.

The articular cavities of the capitular articulation (fig. 332) consist of two closed sacs which do not communicate: one above, and the other below, the interarticular ligament. The synovial stratum is imperfect. In the case of the first, tenth, eleventh, and twelfth articulations, there is but one synovial membrane, as these joints have no interarticular ligament.

(b) THE COSTOTRANSVERSE ARTICULATION

This joint [articulatio costotransversaria] is formed by the convex articular surface of the tubercle of the rib meeting the concave articular surface of the transverse process. The articular surfaces are covered with hyalin cartilage. The eleventh and twelfth ribs are devoid of these joints, for the tubercles of these ribs are absent, and the transverse processes of the eleventh and twelfth thoracic vertebræ are rudimentary.

The ligaments of the union are articular capsule, ligament of the neck of the rib, ligament of the tubercle of the rib, anterior costotransverse ligament, and posterior costotransverse ligament.

The **articular capsule** (figs. 330, 332) forms a thin, loose, fibrous envelope to the thin synovial membrane. Its fibers are attached to the bones just beyond the articular margins, and are thickest below, where they are not strengthened by any other structure. It is connected medially with the neck ligament, above with the costotransverse, and laterally with the tubercular ligaments.

The **neck ligament** [lig. colli costæ] (fig. 332), consists of short fibers passing between the back of the neck of the rib and front of the transverse process, with which the tubercle articulates. It extends from the capsule of the capitular joint to that of the costotransverse. It is best seen on horizontal section through the bones, filling the **costotransverse foramen.** In the eleventh and twelfth ribs this ligament is rudimentary.

The **tubercular ligament** [lig. tuberculi costæ] (fig. 332) is a short but thick, strong, and broad ligament, which extends laterally and upward from the extrem-

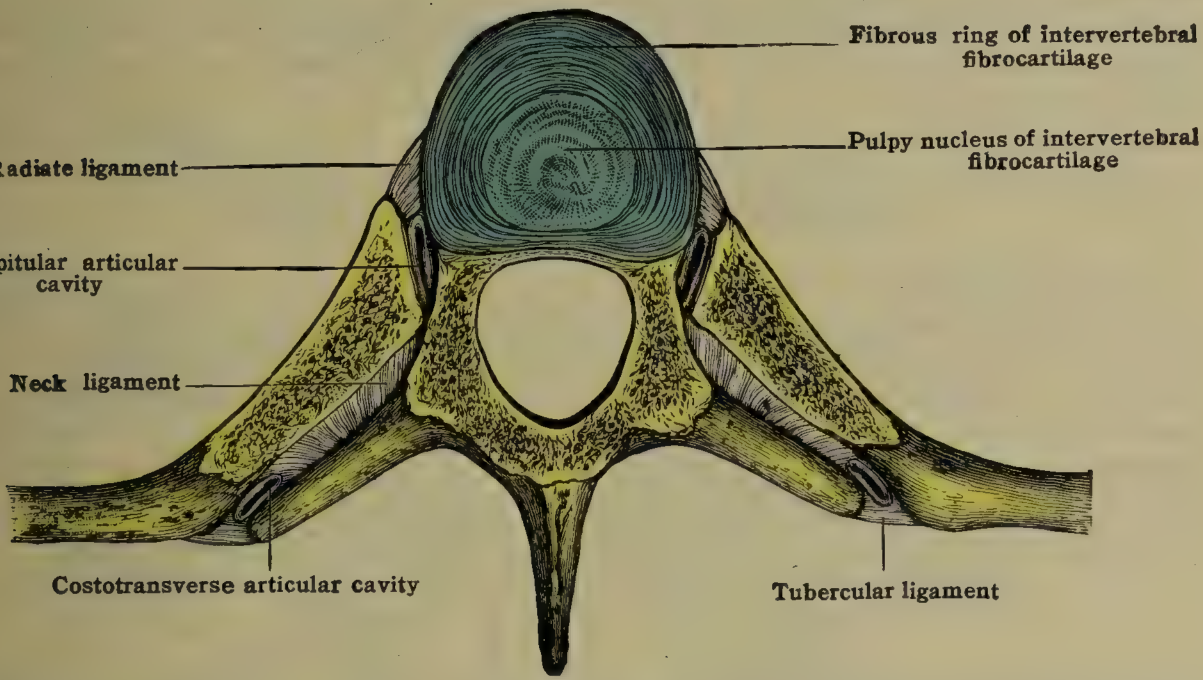


Fig. 332.—Horizontal Section through the Intervertebral Fibrocartilage and Ribs

ity of the transverse process to the non-articular surface of the tubercle of the corresponding rib. The eleventh and twelfth ribs have no posterior ligament.

The **costotransverse ligament** (fig. 331) is a strong, broad band of fibers which ascends laterally from the crest on the upper border of the neck of the rib, to the lower border of the transverse process above. A few scattered posterior fibers pass upward and medially from the neck to the transverse process. The costotransverse ligament is subdivided into a stronger anterior portion, **anterior costotransverse ligament** [lig. costotransversarium anterius], best seen from the front (fig. 331), and a weaker posterior portion, **posterior costotransverse ligament** [lig. costotransversarium posterius]. Its medial border bounds the foramen through which the posterior branches of the intercostal vessels and nerves pass. To the lateral border is attached the thin aponeurosis covering the external intercostal muscles. Its anterior surface is in relation with the intercostal vessels and nerve; the posterior with the longissimus dorsi muscle. The **first** rib has no costotransverse ligament. The twelfth rib is firmly bound down by the **lumbocostal ligament** [lig. lumbocostale], a specially strong mass of fibers in the anterior layer of the lumbodorsal fascia connected medially with the tips of the transverse processes of the first two lumbar vertebræ.

The **synovial membrane** (fig. 332) of the costotransverse articulation is a single sac.

The **arterial** and **nerve-supplies** of the capitular and costotransverse articulations come from the posterior branches of the intercostal arteries and nerves.

Movements.—The capitular and costotransverse articulations although separate must be considered parts of one mechanism which provides for the movements of the rib as a whole. There is a considerable difference in the degree of mobility of the different ribs, for while the first rib is almost immobile except in a very deep inspiration, the mobility of the others increases from the second to the last; the two floating ribs being the most mobile of all. The character and position of the articular surfaces and the arrangement of the ligaments greatly restrict the sorts of movement and reduce the possibilities to that of *rotation on one axis*, the curved articular surfaces of the head and tubercle gliding in the concavities of the costal pits and transverse

articular surfaces. Backward and forward movement of the neck of the rib is almost impossible, as is also elevation and depression on account of restraining ligaments. The last two ribs are exceptions, since they do not enter into the articulation of the transverse process and therefore rotation of the head of the rib may take place on several axes. The axis of rotation lies in the neck of the rib connecting the mid-points of the tubercle and head of the rib (fig. 334). A very slight degree of movement of the head on a vertical axis has been noted by Fick. The axis through head and tubercle lies in a horizontal plane and is directed obliquely laterally and backward from the center of the head. If prolonged forward and medially the axes of rotation of a pair of ribs would cross in the mid-plane.

STERNOCOSTAL ARTICULATIONS

The **sternocostal articulations** [articulationes sternocostales] comprise the following subdivisions, viz.:—

(*a*) The **sternocostal joints,** or the junction of the costal cartilages with the sternum; (*b*) The **costochondral joints,** or the union of the ribs with their costal cartilages; (*c*) The **interchondral joints,** or the union of five costal cartilages (sixth, seventh, eighth, ninth, and tenth) with one another, with which may be included for convenience; (*d*) The **intersternal joints,** or the union of the several parts of the sternum with one another.

(*a*) The Sternocostal Articulations

These diarthrodial articulations are between the costal notches of the lateral borders of the sternum and the ends of the costal cartilages of the upper seven ribs. The surfaces of the costal notches are coated with a thin layer of hyalin cartilage. The union of the first rib with the sternum is *synchondrodial,* and therefore forms an exception to the others. From the second to the seventh inclusive, the articulations have the following ligaments, which together with the perichondrium of the costal cartilage and periosteum of the sternum form a complete capsule:—

Radiate sternocostal.	Interarticular sternocostal.

The **radiate sternocostal ligament** [lig. sternocostale radiatum] (fig. 333) is a triangular band composed of strong fibers which cover the medial one centimeter of the front of the costal cartilage, and radiate upward and downward upon the front of the sternum. Some of the fibers decussate across the middle line with fibers of the opposite ligament.

The **posterior sternocostal ligament** consists of little more than a thickening of the fibrous envelopes of the bone and cartilage, the joint being completed behind by a continuity of perichondrium with periosteum. The periosteum of the sternum, augmented by the fibers of the anterior and posterior ligaments forms a dense layer enveloping the sternum and has been termed the **membrana sterni.**

Deeper than the fibers of these ligaments are short fibers passing from the margins of the sternal notches to the edges of the facets on the cartilages; they are most distinct in the front and lower part of the joint, and may encroach so much upon the synovial cavity as to reduce it to a very small size, or almost obliterate it. This occurs mostly in the case of the sixth and seventh joints, especially the latter.

The **interarticular sternocostal ligament** [lig. sternocostale interarticulare] (fig. 333) is by no means constant, but is usually present in the second joint on one, if not on both sides of the same subject. It consists of a strong transverse fibrocartilaginous layer passing from the ridge on the facet of the cartilage to the fibrous substance between the manubrium and body; sometimes the upper part of the synovial cavity is partially or entirely obliterated by short, fine, ligamentous fibers.

The interarticular ligament is present in the third joint in one-fifth of the cases, in the fourth in one-tenth and is still rarer in the remaining sternocostal articulations (Tschaussow). There is a tendency for the sixth and seventh sternocostal junctions to be synchondroses.

The **costoxiphoid ligament** (fig. 333) is a strong flat band of fibers passing obliquely upward and laterally from the front surface of the xiphoid cartilage to the anterior surface of the sternal end of the seventh costal cartilage, and most frequently to that of the sixth also. It is not always present.

Synovial membranes.—The union of the first cartilage with the sternum, being synchondrodial, has no synovial membrane; the second has usually two, separated by the interarticular ligament. The rest usually have one synovial membrane, which may occasionally be subdivided into two (fig. 333).

The **arterial supply** is derived from perforating branches of the internal mammary; and the **nerves** come from the anterior branches of the intercostals.

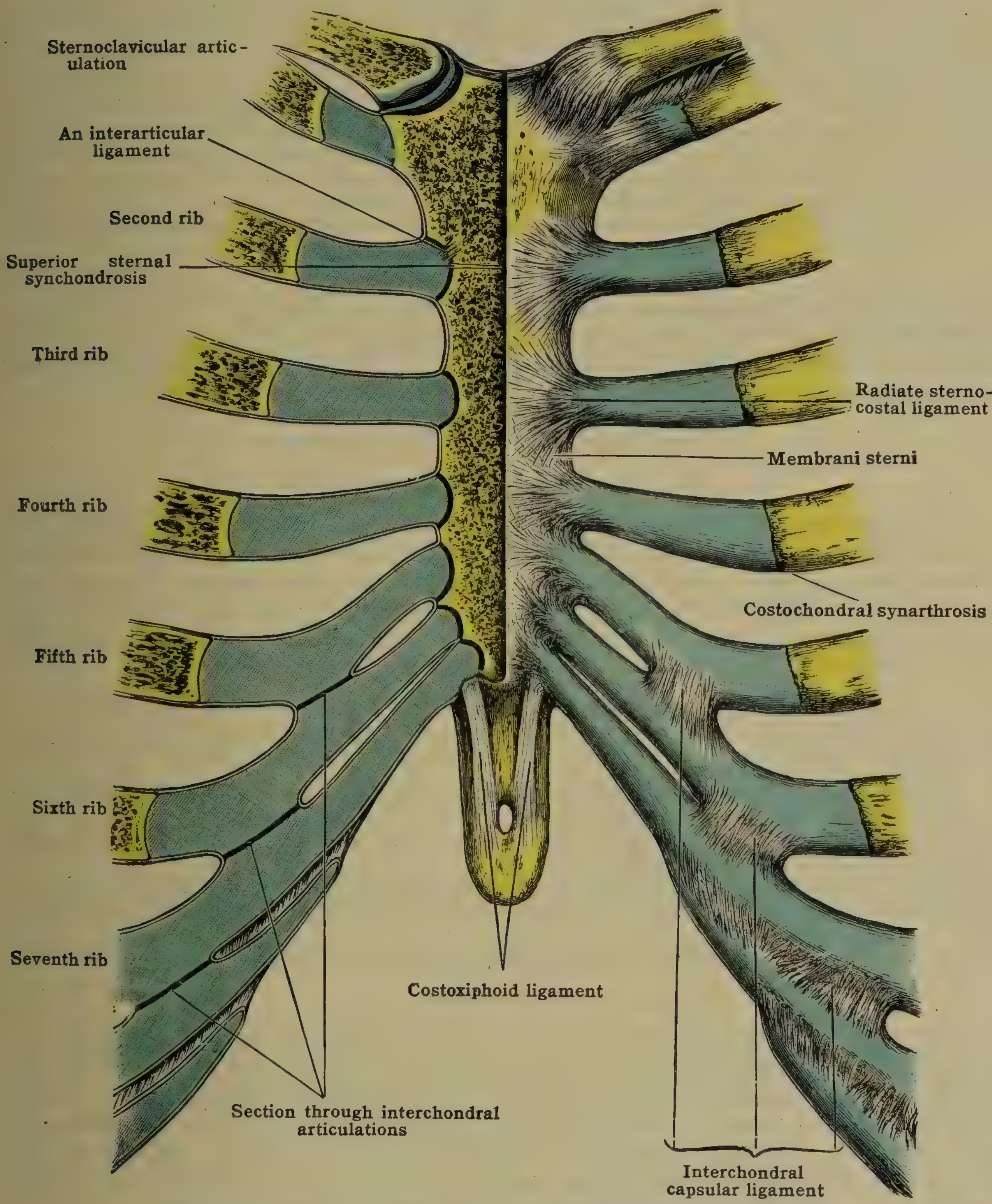


Fig. 333.—The Articulations at the Front of the Thorax. (Left side, showing ligaments; right side, the articular cavities.)

(b) The Costochondral Joints

[Synarthroses costochrondales—Fick]

The extremity of the costal cartilage is received into a cup-shaped depression at the end of the bony rib, which is somewhat larger than the cartilage. The two are joined together by the continuity of the investing membranes, the periosteum of the rib being continuous with the perichondrium of the cartilage. Calcification of the cartilage occurs at its junction with the rib.

In the sternal and vertebral ends of the intercostal spaces membranes uniting the costal elements are found in the planes of the intercostal muscles: **external intercostal ligaments** (not present in the tenth and eleventh, sometimes absent from the first space), and **internal intercostal ligaments.** Short ligamentous bands unite the cartilages of the seventh to tenth ribs where they stand in contact (see fig. 333).

(c) The Interchondral Articulations

Somewhat medial to the point where the costal cartilages bend upward toward the sternum (fig. 333) the sixth is united with the seventh, the seventh with the eighth, the eighth with the ninth, and the ninth with the tenth.

At this point each of the cartilages from the sixth to the ninth inclusive is wider than elsewhere, owing to the projection downward from its lower edge, of a broad blunt process which comes into contact with a somewhat concave surface of the cartilage next below. Each of the apposed surfaces is smooth, and they are connected at their margins by ligamentous tissue, which forms a complete **capsule** for the articulation, inclosing an articular cavity (fig. 333). The largest of these cavities is between the seventh and eighth; those between the eighth and ninth, and ninth and tenth are smaller, and are not free to play upon each other in the whole of their extent, being held together by ligamentous tissue at their anterior margins. Sometimes this fibrous tissue completely obliterates the synovial cavity.

The **arteries** are derived from the musculophrenic, and the **nerves** from the intercostals.

(d) The Intersternal Joints

The sternum being composed, in the adult, of three distinct pieces—the manubrium, body, and the xiphoid process—has two articulations, viz., the superior, which unites the manubrium with the body, and the inferior, which unites the body with the xiphoid.

1. The Superior Sternal Synchondrosis

[Synchondrosis sternalis superior]

The lower border of the manubrium and the upper border of the body of the sternum present oval-shaped, flat surfaces, with their long axes transverse, and covered with a thin layer of hyalin cartilage. An **interosseous fibrocartilage** is interposed between the surfaces; it corresponds exactly in shape and intimately adheres to them. At each lateral border this fibrocartilage enters into the formation of the second chondrosternal articulation (fig. 333).

In consistence it varies, being in some cases uniform throughout, in others softer in the center than at the circumference, and in others again an oval-shaped synovial cavity is found toward its anterior part. When such a cavity exists in the fibrocartilage this joint has a remote resemblance to the diarthroses.

The periosteum passes uninterruptedly over the joint from one segment of the sternum to the other, forming a kind of capsular ligament. This capsule is strengthened, especially on its posterior aspect, by longitudinal ligamentous fibers as well as by the radiating and decussating fibers of the chondrosternal ligaments.

In some instances the fibrocartilage is replaced by short bundles of fibrous tissue which unite the cartilage-coated articular bone surfaces. Synostosis sometimes occurs in old age.

2. The Inferior Sternal Synchondrosis

[Synchondrosis sternalis inferior]

The body is joined to the xiphoid cartilage by a thick investing membrane, by anterior and posterior longitudinal fibers, and by radiating fibers of the sixth and seventh chondrosternal ligaments. The **costoxiphoid ligament** [lig. costoxiphoideum] also connects the xiphoid with the anterior surface of the sixth and seventh costal cartilages, and thus indirectly with the body; and some fine fibroareolar tissue also connects the xiphoid with the back of the seventh costal cartilage.

The junction of the xiphoid with the body of the sternum is on a level somewhat posterior to the junction of the seventh costal cartilage with the sternum. The union is a synchondrosis, each bone being covered by hyalin cartilage which is connected with the intervening fibrocartilage plate.

MOVEMENTS OF THE THORAX

Movements.—In the *sternocostal articulations* movement takes place on two axes, (1) an anteroposterior, by which elevation and depression of the cartilage results, (2) a vertical axis on which movement of the cartilage occurs in a transverse plane. These movements are probably accompanied by some twisting of the costal cartilage, fastened as it is by its lateral end to the bony rib. At the *costochondral synarthrosis* the chief movement is upon an anteroposterior axis or axes permitting the widening or narrowing of the angle formed by the bony rib and cartilage in the 1–5 ribs, by the costal cartilage itself in the lower ribs. The *interchondral articulations* permit a small amount of gliding of the upper convex surface upon the lower concave surface of adjacent costal cartilages. At the *superior sternal synchondrosis* a forward projecting angle (angle of Louis) is made by the manubrium and corpus sterni. In

breathing, movement on a transverse axis takes place in this joint, by which the prominence of the angle of Louis varies. The range of movement is 14° in men and 12° in women (Rothschild). The costoxiphoid ligament of the *inferior sternal synchondrosis* tends to prevent the xiphoid cartilage from being drawn backward by the action of the diaphragm.

Movements of the ribs. *True ribs.*—The path followed by a rib in its movements is determined by the direction of the axis of its articulations with the spine and to less extent by its connections at its sternal end. The path will be at right angles to the axis and therefore will be longitudinal in the body and in an oblique plane inclined from behind and medially, forward and laterally. The movements of a rib are elevation and depression in this path. The rib is inclined downward and forward, and in rising, the obliquity of its axis of movement will affect the path of any point in the body of the rib: e.g., the anterior end of the rib in rising will also advance, because of the 'transverse element' in the oblique axis; it will also move laterally, on account of the 'sagittal element' in direction of the axis. The lower margin of the rib will also move toward the surface of the body.

The path followed by a *false rib* is not quite so well defined, owing to the differences in orientation of the costotransverse joint, less stability of the capitular joint in the absence of the interarticular ligament and the presence of interchondral joints. Movements of the eleventh and twelfth ribs have been observed to take an opposite direction from that of the upper ribs in the respiratory phases.

Movements of the sternum.—These are elevation and forward movement, and the reverse, taking place in the sternum as a whole, and caused by the movements, upward and downward, of the ribs. The manubrium undergoes but slight forward movement and because of this, the angle of Louis is flattened with the elevation and advance of the body of the sternum.

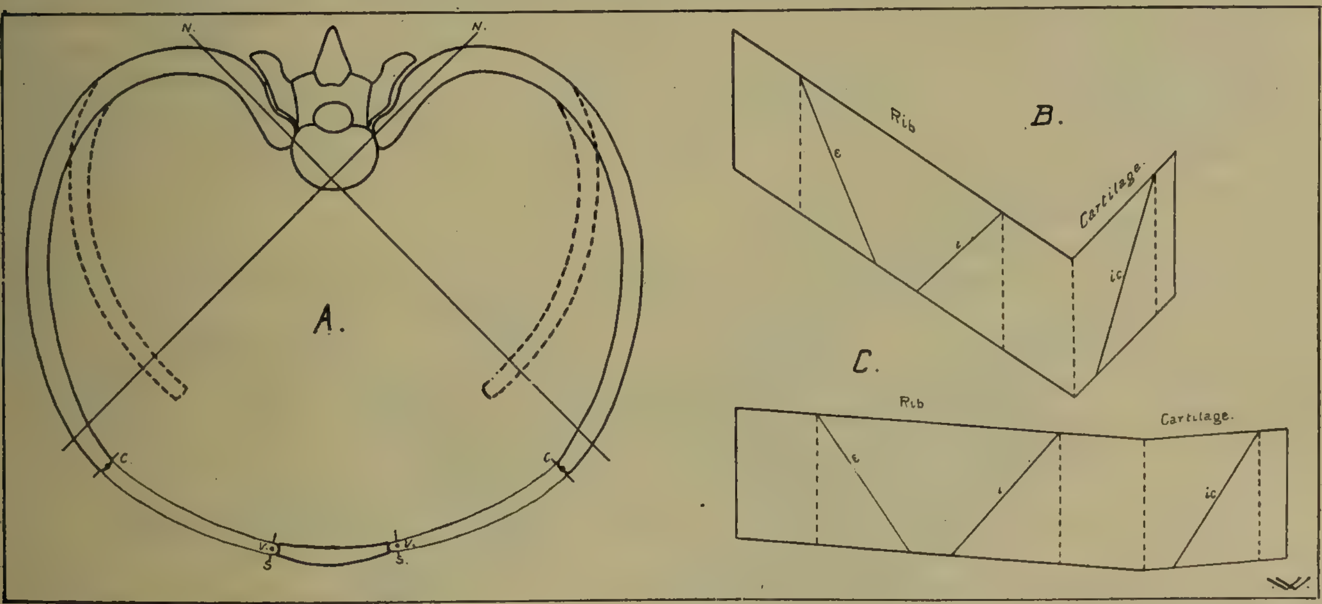


FIG. 334.—A. HORIZONTAL PROJECTION OF THE COSTAL RING FORMED BY THE FIFTH RIBS. N, axis about which the rib rotates, *c*, axis for costochondral joint; *s*, anteroposterior axis of chondrosternal joint; *v*, vertical axis of chondrosternal joint. B and C (after Fick). Hamberger's scheme for illustrating the action of the intercostal muscles. In B, the rib is depressed; in C, elevated. *e*, external intercostal; *i*, internal intercostal; *ic*, interchondral part of internal intercostal.

Movements of rib and costal cartilage.—Movements of the costal cartilage are the consequence chiefly of its connection with the bony rib, but the cartilage is probably also directly affected by muscular action. With elevation of a true rib the angle made with its costal cartilage, or the angle in the cartilage itself is widened, as if the cartilage were stretched. At the same time elevation of the cartilage occurs, together with forward shoving of its sternal end. The eversion of the rib is carried into slight torsion of the cartilage. In the absence of the flexible piece given by the costal cartilage, it would be impossible for the bony rib, articulated at both its ends, to follow the path determined by its oblique vertebral axis.

Movements of the thorax as a whole.—Each rib above the tenth moves on an axis which passes through the costotransverse and capitular articulations approximately parallel with the direction of the neck of the rib, fig. 334. The axes of rotation of the pairs of ribs converge in front to intersect in the mid-plane, in angles which diminish from above downward, following the differences in form of rib and vertebra in the upper and lower ends of the series. The movements which take place in the upper ribs for the same cause differ from those occurring in the pairs of lower ribs. During inspiration and expiration, the anterior extremities of the first pair of costal arches move up and down, the tubercles and the heads of the ribs acting in a hinge-like manner, around an axis whose direction tends to approach a right angle with the sagittal plane. By this movement the anterior ends of these costal arches are simply raised or depressed, and the manubrium very slightly elevated or lowered. (Cf. p. 574.)

The movements of the other ribs, particularly in the midregion of the thorax, are more complex, the axes of rotation tending to pass in a sagittal direction; so, besides the elevation of the anterior extremities, the bodies and angles of the ribs rise nearly as much as the extremities themselves. In this movement the tubercles of the ribs glide upward and backward in inspiration, and downward and forward in expiration.

During **inspiration** the cavity of the thorax is increased in every direction. The **anteroposterior diameter** is increased by the thrusting forward of the sternum, caused by the elevation of the costal cartilages and fore part of the ribs, whereby they are brought to nearly the

same level as the heads of the ribs. The **transverse diameter** is increased: (1) Behind, by the elevation of the middle part of the ribs; for when at rest the midpart of the rib is on a lower level than either the costovertebral or chondrosternal articulations. Owing to this obliquity the transverse diameter is increased when the rib is raised, and the increase is proportionate to the degree of obliquity. (2) By the eversion of the lower border of the rib, which turns outward as the rib is raised. (3) The transverse diameter is increased in front by the abduction of the anterior extremity of the rib and widening of the costochondral angle, at the same time as the rib is elevated and thrust forward.

The increase in the **vertical diameter** of the thorax is due to the elevation of the ribs, especially the upper ones, and the consequent widening of the intercostal spaces; but the chief increase in this direction is due to the descent of the diaphragm.

The greatest increase both in the anteroposterior and transverse diameters takes place where the ribs are longest, most oblique, and most curved at their angles, and where the bulkiest part of the lung is enclosed. This is on a level with the sixth, seventh, and eighth ribs.

At the lower part of the thorax, where the ribs have no relation to the lungs, and do not affect respiration directly by their movements, it is important that the ribs should be thrown well outward in order to counteract the compression of the abdominal viscera by the contraction of the diaphragm.

By widening and steadying the lower part of the thorax during inspiration, the attachments of the muscular fibers of the diaphragm are widened, and their power increased.

In **expiration**, the ribs rotate downward and inward and undergo inversion, the costochondral angle is narrowed, the sternum is lowered and retracted, the angle of Louis narrowed.

Muscles which take part in the movement of inspiration (cf. p. 574).—(*a*) *Ordinary inspiration;* The external and internal (?) intercostals, the diaphragm; the quadratus lumborum and serratus posterior inferior fixing the lower ribs, possibly the posterior fibers of the external oblique also helping to fix the lower ribs. (*b*) *Extraordinary inspiration:* The superior extremities are raised and fixed. The cervical part of the vertebral column and the head are extended, and in addition to the muscles of ordinary inspiration, the following muscles also come into play: The pectoralis minor, scalene, serrati, trapezius, the muscles which extend the head and the cervical part of the vertebral column, the sternomastoid and the supra- and infrahyoid muscles, the lower fibers of the pectoralis major, some of the lower fibers of the serratus anterior, and, when the clavicle is fixed, the subclavius.

Expiration is produced by the elasticity of the lungs and the weight of the walls of the thorax, aided by the elastic reaction and contraction of the costal part of the internal intercostals, subcostals, transverse thoracic, the external (?) and internal oblique muscles, the recti and pyramidales, the transversus abdominis, and the levatores ani and coccygei. In *forcible expiration* all muscles which depress the ribs and reduce the dimensions of the abdomen; the iliocostalis, serratus posterior inferior, longissimus dorsi are thrown into action. The internal intercostals probably tend to contract the thorax, excepting the interchondral parts, which tend to expand the thorax.

THE ARTICULATIONS OF THE UPPER EXTREMITY

The articulations of the upper extremity include those of the pectoral girdle (sternoclavicular and scapuloclavicular) as well those of the upper limb proper, as follows:

1. The **sternoclavicular articulation.**
2. The **scapuloclavicular union.**
3. The **shoulder-joint.**
4. The **elbow-joint.**
5. The **radioulnar union.**
6. The **hand-joint.**
7. The **radiocarpal** or **wrist-joint.**
8. The **carpal joints.**
9. The **carpometacarpal joints.**
10. The **intermetacarpal joints.**
11. The **metacarpophalangeal joints.**
12. The **interphalangeal joints.**

1. THE STERNOCLAVICULAR ARTICULATION

At the **sternoclavicular articulation** [articulatio sternoclavicularis] (figs. 333, 335, 336) the large medial end of the clavicle meets with its sternal articular surface, the clavicular notch of the manubrium sterni, and is united to it and to the first costal cartilage by ligaments. It is the only joint between the upper extremity and the trunk, and takes part in all the movements of the pectoral girdle. Looking at the bones, one would say that they were in no way adapted to articulate with one another, and yet they assist in constructing a joint of security, strength, and freedom of movement. The articular surfaces are incongruent, and the bones are nowhere in actual contact, being completely separated by an articular disk. The interval between the joints of the two sides varies from

2.5 to 4 cm. The ligaments of this joint are the articular capsule, sternoclavicular, interclavicular, articular disk, and costoclavicular.

The **articular capsule** (fig. 335) consists of fibers, having varying directions and being of differing strength and thickness, which completely surround the articulation, and are firmly connected with the edges of the articular disk.

The fibers at the back of the joint, sometimes styled the **posterior sternoclavicular ligament,** are stronger than those in front or below. The fibers in front, the **anterior sternoclavicular ligament,** are well marked, but more lax and less tough than the posterior, and are overlaid by the tendinous sternal origin of the sternomastoid, the fibers of which run parallel to those of the ligament. The fibers which cover the joint below are short, and consist more of fibroareolar tissue than true fibrous tissue; they extend from the upper border of the first costal cartilage to the lower border of the clavicle just lateral to the articular margin, and fill up the gap between it and the costoclavicular ligament. The superior portion consists of short tough fibers passing from the sternum to the articular disk and of others binding the fibrocartilage to the upper edge of the clavicle.

The **interclavicular ligament** [lig. interclaviculare] (fig. 336) is a strong, concave band, materially strengthening the superior portion of the capsule. It is about 6 mm. deep with a concavity upward, its upper border tapering to a narrow, almost sharp edge. It is connected with the posterior superior angle of the sternal extremity of each clavicle, and with the fibers which bind the articular disk to the clavicle, and then passes across from clavicle to clavicle along the posterior aspect of the upper border of the manubrium sterni. The lowest fibers are attached to the sternum, and join the posterior fibers of the capsule of each joint. In the

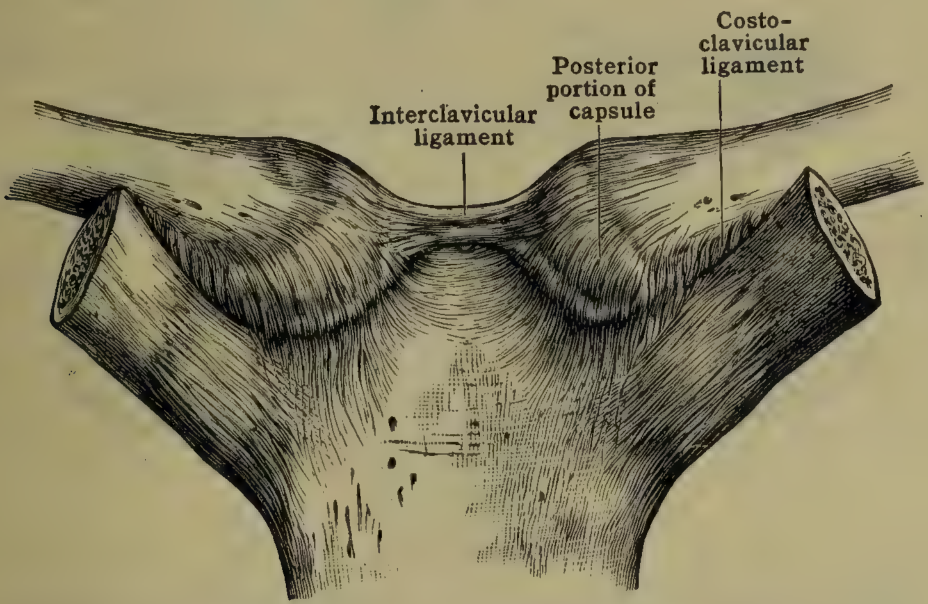


Fig. 335.—Posterior View of the Sternoclavicular Joint.

midline, between the ligament and the sternum, there is an aperture for the passage of a small artery and vein.

In addition to the interclavicular ligament, Carwardine (Journal of Anatomy and Physiology, vol. 7, n.s., p. 232) has described a special band of the upper portion of the sternoclavicular capsule which he proposes to name the 'suprasternal ligament.' It descends from the upper border of the sternal end of the clavicle to the upper border of the sternum, and is of special importance as it encloses the **suprasternal bones,** when these rudiments are present.

The **costoclavicular** (or rhomboid) **ligament** [lig. costoclaviculare] (fig. 335) is a strong dense band, composed of fine fibers massed together into a membranous structure. It extends from the upper border of the first costal cartilage (and rib), upward, backward, and distinctly laterally to the costal tuberosity on the under surface of the medial extremity of the clavicle, to which it is attached just lateral to the lower part of the capsule. It is from 1.5 to 2 cm. broad.

The **articular disk** [discus articularis] (fig. 336) is a flattened fibrocartilage of nearly the same size and outline as the medial articular end of the clavicle, which it fairly accurately fits. It is attached above to the upper border of the posterior edge of the clavicle; and below to the cartilage of the first rib at its union with the sternum, where it assists in forming the socket for the clavicle. At its circumference it is connected with the articular capsule, and this connection is very strong behind, and still stronger above, where it is blended with the interclavicular ligament.

The disk compensates for the incongruity of the two articular surfaces. It is usually thinnest below, where it is connected with the costal cartilage. It varies in thickness in different parts, sometimes being thinner in the center than at the circumference, sometimes the reverse, and is occasionally perforated in the center. It divides the joint into two compartments.

There are two **articular cavities** and two **synovial layers** (fig. 336); a lateral one, which is reflected from the clavicle and capsule over the lateral aspect of the disk and is looser than the medial one; the medial is reflected from the sternum over the medial side of the articular disk, costal cartilage, and capsule. Occasionally a communication takes place between them.

The **arterial supply** of the sternoclavicular joint is derived from branches—(1) from the internal mammary; (2) from the superior thoracic branch of the axillary; (3) twigs of a muscular branch often arising from the subclavian artery which pass over the interclavicular notch; (4) twigs of the transverse scapular (suprascapular) artery.

The **nerve-supply** is derived from the nerve to the subclavius and supraclavicular nerves.

Relations.—In front of the joint is the sternal head of the sternomastoid. Behind it are the sternohyoid and sternothyroid muscles. Still further back, on the right side, are the innominate and internal mammary arteries, and, on the left side, the left common carotid, the left subclavian, and the internal mammary arteries. Above and behind, between the sternomastoid and sternohyoid muscles, the anterior jugular vein passes back and laterally toward the posterior triangle of the neck.

The **movements** (cf. p. 575) permitted at this joint are various though limited, owing to the capsular ligament being moderately tense in every position of the clavicle. With the adaptable articular disk, conditions are provided for all the movements of a spherical joint, triaxial, a joint of 3° of freedom. Motion takes place in nearly every direction—viz., upward, downward, forward, backward, in a circumductory path and also rotatory. The upward and downward motions occur between the clavicle and the articular disk; during elevation of the shoulder, the upper edge of the clavicle with its attached articular disk is pressed into the sternal socket, and the lower edge glides away from the disk; during depression of the limb, the lower edge of the clavicle presses on to the disk, while the rest of the articular surface of the clavicle inclines laterally, bringing with it to a slight degree the upper edge of the articular disk. These movements occur on an anteroposterior axis drawn through the sternal end of the clavicle. The forward and backward motions take place between the articular disk and sternum, the clavicle with the disk gliding backward upon the sternum when the shoulder is brought forward, and forward when the shoulder is forced backward; these movements occur round an axis drawn nearly vertically through the manubrium sterni close to the clavicular notch. These angular movements may be combined in succession whereby the clavicle revolves upon the sternoclavicular joint and describes a circle at its acromial end carrying with it the scapula; in this circumductory movement the shaft of the clavicle travels in the mantle of a cone. Lastly, rotation of the bone on an axis passing through the shaft and the center of the sternal articulation is permitted.

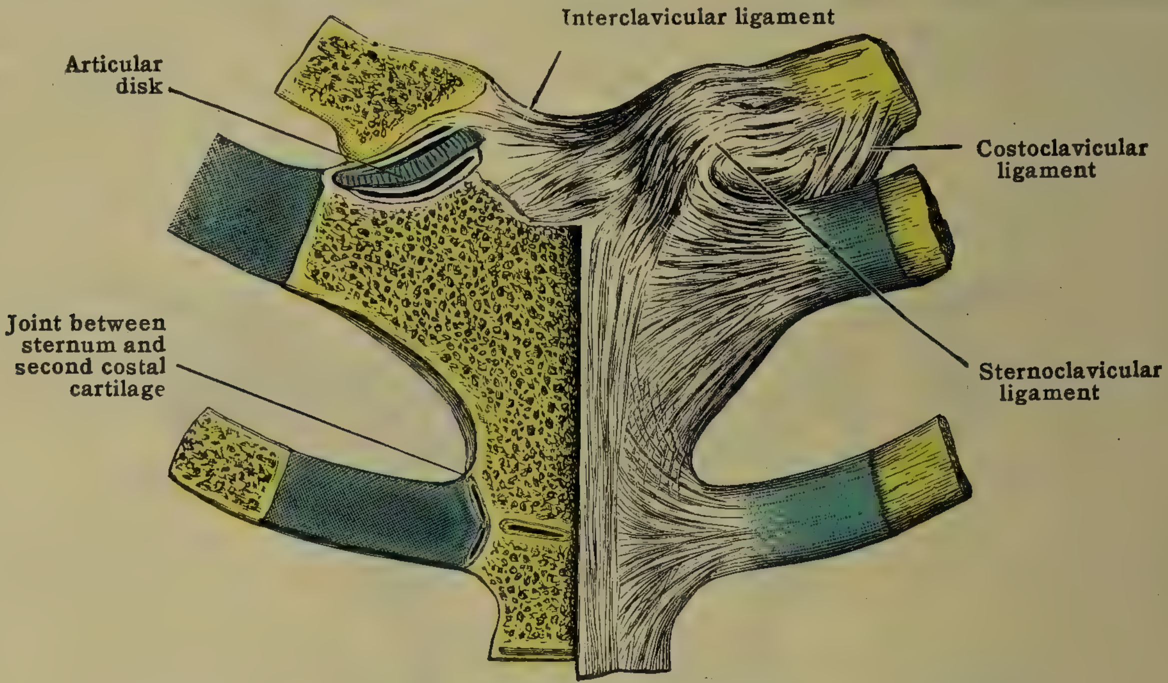


Fig. 336.—Anterior View of Sternoclavicular Joint, with Section showing Cavities opened on the Right Side.

The articular disk serves materially to bind the bones together, and to prevent the medial and upward displacements of the clavicle. It also forms an elastic buffer which tends to break shocks. The capsule, by being moderately tight, tends to limit movements in all directions, while the interclavicular ligament is a safeguard against upward displacement during depression of the arm. The costoclavicular ligament prevents dislocation upward during elevation of the arm, and resists displacements backward.

Muscles which move the clavicle at the sternoclavicular joint (cf. p. 575).—*Elevators.*—Trapezius (upper part), clavicular part of sternomastoid, levator scapulæ. *Depressors.*—Sub-

clavius, pectoralis minor, lower fibers of trapezius. Depression is aided by the weight of the upper extremity. *Protractors.*—Pectoralis major and minor, serratus anterior. *Retractors.*—Latissimus dorsi, trapezius (middle part), rhomboids. *Rotators.*—Trapezius and serratus anterior turn the clavicle so that the superior surface of the acromial end looks backward; rhomboideus major and pectoralis minor produce opposite rotatory movement.

Clinical relations.—The expanded end of the clavicle and the lack of proportion between this and the sternal facet, on which largely depends the mobility of the sternoclavicular joint, can easily be made out through the skin. The strength of the joint, considerable when the rarity of dislocation compared with fracture of the clavicle is considered, depends mainly on its ligaments, the buffer-bond meniscus, the costoclavicular ligament, which checks excessive upward and backward movements, and the fact that the elastic support of the first rib comes into play in strong depression of the shoulder as in carrying a weight. The relative weakness of the anterior ligament determines the greater frequency of anterior dislocation of the clavicle at this joint. Behind the joint lie, on the right side, the innominate artery, right innominate vein, and pleura; on the left, the left innominate vein, the left carotid, and the pleura.

2. THE SCAPULOCLAVICULAR UNION

The scapula is connected with the clavicle by a diarthrodial joint with its ligaments at the acromioclavicular articulation; and also by a set of ligaments passing between the coracoid process and the clavicle constituting a syndesmosis. So that we have to consider—

(*a*) The **acromioclavicular joint.**
(*b*) The **coracoclavicular union.**

(*a*) The Acromioclavicular Joint

The **acromioclavicular joint** [articulatio acromioclavicularis] is a diarthrosis uniting the acromial end of the clavicle and acromion process of the scapula. The articular surfaces of the two bones (see pp. 195, 198) are variable in size and form and there is usually an overriding of the clavicle upon the acromion. They are covered with thick layers of fibrocartilage. The joint is surrounded by an articular capsule and frequently contains an articular disk.

The **articular capsule** (figs. 339, 342) completely surrounds the articular margins and is composed of strong, coarse fibers arranged in parallel fasciculi, of fairly uniform thickness, which are attached to the borders as well as to the surfaces of the bones. It is somewhat lax in all positions of the joint, so that the clavicle is not tightly braced to the acromion. The fibers extend about 2 cm. along the clavicle posteriorly, but only 6 mm. anteriorly. Superiorly, they are attached to an oblique line joining these two points, while inferiorly they reach to the ridge for the trapezoid ligament with which they blend.

At the acromion they extend half way across the upper and lower surfaces, but at the anterior and posterior limits of the joint they are attached close to the articular facet. The anterior fibers become blended with the insertion of the coracoacromial ligament. The fibers are strengthened above by the aponeuroses of the trapezius and deltoid muscles; and all run from the acromion to the clavicle medially and backward. The upper portion of the capsule has been designated the **acromioclavicular ligament** [lig. acromioclaviculare].

The **articular disk** [discus articularis] is occasionally present, but is usually imperfect, occupying only the upper part of the joint where it is connected with the capsule; it may completely divide the joint into two cavities, or be perforated in the center. It is usually thicker at the edge than in the center, and some of the fibers of the articular capsule are blended with its edges. The **articular cavity** of the joint is accordingly either partially or entirely divided into two by the articular disk.

Relations.—Superiorly skin and fascia and the tendinous intersection between the deltoid and the trapezius. Inferiorly, the coracoacromial ligament and supraspinatus muscle. Anteriorly, part of the origin of the deltoid. Posteriorly, part of the insertion of the trapezius.

Arterial supply.—Acromial rete contributed to by branches of the subclavian, axillary and brachial arteries.

Nerves.—Anterior thoracic, suprascapular and axillary.

Movements.—Incongruent articular surfaces, thick cartilages and in some instances the presence of an articular disk, together with a sufficiently loose capsule give to this joint the freedom of movements on many axes, permitting the angular movements and rotation of the scapula on the end of the collar bone. The most important movement is a rotation of the scapula whereby the glenoid cavity is turned forward and upward, or downward. As these movements occur the inferior angle of the scapula moves forward as the glenoid cavity turns upward and the superior angle recedes.

The forward movement of the inferior angle is produced mainly by the inferior fibers of the serratus anterior, aided by the inferior fibers of the trapezius, and it is by this movement

that the arm is raised above the level of the shoulder. The reverse movement is produced mainly by the rhomboideus major and pectoralis minor, aided by the latissmus dorsi.

(b) The Coracoclavicular Union

[Syndesmosis coracoclavicularis]

The clavicle and scapula are further united by a strong syndesmosis between the acromial end of the former and the coracoid process of the latter. The uniting band, the **coracoclavicular ligament** [lig. coracoclaviculare] (figs. 337, 339, 342) consists of two parts, the conoid and the trapezoid ligaments.

The **conoid ligament** [lig. conoideum] is the medial and posterior portion, and passes upward and laterally from the coracoid process to the clavicle.

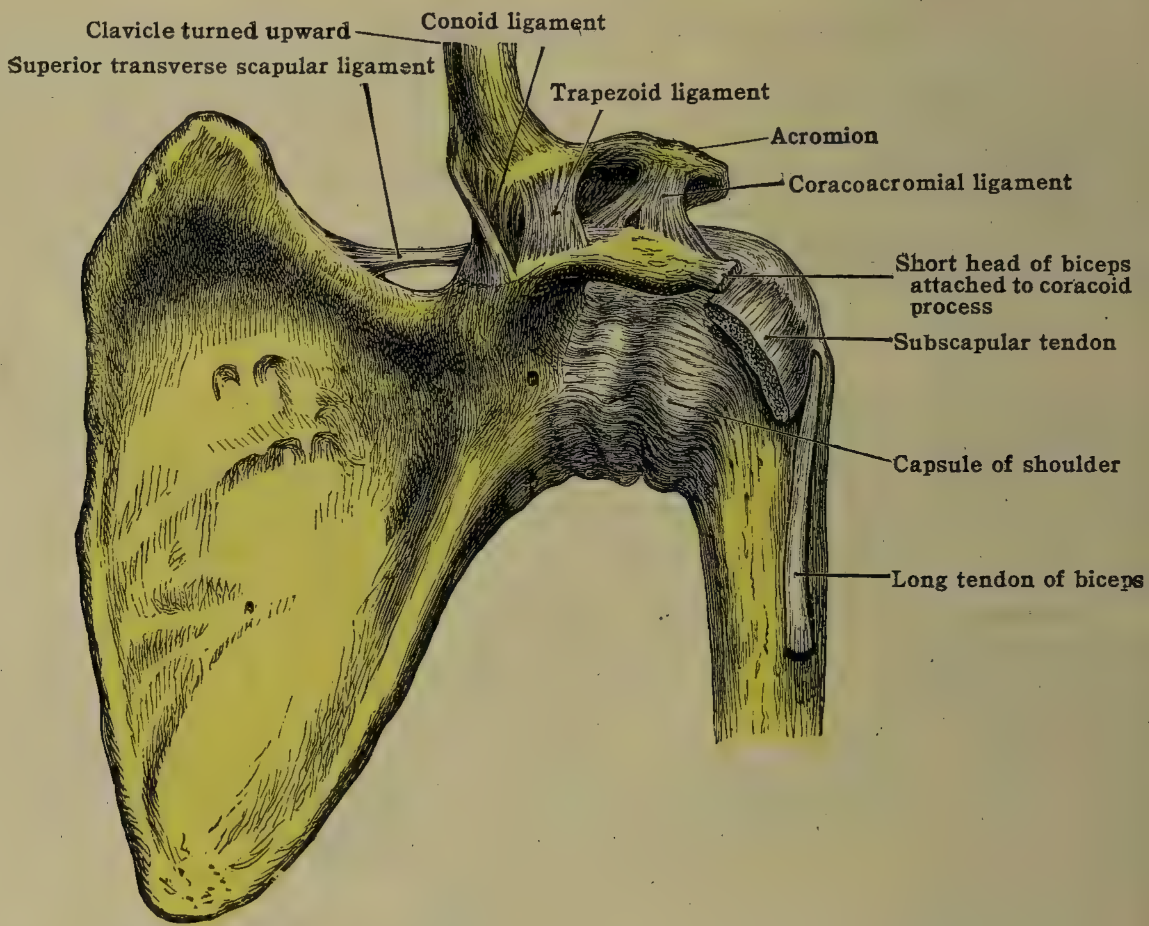


Fig. 337.—Anterior View of Shoulder, Showing also Coracoclavicular and Coracoacromial Ligaments.

It is a very strong and coarsely fasciculated band of triangular shape, the apex being fixed to the medial and posterior edge of the root of the coracoid process just in front of the scapular notch, some fibers joining the transverse ligament. Its base is at the clavicle, where it widens out, to be attached to the posterior edge of the inferior surface, as well as to the conoid tubercle. It is easily separated from the trapezoid, without being absolutely distinct. A small bursa often exists between it and the coracoid process; medially, some of the fibers of the subclavius muscle are often attached to it.

The **trapezoid ligament** [lig. trapezoideum] is the anterior and lateral portion of the coracoclavicular ligament. It is a strong, flat, quadrilateral plate of closely woven fibers, the surfaces of which look upward and medially toward the clavicle, and downward and laterally over the upper surface of the coracoid process.

At the coracoid it is attached for about 2.5 cm. to a rough ridge which runs forward from the angle, along the anterior border of the process. At the clavicle it is attached to the oblique ridge which runs laterally and forward from the conoid tubercle, reaching as far as, and blending with the inferior part of the acromioclavicular ligament. Its anterior edge is free, and overlies the coracoacromial ligament; the posterior edge is shorter than the anterior, and is in contact with the posterior and lateral portions of the conoid ligament. Two layers of the ligament are sometimes manifested, a bursa standing between them.

Besides the function of establishing a strong union of clavicle and scapula, the trapezoid ligament checks forward movement of the scapula and medial shoving of the acromion beneath the clavicle; the conoid is tightened when the shoulder blade is forced backward.

The **arterial supply** is derived from the transverse scapular, acromial branches of the thoracoacromial, and the anterior circumflex.

The **nerve-supply** is derived from the suprascapular and axillary nerves.

Movements of the pectoral girdle (cf. p. 575).—In the movements of the shoulder girdle, the scapula moves upon the lateral end of the clavicle, and the clavicle, in turn, carried by the uniting ligaments, moves upon the sternum; so that the entire scapula moves in arcs of circles centering at the sternocavicular joint (fig. 338). The scapula, in moving upon the clavicle, also moves upon the thorax forward and backward, upward and downward, and also in a rotatory direction upon an axis drawn at right angles to the center of the bone. In these gliding movements the scapula follows the curves of the chest wall, the changes in its orientation being permitted by the acromioclavicular joint. When the scapula advances the angle between clavicle and acromion widens, in the backward excursion the angle narrows. Throughout these movements the inferior angle and base of the scapula are kept in contact with the ribs by the latissimus dorsi, which straps down the former, and the rhomboids and serratus anterior, which brace down the latter. By means of the acromioclavicular joint, the scapula

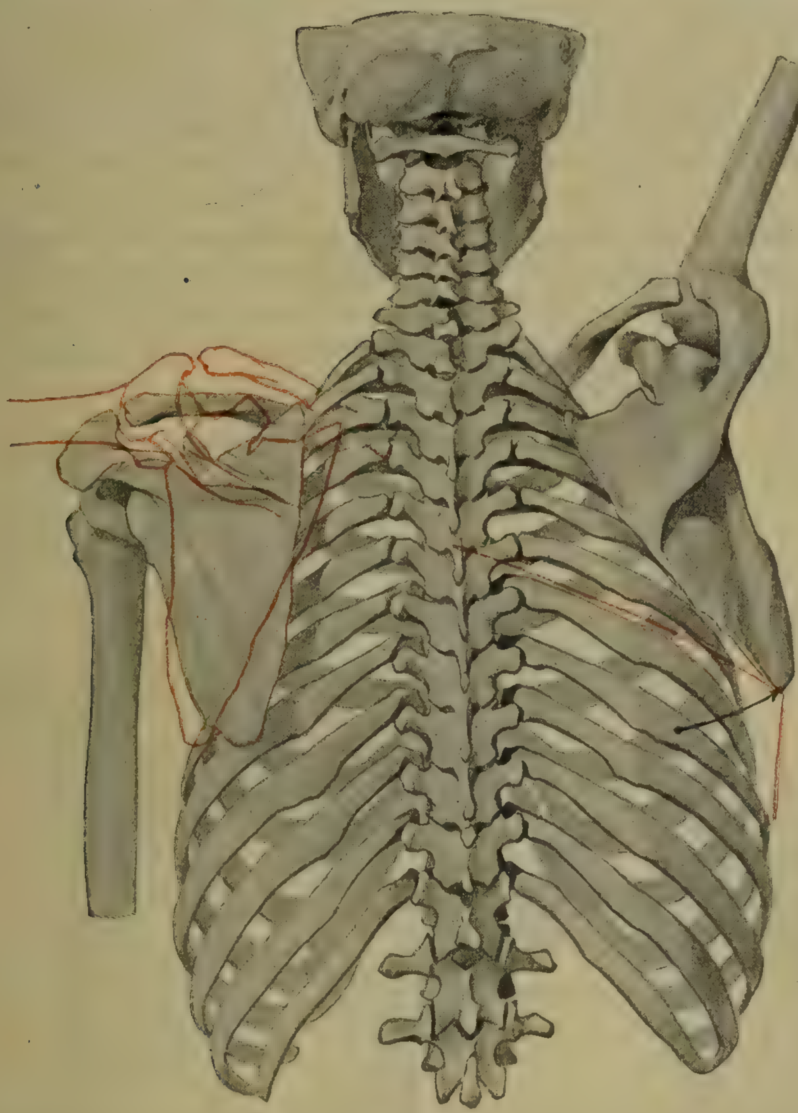


Fig. 338.—Abduction and Elevation of the Arm. (After Mollier, in Braus, Anatomie des Menschen.)

On the left, the arm and shoulder are at rest (solid color), and the arm elevated to the horizontal (red outline); apparently the clavicle and glenoid cavity are lifted. On the right, the arm is raised toward the vertical; the red line marks the outline of the rhomboideus and serratus anterior margin; the arrow indicates the path taken by the inferior angle of the scapula in moving from the resting position.

can be forcibly advanced upon the thorax, the glenoid cavity all the time keeping its face duly forward. Thus the muscles of the shoulder and forearm can be with advantage combined, as, for example, in giving a direct blow. The acromioclavicular joint also permits the lower angle of the scapula to be retained in contact with the chest wall during the rising and falling of the shoulder, the scapula turning in a hinge-like manner round the horizontal axis of the joint.

There are no ordinary actions in which the scapula moves on a fixed clavicle, or the clavicle on a fixed scapula; the two bones, bound together by their connecting ligaments, move in unison.

The Ligaments of the Pectoral Girdle

There are three intrinsic ligaments of the pectoral girdle [ligg. cinguli extremitatis superioris], which pass between different portions of the scapula, viz.—coracoacromial, superior transverse scapular, and inferior transverse scapular.

The **coracoacromial ligament** [lig. coracoacromiale] (figs. 337, 342) is a flat, triangular band with a broad base, attached to the lateral border of the coracoid process, and with a blunt apex fixed to the tip of the acromion. It is made up of two broad marginal bands, and a smaller and thinner intervening portion. The

anterior band, which arises from the anterior portion of the coracoid process, is the stronger, and some of its marginal fibers can often be traced into the short head of the biceps, which can then make tense this edge of the ligament. The **posterior band,** coming from the posterior part of the coracoid process, is also strong. The intermediate part, of variable extent, is thin and membranous; it is often incomplete near the coracoid process, leaving a small gap (fig. 337).

The superior surface of the ligament looks upward and a little forward, and is covered by the deltoid muscle; the inferior looks downward and a little backward, and is separated from the capsule of the shoulder-joint by the subacromial bursa and the tendons of the supraspinatus and subscapularis muscles. At the coracoid process it overlies the coracohumeral ligament. It is barely 8 mm. above the capsule of the shoulder, and in the undissected state there is scarcely a 6 mm. interval. The anterior band projects over the center of the head of the humerus, and is continued into a tough fascia under the deltoid; the posterior band is continuous with the fascia over the supraspinatus muscle. The coracoacromial ligament binds the two scapular processes firmly together, and so strengthens each; it holds the deltoid off the capsule of the shoulder, and protects this joint from slight injuries directed downward and backward against it.

The **superior transverse** (suprascapular) **ligament of the scapula** [lig. transversum scapulae superius] (figs. 337, 339) is a small triangular band of fibrous tissue, the surfaces of which look forward and backward; its edges, which are thin and sharp, are turned upward and downward. It continues the superior border of the scapula, bridging over the scapular notch.

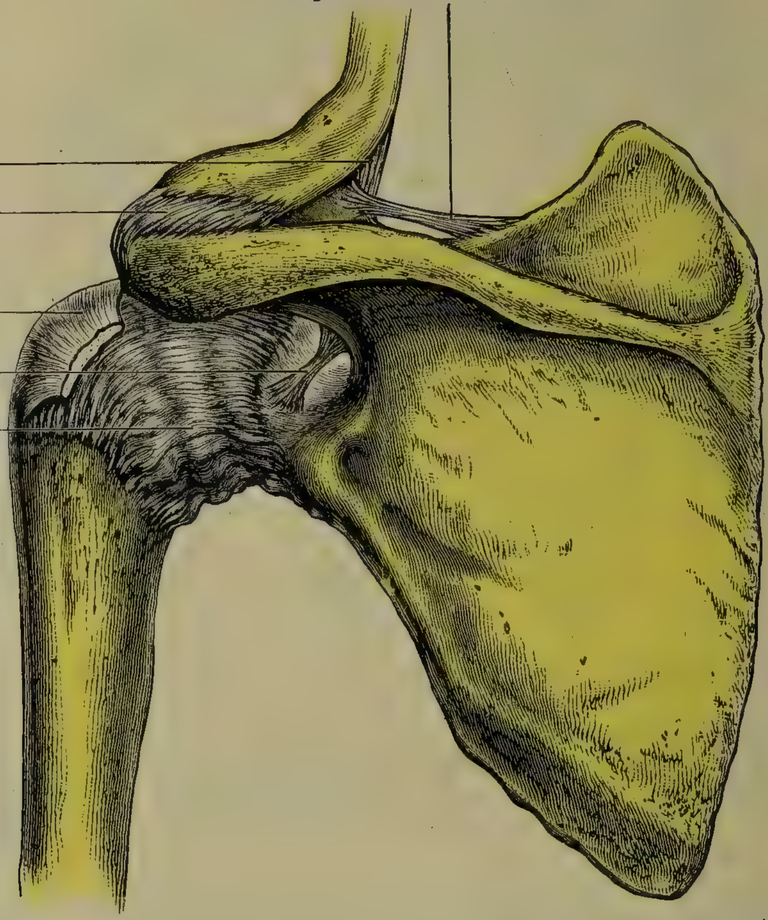


Fig. 339.—Posterior View of the Shoulder-joint, Showing also the Acromioclavicular Joint and the Special Ligaments of the Scapula.

It is broader medially, where it springs from the upper border of the scapula on its dorsal surface; and narrow laterally, where it is attached to the base of the coracoid process; some of its fibers are inserted under the edge of the trapezoid ligament, and others pass upward with the conoid to reach the clavicle. The transverse scapular (suprascapular) artery passes over it, and the suprascapular nerve beneath it. Medially, some fibers of the omohyoid muscle arise from it. The ligament is sometimes ossified, so converting the suprascapular notch into a bony walled foramen (normal in the sloths).

The weak **inferior transverse ligament** [lig. transversum scapulæ inferius] (fig. 339) reaches from the lateral border of the spine of the scapula to the margin of the glenoid cavity, and so forms a foramen through which the transverse scapular (suprascapular) vessels and suprascapular nerve gain the infraspinous fossa.

3. THE SHOULDER-JOINT

The **shoulder-joint** [articulatio humeri] is one of the most perfect and most movable of joints, the large spherical head of the humerus playing upon the

shallow concave, glenoid cavity of the scapula (see pp. 198, 201). It is retained in position much less by ligaments than by muscles, and, owing to the looseness of its capsule, as well as to all the other conditions of its construction and position, it is exceedingly liable to be displaced; on the other hand, it is sheltered from violence by the two projecting processes—the acromion and coracoid.

The ligaments of the shoulder-joint are the articular capsule, glenohumeral, coracohumeral, and glenoid lip.

The **articular capsule** (figs. 337, 339, also 340) is a loose sac, insufficient in itself to maintain the bones in contact. It consists of fairly distinct but not coarse fibers, closely woven together, and directed, some straight, others obliquely, between the two bones, a few circular ones being interwoven amongst them. At the scapula, it is fixed on the dorsal aspect to the prominent rough surface around the margin of the glenoid cavity, reaching as far as the neck of the bone. Superiorly, it is attached to the root of the coracoid process; anteriorly, to the ventral surface, at a variable distance from the articular margin, often reaching 12 mm. upon the neck of the bone, and thus allowing the formation of a pouch; it may not, however, extend for more than 6 mm. beyond the articular margin; inferiorly, it blends with the origin of the long head of the triceps. At

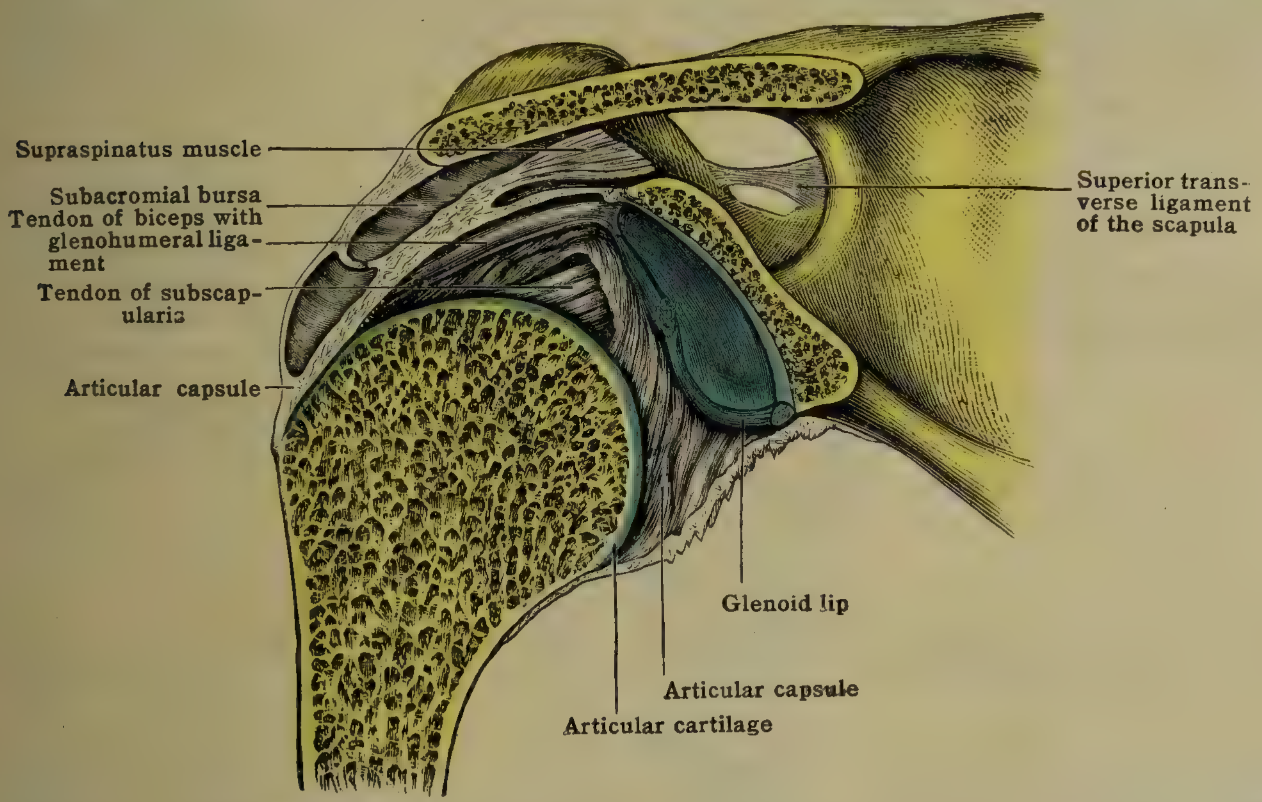


Fig. 340.—Vertical Section through the Shoulder-joint to Show the Glenohumeral Ligament.
(The joint is opened from behind.)

the humerus, the superior half is fixed to the anatomical neck, sending a prolongation downward between the two tubercles which attenuates as it descends, and covers the transverse humeral ligament. The lower half of the capsule descends upon the humerus further from the articular margin, some of the deeper fibers being reflected upward so as to be attached close to the articular edge, thus forming a kind of fibrous investment for the neck of the humerus. This ligament is more uniform in thickness than that of the hip.

The **synovial layer** of the capsule lines the glenoid ligament, and then continues with the fibrous layer of the capsule as far as its attachment to the humerus, from which it ascends as far as the edge of the articular cartilage. The tendon of the biceps receives a long tubular sheath, which is continuous with the synovial membrane, both at its attached extremity and at the bicipital groove, but is free in the rest of its extent. The synovial cavity almost always communicates with the bursa beneath the subscapularis, and sometimes with one under the infraspinatus muscle.

It also sends a pouch-like prolongation beneath the coracoid process when the fibrous capsule is attached wide of the margin of the glenoid fossa. A subcoracoid bursa, often connected with the subscapular bursa, opens widely into the shoulder joint. A few synovial fringes are near the edge of the glenoid cavity, and there is often one which runs down the medial edge of the biceps tendon, extending slightly below it and making a shallow groove for the tendon.

The **coracohumeral ligament** [lig. coracohumerale] (fig. 342) is a strong broad band, which is attached above to the lateral edge of the root and horizontal limb of the coracoid process nearly as far as the tip. From this origin it is directed backward along the line of the biceps tendon to blend with the capsule, and is inserted into the greater tubercle of the humerus.

Seen from the back, it looks like an uninterrupted continuation of the capsule, while from the front it appears as a fan-shaped prolongation from it overlying the rest of the ligament. At its origin there is sometimes a bursa between it and the capsule.

Glenohumeral bands of the capsule (figs. 340, 341).—There are three variable, accessory bands, the *superior, middle* and *inferior glenohumeral bands*, which project toward the interior of the joint from the fore part of the capsule and are consequently best seen when the joint is opened from behind.

The **middle** band reaches from the anterior margin of the glenoid cavity along the lower border of the subscapularis tendon to the lower border of the lesser tubercle; the **inferior** band from the inferior part of the glenoid cavity to the inferior part of the neck of the humerus. The **superior** band runs from the edge of the glenoid cavity at the root of the coracoid process, just medial to the origin of the long tendon of the biceps, and, passing laterally and downward at an acute angle to the tendon, for which it forms a slight groove or sulcus, is fixed to a depression, the fovea capitis humeri, above the lesser tubercle of the humerus. It is a thin, ribbon-like band, of which the superior surface is attached to the capsule, while the inferior is free and turned toward the joint. In the fetus it is often, and in the adult occasionally, quite free from the capsule, and may be as thick as the long tendon of the biceps (fig. 341).

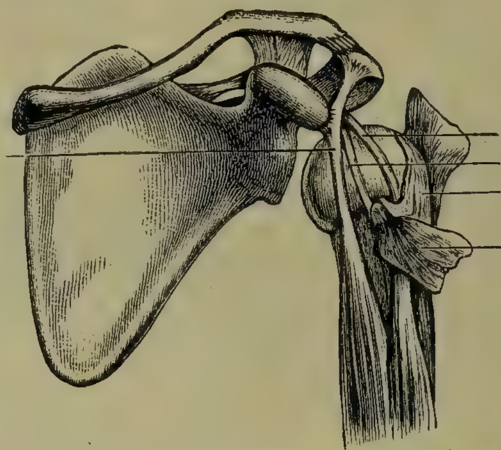


Fig. 341.—Fetal Shoulder-joint, Showing the Glenohumeral Ligament, and also the Short Head of the Biceps, being continuous with the Coracoacromial Ligament.

The tendons of the supra- and infraspinatus, teres minor, and subscapularis muscles strengthen and support the capsule, especially near their points of insertion, and can with difficulty be dissected off from it. The long head of the triceps supports and strengthens the capsule below. The capsule also receives an upward slip from the pectoralis major. The supraspinatus often sends a slip into the capsule from its upper edge (fig. 340).

The **glenoid lip** [labrum glenoidale] (labium articulare NK) (fig. 340) is a narrow rim of dense fibrocartilage, which surrounds the edge of the glenoid cavity and deepens it. It is about 6 mm. wide above and below, but less at its sides. Its peripheral edge is inseparably attached, near the bone, with the articular capsule. Its structure is almost entirely fibrous, with but few cartilage cells intermixed. At the upper part of the fossa the **biceps tendon** is prolonged into the glenoid lip, the tendon usually dividing and sending fibers into the medial and lateral sides of the ligament, which may wind round nearly the whole circumference of the socket.

The **articular cartilage** covering the glenoid cavity is thicker at the circumference than in the center, thus tending to deepen the cavity. It is usually thickest at the lower part of the fossa; over the head of the humerus the cartilage is thickest at and below the center. The cartilage is hyalin generally, but a spot near the center of the glenoid cavity is marked by fibrocartilage.

The **transverse humeral ligament** (fig. 342) is so closely connected with the capsule of the shoulder that, although it is a proper ligament of the humerus, it may well be described here. It is a strong band of fibrous tissue, which extends between the two tubercles, roofing in the intertubercular (bicipital) groove. It is covered by a thin expansion of the capsule. It is limited to the portion of the bone above the epiphysial synchondrosis (fig. 343).

Relations.—The following muscles are in contact with the capsule of the shoulder-joint. In front, the subscapularis; above, the supraspinatus; above and behind, the infraspinatus; behind, the teres minor; below, the long head of the triceps and the teres major. In the interval between the acromion and coracoacromial ligament above and the subscapularis and the supraspinatus tendons below, the subacromial bursa is interposed, lying close to the capsule and occasionally communicating with the cavity of the joint.

The axillary (circumflex) nerve and posterior circumflex artery pass beneath the capsule in the interval between the long head of the triceps, the humerus, and the teres major. When the arm is abducted, the long head of the triceps and the teres major are drawn into closer relation with the capsule and help to prevent dislocation of the humerus.

The axillary vessels, the great nerves of the axilla, the short head of the biceps, and the coracobrachialis are separated from the joint by the subscapularis, whilst the deltoid forms a kind of cap, which extends from the front to the back over the more immediate structures, the subdeltoid bursa intervening.

The **arterial supply** is derived from the transverse scapular (suprascapular), anterior and posterior circumflex, subscapular, circumflex scapular (dorsalis scapulæ) arteries, and a branch from the second portion of the axillary artery. **Lymph-vessels** in the capsule drain to the subclavian nodes.

The **nerve-supply** is derived from the suprascapular, by branches in both fossæ; and from the axillary (circumflex) and subscapular nerves.

The **movements** (cf. p. 576) of the shoulder-joint follow from its structure, namely a diarthrosis of spherical articular surfaces, a triaxial joint with three degrees of freedom. The inequality in size of the two articular surfaces, the shallowness of the glenoid cavity and the looseness of the articular capsule combine to make the shoulder joint most free in its range of movements. The axes pass through the head of the humerus one in a plane parallel to the

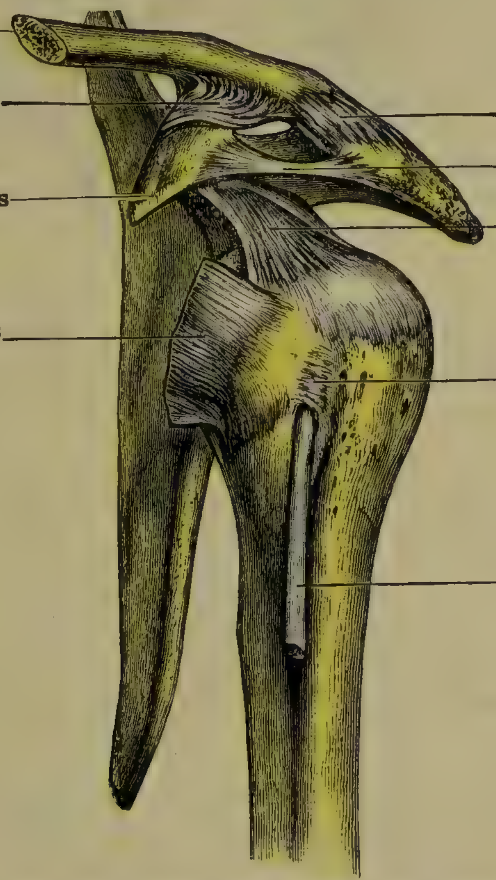


Fig. 342.—Lateral View of the Shoulder-joint, showing the Coracohumeral and Transverse Humeral Ligaments.

glenoid cavity, one in a plane at right angles to the center of the glenoid cavity, and the third from the center of the head longitudinally through the shaft of the humerus to the center of the capitulum. The gliding movements of the head around these axes in the glenoid cavity produce in the arm flexion, extension, adduction, abduction, circumduction and rotation. While the range of movements is great at the shoulder joint itself, still greater freedom of range for the upper limb follows from the participation of the joints of the shoulder girdle in many movements initiated at the shoulder.

Flexion is the swinging forward, *extension* the swinging backward, of the humerus; *abduction* is the raising of the arm from, and *adduction* depression of the arm to, the side. In flexion and extension the head of the humerus moves upon the center of the glenoid cavity round an oblique line corresponding to the axis of the head and neck of the humerus, flexion being more free than extension; in extreme flexion the scapula follows the head of the humerus, so as to keep the articular surfaces in apposition. In extension the scapula moves much less, if at all. In abduction and adduction the scapula is fixed, and the humerus rolls up and down upon the glenoid cavity; during abduction the head descends until it projects beyond the lower edge of the glenoid cavity, and the greater tubercle impinges against the arch of the acromion; during adduction, the head of the humerus ascends in its socket, the arm at length reaches the side, and the capsule is completely relaxed.

In *circumduction*, the humerus, by passing through these angular movements, describes a cone, whose apex is at the shoulder-joint, and the base at the distal extremity of the bone. *Rotation* takes place round a longitudinal axis drawn through the extremities of the humerus from the center of the head to the capitulum; in rotation medialward (that is, forward) the head of the bone rolls back in the socket as the great tubercle and shaft are turned forward; in rotation lateralward (that is, backward) the head of the bone glides forward, and the greater tubercle and shaft of the humerus are turned lateralward, i. e., backward.

Great freedom of movement is permitted at the shoulder, and this is increased by the mobility of the scapula. Restraint is scarcely exercised at all upon the movements of the shoulder by the ligaments, but chiefly by the muscles of the joint. In abduction, the lower part of the capsule is somewhat, and in extreme abduction considerably, tightened; and in rotation medialward and lateralward, the upper part of the capsule is made tense, as is also, in the latter movement, the coracohumeral ligament.

The movements of abduction and extension have a most decided and definite resistance offered to them other than by muscles and ligaments, for the greater tubercle of the humerus, by striking against the acromion process and coracoacromial ligament, stops short any further advance of the bone in these directions, and thus abduction ceases altogether as soon as the arm is raised to a right angle with the trunk, and extension shortly after the humerus passes the line

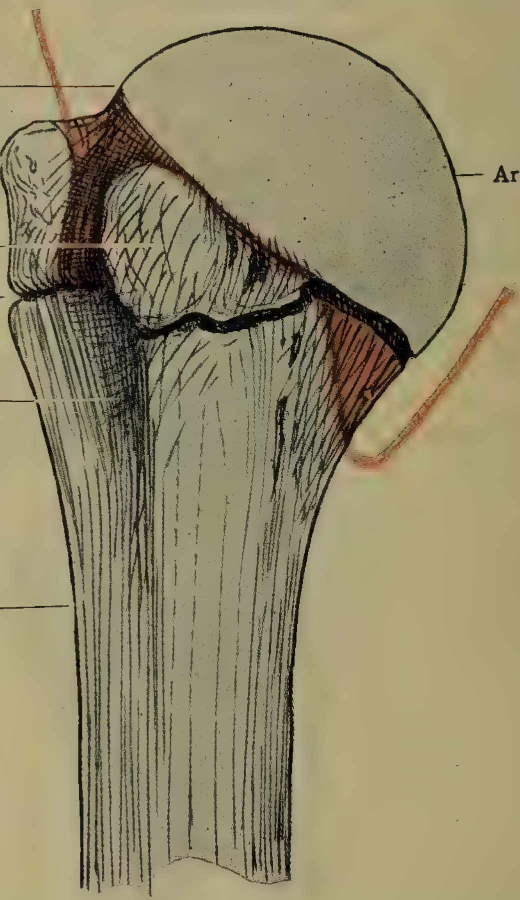


Fig. 343.—The Upper Extremity of the Humerus, Anterior View, to Show the Relation of the Articular Capsule of the Shoulder-joint (in red) to the Epiphysial Line.

of the trunk. Further elevation of the arm beyond the right angle, in the abducted or extended position is effected by the rotation of the scapula round its own axis by the action of the trapezius and serratus anterior muscles upon the sternoclavicular and acromioclavicular joints respectively (fig. 338).

The acromion and coracoid process, together with the coracoacromial ligament, form an arch, which is separated by the subacromial bursa and the tendon of the supraspinatus from the capsule of the shoulder. Beneath this arch the movements of the joint take place, and against it the head and tubercles are pressed when the weight of the trunk is supported by the arms; the greater tubercle and the upper part of the shaft impinge upon it when abduction and extension are carried to their fullest extent.

No description of the shoulder-joint would be complete without a short notice of the peculiar relation which the biceps tendon bears to the joint. It passes over the head of the humerus a little to the medial side of its summit, and lies free within the capsule, surrounded only by a tubular process of the synovial stratum. It is flat, with the surfaces looking upward and downward, until it reaches the intertubercular (bicipital) groove, when it assumes a rounded form. It strengthens the articulation along the same course as the coracohumeral ligament, and tends to prevent the head of the humerus from being pulled upward too forcibly against the inferior surface of the acromion. It also serves the purpose of a ligament by steadying the head of the humerus in various movements of the arm and forearm; it is let into a groove at the upper end of the bone, from which it cannot escape on account of the abutting tubercles and the strong transverse humeral ligament which binds it down. Further, it acts as do the four shoulder muscles which pass over the capsule, in keeping the head of the humerus against the glenoid socket; and, moreover, it resists the tendency of the pectoralis major and latissimus dorsi muscles, in certain actions when the arm is away from the side of the body, to pull the head of the humerus below the lower edge of the cavity.

Muscles which act upon the shoulder-joint (cf. p. 576).—*Flexors or protractors.*—Deltoid (anterior fibers), pectoralis major (clavicular fibers), coracobrachialis, biceps (short head), subscapularis (upper fibers). *Extensors or retractors.*—Latissimus dorsi, deltoid (posterior fibers), teres major, teres minor. *Abductors.*—Deltoid, supraspinatus, biceps (long head). *Adductors.*—Pectoralis major, latissimus dorsi, subscapularis, infraspinatus, teres major, teres minor, coracobrachialis, biceps (short head), triceps (long head). *Medial rotators.*—Pectoralis major, latissimus dorsi, teres major, subscapularis, deltoid (anterior fibers), long head of biceps. *Lateral rotators.*—Deltoid (posterior fibers), infraspinatus, teres minor. *Circumductors.*—The above groups acting consecutively.

Clinical relations of the shoulder-joint.—The frequency of **dislocations** here calls attention to the points contributing to make the joint alike insecure and safe. **Strength** is given by (1) the intimate blending of the tendons of the short scapular muscles, especially the subscapularis with the capsule; (2) the coracoacromial vault; (3) atmospheric pressure; (4) the long tendon of the biceps; (5) the elasticity of the clavicle; (6) the mobility of the scapula. The **weakness of the joint** is readily explained by its free mobility, the want of correspondence in area between the articular surfaces, its exposure to injury, and the length of the humeral lever.

The rent in the capsule is usually anterior and below, and to this spot the head of the humerus must be made to return. While dislocations are usually primarily subglenoid, owing to the lower part of the capsule being the thinnest and least protected, they take usually a secondarily forward direction, as the triceps prevents the head passing backward. The coracohumeral ligament usually remains intact and is used in manipulations to reduce the dislocation. In addition to the above features of the lower part of the capsule, laxity is here also a marked feature, allowing free abduction and elevation. This movement will be accordingly much checked by any inflammatory matting of this part of the capsule.

The **best incision for exploring the joint** is one commencing midway between the coracoid and acromion processes and carried downward parallel with the anterior fibers of the deltoid. The cephalic vein and biceps tendon are to be avoided. If drainage is needed, it must be supplied by a counter incision behind. This may be made along the posterior border of the deltoid, part of its humeral attachment being divided if necessary. The axillary (circumflex) nerve must be avoided in the upper part of the incision.

The subdeltoid bursa does not communicate with the shoulder-joint. It frequently becomes inflamed. When inflamed it may seriously interfere with movement of the shoulder joint. It may even become calcified, giving an *X*-ray shadow lateral to the head of the humerus.

Rupture, partial or complete, of the tendon of the supraspinatus is of frequent occurrence, may involve the joint, and must be differentiated from subdeltoid or subacromial bursitis.

4. THE ELBOW-JOINT

The **elbow-joint** [articulatio cubiti] is a complete hinge, and, unlike the knee, depends for its security and strength upon the configuration of its bones rather than on the number, strength, or arrangement of its ligaments. The bones composing it are the lower end of the humerus above, and the upper ends of the radius and ulna below; the articular surface of the humerus being received partly within the semilunar notch (great sigmoid cavity) of the ulna, and partly upon the cup-shaped area (fovea) of the radial head. Thus it will be noted that the elbow includes two articulations: the **humeroulnar** and **humeroradial joints** [articulatio humeroulnaris; humeroradialis]. Besides these which enter into the mechanism of the hinge movement, there is also present within the capsule of the elbow, the **proximal radioulnar articulation,** concerned in the movements of pronation and supination.

The articular surface of the humerus is covered with hyalin cartilage, thickest toward the radial margin, thinnest at the ulnar end; it may be absent in patches from the radial lip. The semilunar notch of the ulna presents two cartilage-covered surfaces separated by a groove devoid of cartilage. These surfaces are subdivided by a longitudinal 'guide ridge' into medial and lateral facets which meet the two convex surfaces of the trochlea, whereas the ridge is received by the trochlear groove.

The ligaments of the elbow form one large and capacious **capsule** [capsula articularis], which, by blending with the annular ligament of the radius, and then passing on to be attached to the neck of the radius, embraces the elbow and the superior radioulnar joints, uniting them into one (fig. 347). Laterally, the capsule is considerably strengthened by superadded fibers arising from the epicondyles of the humerus and inseparably connected with it. For convenience of description it will be spoken of as consisting of four portions: anterior, posterior, medial, and lateral.

The **anterior portion** (fig. 344) is attached to the front of the humerus above the articular surface and coronoid fossa, in an inverted V-shaped manner, to two very faintly marked ridges which start from the front of the medial and lateral epicondyles, and meet a variable distance above the coronoid fossa. Below, it is fixed, just beyond the articular margin, to the front of the coronoid process and it is intimately blended with the front of the annular ligament, a few fibers passing on to the neck of the radius.

The fibrous layer of the capsule varies in thickness, being in some cases so thin as barely to cover the synovial stratum; in others, thick and strong, and formed of coarse decussating fibers, the majority of which descend from the medial side laterally to the radius.

The **posterior portion** (fig. 345), thin and membranous, is attached superiorly to the humerus, in much the same inverted V-shaped way as the anterior; ascending from the medial epicondyle, along the medial side of the olecranon fossa nearly to the top; then, crossing the bottom of the fossa, it descends on the lateral side, skirting the lateral margin of the trochlear surface, and turns laterally along

FIG. 344.—MEDIAL VIEW OF THE LEFT ELBOW-JOINT. (Forearm in pronation.)

the posterior edge of the capitulum. Inferiorly, it is attached to a slight groove along the superior and lateral surfaces of the olecranon, and the rough surface of the ulna just beyond the radial notch, and to the annular ligament, some fibers passing on to the neck of the radius.

It is composed of decussating fibers, most of which pass straight or obliquely downward, a few taking a transverse course at the summit of the olecranon fossa where the ligament is usually thinnest.

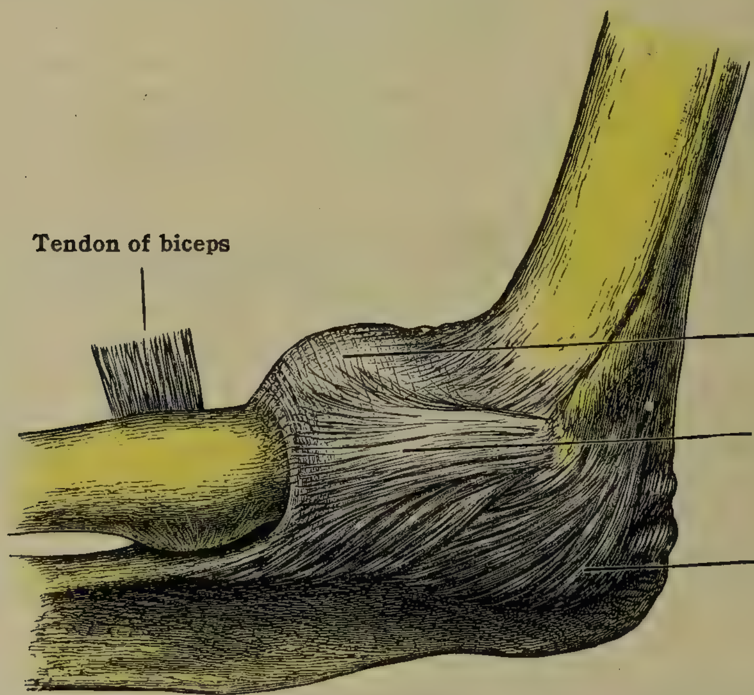


FIG. 345.—LATERAL VIEW OF THE LEFT ELBOW-JOINT. (Forearm in pronation.)

The **medial portion**, the **ulnar collateral ligament** [lig. collaterale ulnare] (fig. 344), is thicker, stronger, and denser than either the anterior or posterior portions. It is triangular in form, its apex being attached to the anterior and inferior aspect of the medial epicondyle, and to the condyloid edge of the groove between the trochlea and the epicondyle. The fibers radiate downward from this

attachment, the anterior passing forward to be fixed to the rough overhanging medial edge of the coronoid process; the middle descend less obliquely to a ridge running between the coronoid and olecranon processes, while the posterior pass obliquely backward to the medial edge of the olecranon just beyond the articular margin.

An oblique fibrous band (the *oblique ligament* of Cooper) connects the margin of the olecranon process with the margin of the coronoid process. It lies superficial to the posterior fibers of the ulnar collateral ligament.

The **lateral portion,** the **radial collateral ligament** [lig. collaterale radiale] (fig. 345), is attached above to the lower part of the lateral epicondyle, and from this the fibers radiate to their attachment into the lateral side of the annular ligament, some fibers being prolonged to reach the neck of the radius. The anterior fibers reach further forward than the posterior do behind. It is strong and well-marked, but less so than the medial portion.

The **synovial layer** lines the whole of the fibrous capsule of the elbow-joint, and extends into the superior radioulnar joint, lining the annular ligament.

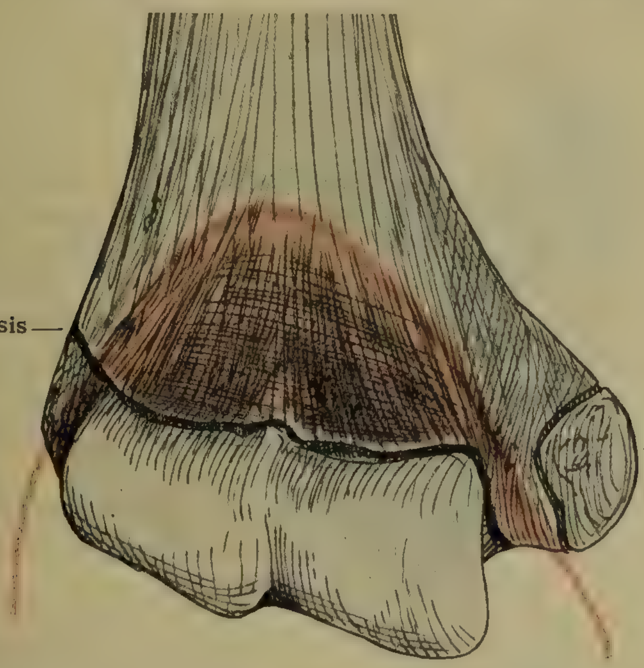


Fig. 346.—Lower Extremity of the Humerus, to Show the Relation of the Articular Capsule of the Elbow-joint (in Red) to the Epiphysial Lines.

It is reflected also into the several fossæ; olecranon, coronoid and radial, being separated from the bone by loose connective tissue and fat (figs. 346, 347).

Outside the synovial layer, but inside the fibrous capsule, are often seen some pads of fatty tissue; one is situated on the medial side at the base of the olecranon, another is seen on the lateral side projecting into the cavity between the radius and ulna; this latter, with a fold of synovial membrane opposite the front of the lateral lip of the trochlea, suggests the division of the joint into two parts—one medially for the ulna, and another laterally for the radius. There are also pads of fatty tissue at the bottom of the olecranon and coronoid fossæ, and at the tip of the olecranon process.

The **arterial supply** is derived from each of the vessels forming the free anastomosis around the elbow, and there is also a special branch to the front and lateral side of the joint, from the brachial artery, and from the arterial branch to the brachialis.

The **nerve-supply** comes chiefly from the musculocutaneous; the ulnar, median, and radial (musculospiral) also gives filaments to the joint.

Relations.—In front of the joint, and in immediate relation with the capsule, are the brachialis muscle, the superficial and deep branches of the radial (musculospiral) nerve, the radial recurrent artery, and the brachioradialis muscle. The brachial artery, the median nerve, and the pronator teres are separated from the capsule by the brachialis. Directly behind the capsule are the triceps, the anconeus, and the posterior interosseous recurrent artery. On the medial side are the ulnar nerve, the superior ulnar collateral (inferior profunda) artery, and the upper parts of the flexor carpi ulnaris and flexor digitorum sublimis muscles. On the lateral side lie the extensor carpi radialis longus and the upper part of the common tendon of origin of the superficial extensors of the wrist and fingers.

The **movements** permitted at the elbow (cf. p. 577) are those of a true hinge-joint, viz., flexion and extension modified by the spiral form of the trochlea and guiding ridge of the semilunar notch to result in a screw movement. The axis of these movements passes through the center of the capitulum and medial trochlear margin (fig. 313). These movements are oblique, so that the forearm is inclined medially in flexion, and laterally in extension; they are limited by the contact respectively of the coronoid and olecranon processes of the ulna with their corresponding fossæ on the humerus, and their extent is determined by the relative

proportion between the length of the processes and depth of the fossæ which receive them, rather than by the tension of the ligaments, or the bulk of the soft parts over them. The anterior and posterior portions of the capsule, together with the corresponding portions of the collateral ligaments, are not put on the stretch during flexion and extension; but, although they may assist in checking the velocity, and thus prevent undue force of impact, they do not control or determine the extent of these movements. The limit of extension is reached when the ulna is nearly in a straight line with the humerus; and the limit of flexion when the ulna describes an angle of from 30° to 40° with the humerus.

The obliquity of these movements is due to the lateral inclination of the upper and back part of the trochlear surface, and the greater prominence of the medial lip of the trochlea below; thus the plane of motion is directed from behind forward and medially, and carries the hand toward the middle third of the clavicle. The obliquity of the joint, the twist of the shaft of the humerus, and the backward direction of its head, all tend to bring the hand toward the midline of the body, under the immediate observation of the eye, whether for defence, employment, or nourishment. In flexion and extension, the cup-like depression of the radial head glides upon the capitulum, and the medial margin of the radial head travels in the groove between the capitulum and the trochlea. This allows the radius to rotate upon the humerus while following the ulna in all its movements. In full extension and supination, the head of the radius is barely in contact with the inferior surface of the capitulum, and projects so much backward that its posterior margin can be felt as a prominence at the back of the elbow. In full flexion the anterior edge of the radial head is received into, and checked against, the depres-

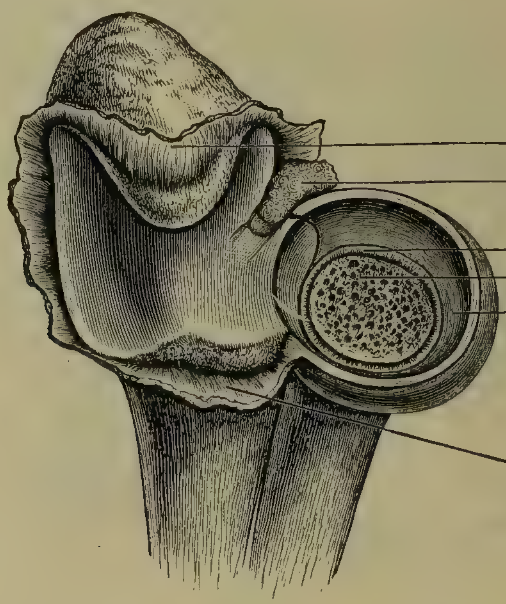


Fig. 347.—Annular Ligament and Capsule of the Elbow-joint.
(The head of the radius removed to show the membranous connection of the annular ligament with the radius.)

sion above the capitulum; while in midflexion the cup-like depression is fairly received upon the capitulum, and in this position, the radius being more completely steadied by the humerus than in any other, pronation and supination take place most perfectly.

Muscles which act upon the elbow-joint (cf. p. 577).—*Flexors.*—Brachialis, biceps, brachioradialis, pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis, flexor carpi ulnaris. *Extensors.*—Triceps, anconeus, and the muscles from the lateral epicondyle.

Clinical relations.—The **bony points**, epicondyles, olecranon, and head of radius, and their relation to one another, should be carefully studied. The *medial epicondyle* is the more prominent of the two, is directed backward as well as medially, and lies a little above its fellow. Above it, can be traced upward the supracondyloid ridge and corresponding intermuscular septum. The *lateral epicondyle* is more rounded, and thus less prominent; below, and a little behind it, the *head of the radius* can be felt moving under the capitulum when the forearm is supinated and flexed. A depression marks this spot and corresponds to the interval between the anconeus and brachioradialis and extensor carpi radialis longus; at the back, the upper part of the *olecranon* is covered by the triceps. The lower part is subcutaneous, and separated from the skin by a bursa. If the thumb and second finger be placed on the epicondyles and the index on the tip of the olecranon, and the forearm completely extended, the tip of the olecranon rises so as to be on the line joining the two epicondyles. In flexion at a right angle, the olecranon is below the line of the epicondyles, and in complete flexion quite in front of them. Between the medial epicondyle and olecranon is a pit, in which lie the ulnar nerve and the anastomosis between the inferior ulnar collateral and the posterior unlar recurrent arteries. The coronoid process is so well covered by muscles, vessels, and nerves that its position cannot be distinctly made out.

The articular cavity of the elbow-joint communicates with that of the superior radioulnar. Hence the facility with which tuberculous disease may be set up after neglected falls on the hand, in early life. At this time the weakness of the annular (orbicular) ligament leads to its being easily injured. Swelling, due to effusion into the joint, appears on either side of the triceps tendon, and soon obliterates the depression below the lateral epicondyle. The simplest incision of an infected elbow-joint is a longitudinal, on the lateral side of the olecranon. A superficial swelling over the tip of the olecranon is due to effusion into the subcutaneous bursa (miner's elbow). A deeper, less easily defined swelling in the same region is due to inflamma-

tion of the bursa between the olecranon and the triceps. A swelling on the medial side of the elbow-joint, if painful and accompanied by inflammation of the skin, may be due to mischief in the **epitrochlear lymphatic node** situated just above the medial epicondyle, and receiving lymphatics from the medial border of the forearm and the two medial fingers. The supracondyloid process occurs as a variation in one per cent. of white people, and has been mistaken for a pathological exostosis. It is usually easily discovered by palpating the humerus about 6 cm. (2 in.) above the medial epicondyle, from in front and medially, the elbow bring flexed; muscles relaxed.

5. THE UNION OF THE RADIUS WITH THE ULNA

The radius is firmly united to the ulna by two joints, and an intermediate fibrous union, viz.:—

(*a*) **The proximal radioulnar**—whereat the head of the radius *rotates* within the radial notch and annular ligament.

(*b*) The **union of the shafts**—the **mid-radioulnar union.**

(*c*) The **distal radioulnar**—whereat the lower end of the radius *rolls round* the head of the ulna.

(*a*) The Proximal Radioulnar Joint

[Articulatio radioulnaris proximalis]

The bones which enter into this joint (often included as a part of the elbow-joint) are the ulna by its radial notch and the radius by the smooth vertical circumferential articular surface on its head (see pp. 209, 213). These surfaces are covered by hyalin cartilage, in the case of the radial notch the thickness of the covering tending to lessen the curvature present in the bone. There is but one ligament special to the joint, viz., the annular ligament of the radius.

The **annular ligament of the radius** [lig. annulare radii] (fig. 347) consists of bands of strong fibers, somewhat thicker than the capsule of the elbow-joint, which encircle the head of the radius, retaining it against the side of the ulna. The bulk of these fibers forms about three-fourths of a circle, and they are attached to the anterior and posterior margins of the radial notch; some few are continued round below the radial notch, and form a complete ligamentous circle.

The ligament is inseparably connected along its upper edge and lateral (i. e., its nonarticular) surface with the anterior, posterior, and lateral portions of the capsule of the elbow, a few of the fibers of these portions, especially of the lateral, descending to be attached to the neck of the radius. The lower part of the articulation is covered in anteriorly, posteriorly, and laterally by a thin independent membranous layer, which passes from the lower edge of the annular ligament to the neck of the radius, strengthened on the lateral side by those fibers passing down from the capsule. They are loose enough to allow the bone to rotate upon its own axis (fig. 313). Medially and below the cavity is closed in by a loose membrane, the ligamentum quadratum, which passes from the lower border of the radial notch to the neck of the radius.

The **synovial layer** is a continuation of that of the elbow-joint, and, after lining the annular ligament, passes on to the neck of the radius, and thence up to the lower margin of the articular cartilage, forming there a pouch, the **recessus sacciformis.** A constant and conspicuous synovial fold projects into the angular crevice between the capitulum of the humerus and head of the radius.

The **arterial** and **nerve-supply** are the same as those to the lateral part of the elbow-joint.
Relations.—Behind lies the anconeus; in front the lateral border of the brachialis muscle.

(*b*) The Mid-Radioulnar Union

There are two interosseous ligaments which pass between the shafts of the radius and ulna and unite them firmly together in syndesmosis. These are the oblique cord and the interosseous membrane. (See fig. 551.)

The **oblique cord** [chorda obliqua] (fig. 344) is a fairly strong, narrow band, which passes from the lower end of the rough lateral border of the coronoid process, downward and laterally to be attached to the posterior edge of the lower end of the tuberosity of the radius and the ridge running from it to the medial border of the bone.

Some of its fibers blend with the fibers of insertion of the biceps tendon; the dorsal interosseous vessels pass in the space between it and the interosseous membrane.

The **interosseous membrane** [membrana interossea antibrachii] (fig. 344) is attached to the ulna at the lowest part of the ridge in front of the depression for the supinator, and along the whole length of the interosseous crest as far as

the inferior radioulnar articulation, approaching the front of the bone in the lower part of its attachment. To the radius it is attached along the interosseous crest, from 2.5 cm. below the tuberosity to the level of the ulnar notch.

It is strongest and broadest in the center, where the fibers are dense and closely packed; it is also well marked beneath the pronator quadratus, and thickens considerably at the lower end, forming a strong band of union between the two bones. Its fibers pass chiefly downward and medially, from the radius to the ulna, though some take the opposite direction; at the lower end some are transverse. Frequently there is a strong bundle as large as the oblique cord, the **inferior oblique ligament**, which stretches from the ulna, an inch and a half above its lower extremity, downward and laterally to the ridge above and behind the ulnar notch of the radius.

At its attachment to the bones, the interosseous membrane blends with the periosteum. Its upper border is connected with the oblique cord by a thin membrane, which is pierced by the dorsal interosseous vessels; and the lower border, which stretches across between the two bones just above the distal radioulnar articulation, assists in completing the capsule of that joint. Its anterior surface is in relation with the flexor digitorum profundus and flexor pollicis longus in the upper three-quarters, the lower fourth being in relation with the pronator quadratus. The volar interosseous vessels and nerve descend along the middle of the membrane, the artery being bound down to it. About an inch from the lower end it is pierced by the volar interosseous artery. The posterior surface is in relation with the supinator, abductor pollicis longus, extensor pollicis longus and brevis, and the extensor indicis proprius; at its lower part, also with the posterior branch of the volar interosseous artery, and the posterior interosseous branch of the radial nerve.

(*c*) The Distal Radioulnar Joint

[Articulatio radioulnaris distalis]

This is, in one respect, the reverse of the proximal; for the radius, instead of presenting a circular head to rotate within a concavity of the ulna, presents a concave surface which rolls round the head of the ulna. The articulation may be said to consist of two parts at right angles to each other; one between the ulnar notch of the radius and the articular circumference of the head of the ulna, and the other between the head of the ulna and the articular disk (see pp. 211, 214). The ulnar notch of the radius is covered by cartilage to a depth of 2 mm. Both articular surfaces of the ulna are cartilage-covered, fibrocartilaginous superficially, hyalin in the depth.

The ligaments are the articular disk and the articular capsule.

The **articular disk** [discus articularis] (fig. 350) assists the radius in forming an arch under which is received the first row of carpal bones. Its base is attached to the margin of the radius separating the ulnar notch from the articular surface for the carpus, while its apex is fixed to the fossa at the base of the styloid process of the ulna. It is joined by fibers of the ulnar collateral ligament of the wrist.

The articular disk measures about 1 cm. from side to side and from before backward. It is thicker at the circumference, where it is fixed to the articular capsule, than in the center; smooth and concave above to adapt itself to the ulna, and smooth and slightly concave below to fit over the triquetral bone. Its anterior and posterior borders are united to the volar and dorsal radioulnar and radiocarpal ligaments. It is the most important structure in the inferior radioulnar articulation, as it is a very firm bond of union between the lower ends of the bones, and serves to limit their movements upon one another more than any other structure in either the upper or lower radioulnar joints. Its structure is fibrous at the circumference, while in the center there is a preponderance of cells. It differs from all other fibrocartilages in entering into two distinct articulations; and separates entirely the articular cavity of the radioulnar joint from that of the wrist.

The lower end of the **interosseous membrane** extends between the ulna and radius immediately above their points of contact. Transverse fibers between the two bones form a sort of arch above the concave ulnar notch of the radius and complete above the articular capsule of the distal radioulnar joint. The following ligaments, sometimes differentiated, represent merely thickenings of the capsule.

The **volar radioulnar ligament** (fig. 348) is attached by one end to the anterior edge of the ulnar notch of the radius, and by the other to the rough bone above the articular surface of the ulna, as well as into the anterior margin of the articular disk from base to apex.

The **dorsal radioulnar ligament** (fig. 349) is similarly attached to the posterior margin of the ulnar notch at one end, and at the other to the rough bone above the articular surface of the extremity of the ulna as far medially as the groove for the extensor carpi ulnaris, with the sheath of which it is connected, as well as into the whole length of the posterior margin of the articular disk. Both the radioulnar ligaments consist of thin, almost scattered fibers.

The **articular capsule** is remarkably loose, is attached to the radius and ulna in proximity to their articular surfaces as described for its special thickenings, the radioulnar ligaments. The **synovial layer** is large and loose in proportion to the size of the joint, reaching upward between the radius and ulna above the level of their articular surfaces to form the **recessus sacciformis.** The articular cavity extends between the terminal articular surface of the ulna and the upper surface of the articular disk.

The **arterial supply** is derived from the volar and dorsal interosseous arteries and branches of the volar and dorsal carpal retia.

The **nerve-supply** comes from the volar interosseous of the median, and the dorsal interosseous of the radial.

Relations.—Behind lies the tendon of the extensor digiti quinti proprius and in front the flexor digitorum profundus.

The movements of the radius (cf. p. 577).—The upper end of the radius rotates upon an axis drawn through the center of its own head and neck within the collar formed by the radial notch and the annular ligament, while the lower end, retained in position by the articular disk glides round the head of the ulna on an axis that passes at right angles to the articular disk at the point of its attachment to the ulna. The entire radius then revolves upon an axis passing from the center of the capitulum of the humerus above to the pit at the base of the styloid process of the ulna below. The combination of the proximal and distal radioulnar joints gives a uniaxial articulation with one degree of freedom; and the cylindrical form of the articular surfaces with longitudinal axis places the combination in the subclass trochoides of diarthrodial joints. The rotation described on the longitudinal axis is called *pronation*, when the radius, from a position nearly parallel to the ulna, turns medialward so as to lie obliquely across it; and *supination*, when the radius turns back again, so as to uncross and lie nearly parallel with the ulna. In these movements the radius carries with it the hand, which rotates on an axis passing along the ulnar side of the hand; thus, the hand when pronated lies with its dorsum upward, as in playing the piano, while when supinated, the palm lies upward—the attitude of a beggar asking alms. Ward thus expresses the relations of the two extremities of the radius in pronation and supination: 'The head of the radius is so disposed in relation to the sigmoid cavity (ulnar notch) at the lower end that the axis of the former if prolonged falls upon the center of the circle of which the latter is a segment;' the axis thus passes through the lower end of the ulna at a point at which the articular disk is attached, and if prolonged further, passes through the ring finger. Thus the radius describes, in rotating, a blunt-pointed cone whose apex is the center of the radial head, and whose base is at the wrist; partial rotation of the bone being unaccompanied by any hinge-like or anteroposterior motion of its head, and pronation and supination occurring without disturbance to the parallelism of the bones at the superior radioulnar joint. Associated with this rotation in the ordinary way, there is some rotation of the humeroulnar shaft, which causes lateral shifting of the hand from side to side; thus, with pronation there is some abduction, and with supination some adduction combined, so that the hand can keep on the same superficies in both pronation and supination. The power of supination in man is much greater than pronation, owing to the immense power and leverage obtained by the curve of the radius, and by the attachment of the biceps tendon to the back of the tuberosity. For this reason all our screw-driving and boring tools are made to be used by supination movements of the right hand.

In the undissected state, the amount of rotation it is possible to obtain is about 135°, so that neither the palm nor the fore part of the lower end of the radius can be turned completely in opposite directions yet in the living subject this amount can be greatly increased by rotation of the humeroulnar shaft at the shoulder-joint.

Pronation is checked in the living subject by (a) the dorsal inferior radioulnar ligament, which is strengthened by the connection of the sheath of the extensor tendons with it; (b) the lowermost fibers of the interosseous membrane; (c) the back part of the ulnar collateral and adjacent fibers of the posterior ligament of the wrist, and (d) the meeting of the soft parts on the front of the forearm.

Supination is checked mainly (a) by the medial ulnar collateral ligaments of the wrist, but partly also by (b) the oblique cord; (c) the volar inferior radioulnar ligament, and (d) the lowest fibers of the interosseous membrane.

The interosseous membrane serves, from the direction of its fibers downward and medially from the radius to the ulna, to transmit the weight of the body from the ulna to the radius in the extended position of the elbow, as in pushing forward with the arms extended, or in supporting one's own weight on the hands, the ulna being in intimate contact with the humerus, but not at all with the carpus; while the area of contact of the radius with the humerus is small, and that of the radius with the carpus large. Hence the weight transmitted by the ulna is communicated to the radius by the tightening of the interosseous membrane. Conversely, in falls upon the hand with the arm extended, the interosseous membrane acts as a sling to break the violence of the shock, and prevents the whole force of the impact from expending itself directly upon the capitulum.

Muscles which act upon the radioulnar joints (cf. p. 577).—*Pronators.*—Pronator teres, pronator quadratus, flexor carpi radialis, palmaris longus. *Supinators.*—Biceps, supinator, extensor pollicis longus. The brachioradialis is chiefly a flexor of the elbow-joint, but it takes part in the initiation of the movements of supination, when the hand is fully pronated, and of pronation when the hand is fully supinated.

Clinical relations.—The position of the **proximal radioulnar joint** is marked by a dimple about 12 mm. (½ in.) below the lateral epicondyle. The **distal radioulnar joint** can just be felt, when the forearm is pronated, between the head of the ulna and lower end of the radius. The recessus sacciformis here may be enlarged in rheumatic and other affections. The **interosseous**

membrane not only ties the bones together and gives attachment to muscles, but in falls on the hand it enables the ulna to participate in the shock.

6. THE HAND JOINT

The **hand joint** [articulatio manus] is constituted by the series of diarthrodial articulations between the bones of the wrist (excepting the pisiform) and the joint between the wrist bones and the radius, the **radiocarpal articulation.** The carpal bones are aligned in a proximal and a distal row, the **intercarpal articulation** being formed between them.

7. THE RADIOCARPAL OR WRIST-JOINT

The radiocarpal articulation [articulatio radiocarpea] is formed by the union of the radius and articular disk above, articulating with the navicular, lunate, and triquetral bones below; the ulna being excluded by the intervention of the

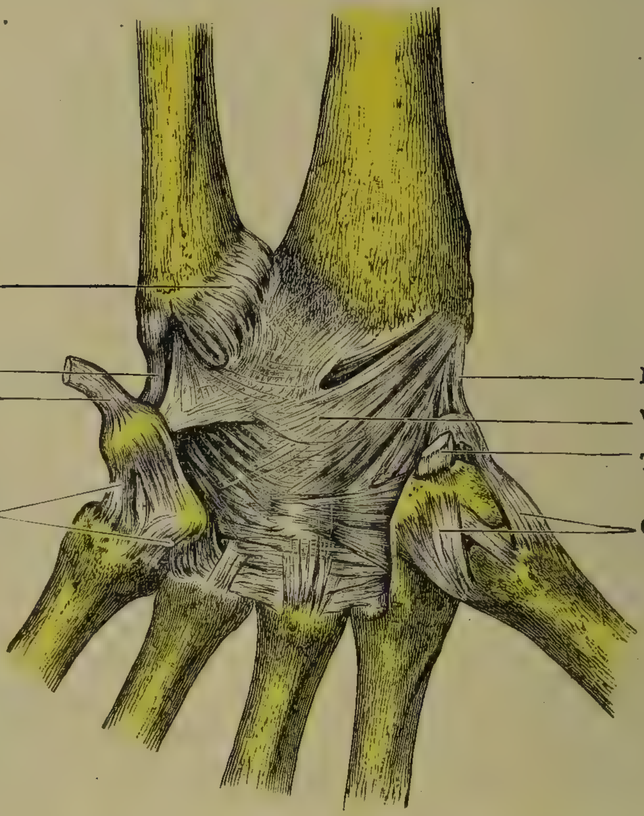


Fig. 348.—Volar View of Wrist-joint.

articular disk. The radius and disk together present a smooth surface, slightly concave both from before backward, and from side to side, whilst the three bones of the proximal row of the carpus present a smooth, oval surface, made uniformly even by the interosseous ligaments which bind them together (see fig. 350). The carpal articular surface of the radius and the opposing articular surfaces of the carpal bones are cartilage-covered. The articular capsule is extensive; the **articular cavity** is sometimes continuous with that of the distal radioulnar joint.

The **capsule** of the wrist-joint has usually been described as four separate ligaments, and it will be convenient for the sake of a complete description to follow this method; but it must be understood that these four portions are continuous around the joint, extending from styloid process to styloid process on both its aspects. The four portions are the volar radiocarpal, the dorsal radiocarpal, the ulnar collateral, and the radial collateral.

The **volar** (or anterior) **radiocarpal** [lig. radiocarpeum volare] (fig. 348) is a thick strong ligament, attached superiorly to the radius immediately above the anterior margin of the terminal articular facet, to the curved ridge at the root of the styloid process of the radius, and to the anterior margin of the articular disk, blending with some fibers of the capsule of the inferior radioulnar joint. It passes downward and in a medial direction to be attached to both rows of carpal bones, especially the second, and to the volar intercarpal ligament.

The strongest and most oblique fibers arise from the root of the styloid process of the radius, and pass obliquely over the navicular, with which only a few fibers are connected, to be inserted into the lunate, capitate, and triquetral bones. Another set, less oblique, passes from the

margin of the facet for the lunate to be attached to the adjacent parts of the capitate, hamate, and triquetral bones. Between the two sets of fibers, small vessels pass into the joint.

The **dorsal** (or posterior) **radiocarpal ligament** [lig. radiocarpeum dorsale] (fig. 349) is attached above to the dorsal edge of the lower end of the radius, the back of the styloid process, and the posterior margin of the articular disk. It passes downward and in a medial direction to be connected with the first row of of the carpal bones, chiefly with the lunate and triquetral, and the dorsal intercarpal ligament. This ligament is thin and membranous.

It is strengthened by (1) strong fibers passing from the back of the articular disk where they are blended with the dorsal inferior radioulnar ligament, and, from the edge of the radius just behind the ulnar notch, to the triquetral bone; (2) from the ridge and groove for the extensor pollicis longus to the back of the lunate and triquetral bones; and (3) from the groove for the radial extensors to the back of the navicular and lunate. It is in relation with, and supported by, the extensor tendons which pass over it.

The **ulnar collateral ligament of the wrist** [lig. collaterale carpi ulnare] (fig. 349) is fan-shaped, with its apex above, at the styloid process of the ulna, to which it is attached on all sides, blending with the apex of the articular disk. Some of the fibers pass forward and laterally to the base of the pisiform bone and to the

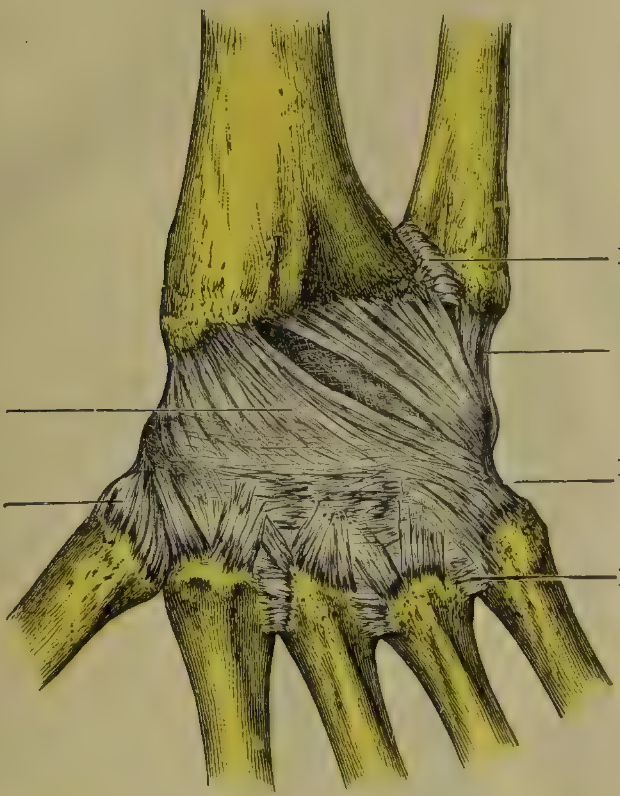


FIG. 349.—DORSAL VIEW OF WRIST-JOINT.

medial part of the upper border of the transverse carpal ligament, where it is attached to the pisiform bone; they form a thick, rounded fasciculus on the front of the wrist. Other fibers descend vertically to the medial side of the triquetral bone, and others again laterally to the dorsal surface of the triquetral. The tendon of the extensor carpi ulnaris is posterior to, and passes over, part of the fibers of the ligament.

The **radial collateral ligament of the wrist** [lig. collaterale carpi radiale] (fig. 348) consists of fibers which radiate from the fore part and tip of the styloid process of the radius. Some pass downward and medially, in front, to the navicular and adjacent edge of the capitate; some downward, a little forward and medially, to the tubercle of the navicular and ridge of the greater multangular; and others downward and laterally to the rough dorsal surface of the navicular.

The fibers of this ligament are not so long and strong, nor do they radiate so much as those of the ulnar collateral ligament. It is in relation with the radial artery, and the tendons of the abductor pollicis longus and extensor pollicis brevis, the artery separating them from the ligament.

The **articular cavity** is extensive, but does not usually communicate with that of the distal radioulnar joint, being shut out by the articular disk. It

is also excluded, in almost every instance, from that of the carpal joints by the interosseous ligaments between the first row of carpal bones. The styloid process of the radius is cartilage-covered medially, and forms part of the articular cavity, while that of the ulna does not.

The **arterial supply** is derived from the volar and dorsal carpal retia, the dorsal division of the volar interosseous, and from twigs direct from the radial and ulnar arteries.

The **nerve-supply** is derived from the ulnar (deep branch) and median (volar interosseous) in front, and the radial (dorsal interosseous) and ulnar (dorsal branch), behind.

Relations.—In front of the radiocarpal joint are the tendons of the flexor muscles of the wrist and fingers, the synovial sheaths associated with them, the radial and ulnar arteries, and the median and ulnar nerves.

Behind the joint are the majority of the tendons of the extensor muscles of the wrist and fingers, with their synovial sheaths, the terminal parts of the anterior and posterior interosseous

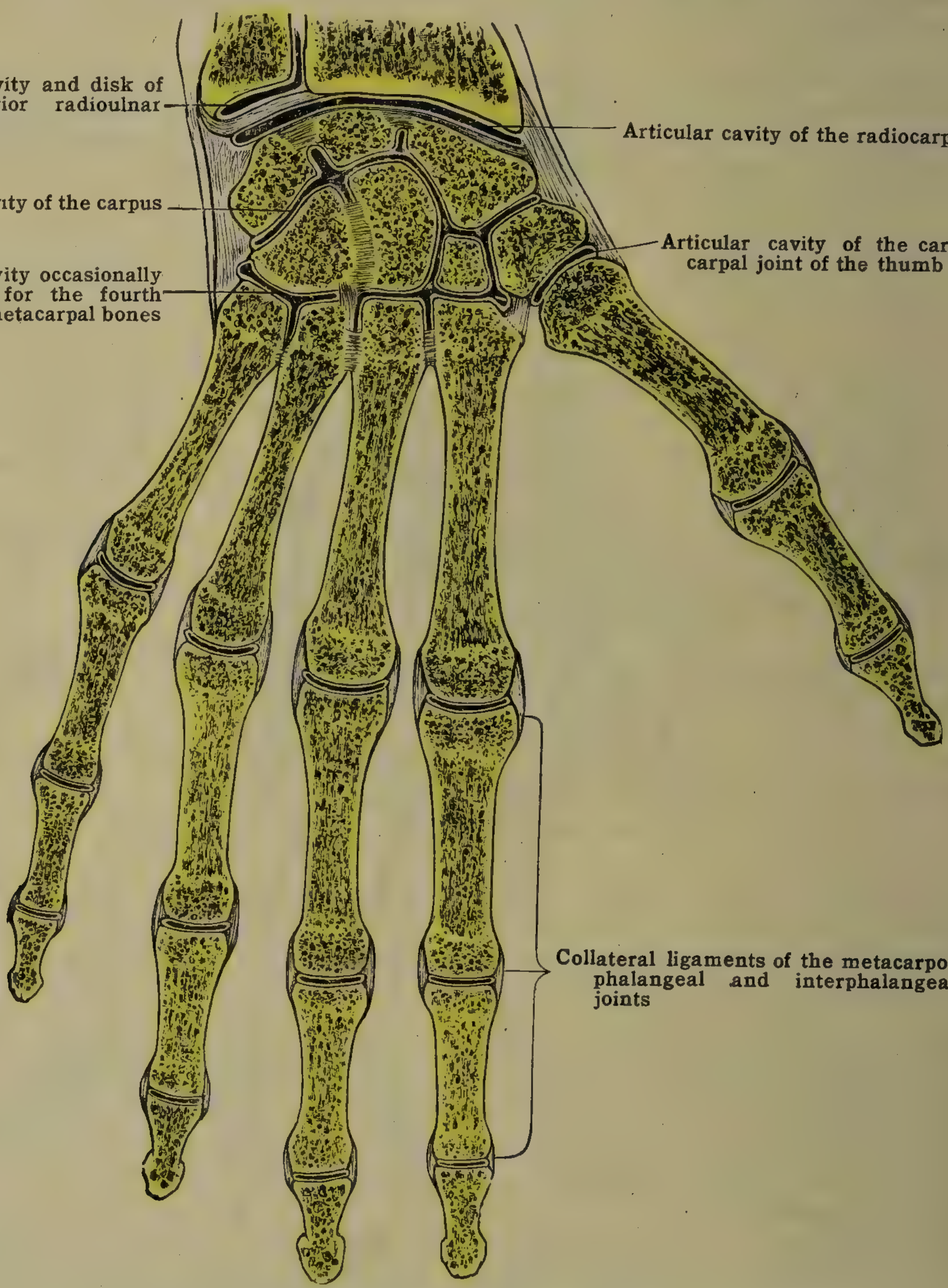


Fig. 350.—Articular Cavities of Wrist, Hand, and Fingers.

arteries, and the deep branch of the radial nerve (dorsal interosseous). On the radial side lie the tendons of the abductor pollicis longus and the extensor pollicis brevis. On the ulnar side the joint is subcutaneous and is crossed by the dorsal cutaneous branch of the ulnar nerve.

Movements.—The movements of the radiocarpal are combined with those of the intercarpal joint in the movements of the hand at the wrist, a description of which is given on p. 331.

Muscles which act upon the radiocarpal joint (cf. p. 577).—*Flexors.*—The flexors of the carpus and the long flexors of the fingers and the thumb, and the palmaris longus. *Extensors.*—The extensors of the carpus and fingers. *Abductors.*—Extensors carpi radialis longus and brevis, the abductor pollicis longus and extensor pollicis longus. *Adductor.*—Flexor carpi ulnaris, extensor carpi ulnaris.

8. THE CARPAL JOINTS

The joints of the carpus may be subdivided into:—
(*a*) The **joints of the proximal row.**
(*b*) The **joints of the distal row.**
(*c*) The **intercarpal articulation,** or junction of the two rows with each other.

(*a*) The Joints of the Proximal Row of Carpal Bones

The bones of the proximal row, the pisiform excepted, are united by two sets of ligaments and two interosseous fibrocartilages (see p. 218).

Dorsal intercarpal. Interosseous intercarpal. Volar intercarpal.

The **two dorsal intercarpal ligaments** [ligg. intercarpea dorsalia] extend transversely between the bones, and connect the navicular with the lunate, and the lunate with the triquetral. Their posterior surfaces are in contact with the dorsal radiocarpal ligament.

The **two volar intercarpal ligaments** [ligg. intercarpea volaria] extend nearly transversely between the bones connecting the navicular with the lunate, and the lunate with the triquetral. They are stronger than the dorsal ligaments, and are placed beneath the volar radiocarpal ligament.

The **two interosseous intercarpal ligaments** [ligg. intercarpea interossea] (fig. 350) are interposed between the navicular and lunate, and the lunate and triquetral bones, reaching from the dorsal to the volar surfaces, and being connected with the dorsal and volar ligaments. They are narrow fibrocartilages which extend between small portions only of the osseous surfaces. They help to form the convex carpal surface of the radiocarpal joint, and are somewhat wedge-shaped, their bases being toward the radiocarpal joint, and their thin edges between the adjacent articular surfaces of the bones.

The **articular cavity** is a prolongation from that of the intercarpal joint.

The **arterial** and **nerve-supplies** are the same as for the intercarpal joint (see below).

Movements.—These are diarthrodial joints of the irregular variety in which gliding movements occur by parallel displacements of slightly curved surfaces.

The Joint of the Pisiform Bone with the Triquetral

This [articulatio ossis pisiformis] is a diarthrodial joint which has a loose fibrous **capsule** attached to both the pisiform and triquetral bones just beyond the margins of their articular surfaces (see p. 220).

Its **articular cavity** is usually separate from the general cavity of the wrist. Two strong rounded or flattened bands pass downward from the pisiform, one to the process of the hamate [lig. pisohamatum], and the other [lig. pisometacarpeum] to the bases of the third to fifth metacarpals; these are regarded as prolongations of the tendon of the flexor carpi ulnaris, and the pisiform bone may be looked upon in the light of a sesamoid bone developed in that tendon. The position of the pisiform is further stabilized by the attachments to it of the ulnar collateral and radiate ligaments.

(*b*) The Joints of the Distal Row of Carpal Bones

The four bones of this row are united by three dorsal, three volar, and three interosseous ligaments.

The **three dorsal intercarpal ligaments** extend transversely and connect the greater with the lesser multangular, the lesser multangular with the capitate, and the capitate with the hamate.

The **three volar intercarpal ligaments** are stronger than the dorsal, and are deeply placed beneath the mass of flexor tendons; they extend transversely between the bones in a manner similar to that of the dorsal ligaments.

Three interosseous intercarpal ligaments connect the bones of the lower row of the carpus together. Two are connected with the capitate, one uniting it with the hamate (fig. 350) and the other binding it to the lesser multangular. The third ligament joins the greater and lesser multangular.

The **articular cavity** is a prolongation of that lining the intercarpal joint.

The **arterial** and **nerve-supplies** are the same as for the intercarpal joint (see below).

(*c*) The Intercarpal Joint between the Two Rows of the Carpus

The inferior surfaces of the bones of the first row are adapted to the superior articular surfaces of the bones of the second row. The line of this articulation is concavo-convex from side to side, and is sometimes described as having the course of a Roman S placed horizontally, ∽, a resemblance by no means strained. (1) The lateral part of the first row consists of the navicular alone; it is convex, and bears the greater and lesser multangulars. (2) Then follows a transversely elongated socket formed by the medial part of the navicular, the lunate, and triquetral, into which are received—(*a*) the head of the capitate, which articulates with the navicular and lunate; (*b*) the upper and lateral angle of the hamate, which articulates with the lunate; and (*c*) the upper convex portion of the medial

surface of the hamate, which articulates with the lateral and concave portion of the inferior surface of the triquetral. (3) The medial part of the inferior surface of the triquetral bone is convex, and turned a little backward to fit into the lower portion of the medial surface of the hamate, which is a little concave and turned forward to receive it. The dorsoventral curvature varies with the several bones. The thickness of the articular cartilage also differs in the range of this sinuous joint. The central part, which forms a socket for the capitate and hamate, has somewhat the character of an ellipsoid joint, the capitate and hamate being the condyle, to fit into the cavity formed by the navicular, lunate, and triquetral; the other portions are irregular. The chief ligaments are: the **capsular** and the **radiate.**

The **capsule,** looser on the dorsal than on the volar aspect, is attached to the rough surfaces of the bones adjacent to the margins of the articular surfaces. The **radiate,** anterior, or volar

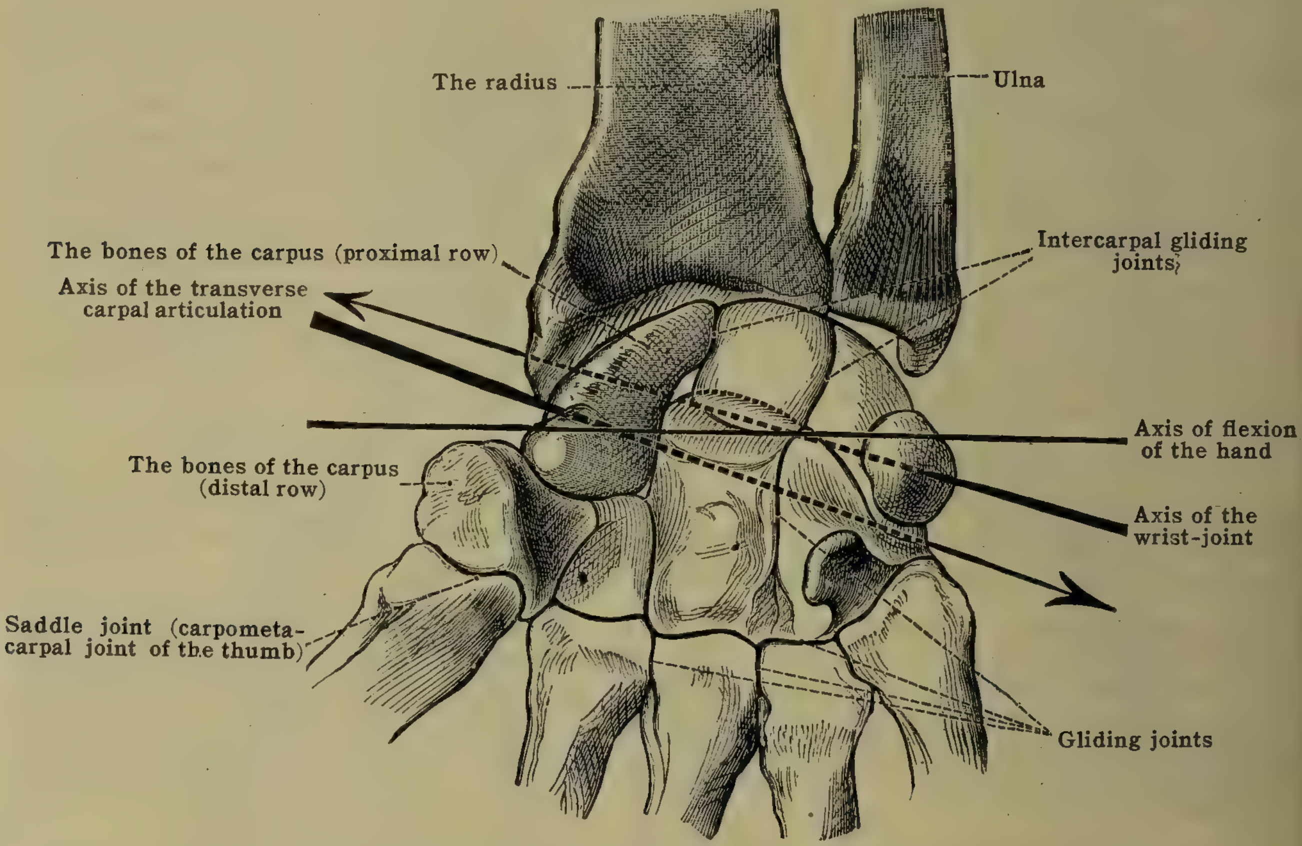


FIG. 351.—ARTICULATIONS OF THE HAND.

The arrows show the dorsal emergence of the axes of the wrist joint and of the transverse carpal articulation respectively. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

intercarpal, is a ligament of considerable strength, consisting mostly of fibers which radiate from the capitate to the navicular, lunate, and triquetral; some few fibers connect the greater and lesser multangular with the navicular, and others pass between the hamate and triquetral; a special band is attached to the pisiform. It is covered over and thickened by fibrous tissue derived from the sheaths of the flexor tendons and the fibers of origin of the small muscles of the thumb and little finger. The following ligaments are not infrequently present.

The posterior or **dorsal intercarpal ligament,** consists of fibers passing obliquely from the bones of the proximal row to those of the distal. It is stronger on the ulnar side than on the radial, but is not so strong as the volar ligament.

The **transverse dorsal ligament** is an additional band, well marked and often of considerable strength, which passes across the head of the capitate from the navicular to the triquetral bone; besides binding down the head of the capitate, it serves to fix the upper and lateral angles of the hamate in the socket formed by the first row.

The dorsal ligaments, like the volar, are strengthened by a quantity of fibrous tissue belonging to the sheaths of the extensor tendons, and by an extension of some of the fibers of the capsule of the wrist. There are no proper collateral intercarpal ligaments; they are but prolongations of the collateral ligaments of the wrist.

The **articular cavity** (fig. 350) of the carpus is common to all the joints of the carpus (excepting usually the pisiform articulation), and extends to the bases of the four medial metacarpal bones. Thus, beyond the intercarpal joint, it extends upward between the three bones of the first row, and downward between the contiguous surfaces of the lesser and greater multangular, the lesser multangular and capitate, and capitate and hamate. From these latter, prolongations of the cavity extend to the four medial carpometacarpal joints and the three intermetacarpal joints. The joint cavities of the pisiform and the carpometacarpal articulation of the thumb are independent of the general carpal articular cavity.

The **arterial supply** is derived from—(*a*) the volar and dorsal carpal retia of the radial and ulnar arteries; (*b*) the carpal branch of the volar interosseous; (*c*) the recurrent branches from the deep volar arch. The terminal twigs of the volar and dorsal interosseous arteries supply the joint on its dorsal aspect.

The **nerve-supply** comes from the ulnar on the ulnar side, the median on the radial side, and the radial (dorsal interosseous) behind.

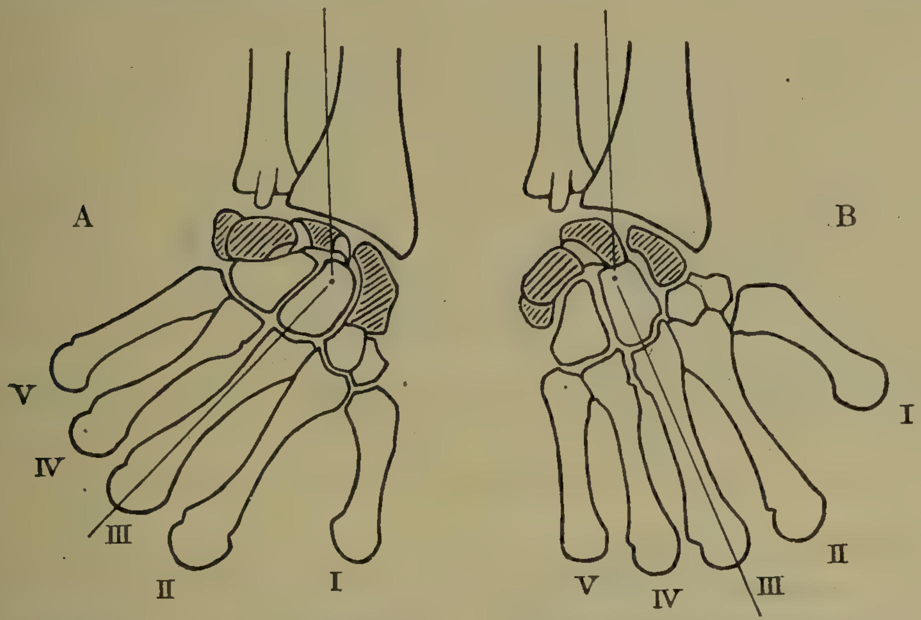


Fig. 352.—Carpal Bones in (A) Adduction, (B) Abduction.

Outline drawings from X-ray plates. Proximal row of carpal bones shaded. Long axis through the forearm and middle finger; dorsovolar axis through a point in the capitate bone. (After Fick and Braus.)

Movements.—The forms of the articular surfaces of the radiocarpal joint are those of an ellipsoidal diarthrosis; those of the intercarpal articulation are such as to permit modified hinge movement. The movements of these two anatomically separate articulations are combined in giving the hand its free motions at the wrist. The movements of the carpal articulations between bones of the same row are very limited and consist only of slight gliding upon one another; but slight as they are, they give elasticity to the carpus and break the jars and shocks which result from blows or falls upon the hand.

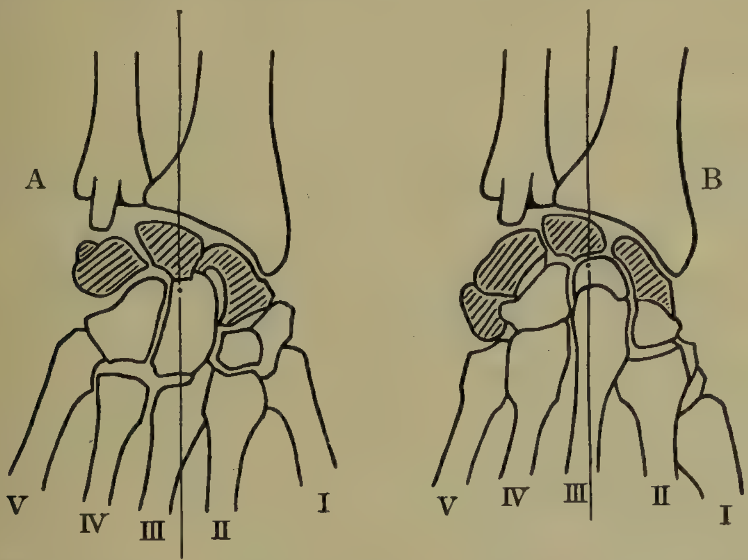


Fig. 353.—Carpal Bones in (A) Flexion, (B) Extension.

Outline drawings from X-ray plates. Proximal row of carpal bones shaded. Long axis through the forearm and middle finger; transverse axis through a point in the capitate bone. (After Fick and Braus.)

All the angular movements, including circumduction, are permitted in this combination of joints. The absence of rotation is compensated for by the movements of pronation and supination of the forearm. Flexion and extension occur around two axes, one for the radiocarpal the other for the intercarpal, which pass obliquely from side to side through the capitate, close together (fig. 351). The range of the excursion is about 85° dorsalwards and volarwards from an intermediate position of the hand. The range is limited chiefly by the dorsal, volar and collateral carpal ligaments.

Abduction and adduction, or radial and ulnar flexion as these movements are often named, take place about an anteroposterior axis through the capitate, and are contributed to by both the radiocarpal and intercarpal articulations (fig. 352). Abduction is more limited than adduction, and is checked by the ulnar collateral ligament and by contact of the styloid process of the radius with the greater multangular; adduction is checked by the radial collateral ligament alone. These side-to-side movements are not simple but are combined with anteropos-

terior motion: abduction with flexion, adduction with extension. X-ray study has helped in clarifying these complex movements, but there is need for continued investigation (fig. 353).

With the exception of the greater multangular, the bones of the distal row are very closely united with the bases of the metacarpals, whereas those of the proximal row are less firmly fixed. Displacements of the bones of the latter series volarwards and dorsalwards are observed to accompany abduction and adduction and seem to explain the concomitant flexion and extension. This displacement seems to be initiated by the movement dorsally and proximally of the lesser multangular which, bound firmly with the second metacarpal, moves with it when the latter is pulled upon by the extensor carpi radialis longus in abduction of the hand. The dorsal and proximal excursion of the lesser multangular forces the movable navicular volarwards, and in consequence of the connections, especially by the interosseous ligaments, the other carpal bones of the proximal row all shift toward the volar surface. Abduction is slight (about 15°) whereas adduction is more than twice as extensive (about 40°).

Cobe (Jour. Bone Surg., 10, 1928) found the average range in every motion of the wrist in men, except ulnar flexion in supination, greater in the left than in the right hand.

Bearing in mind the mobility of this intercarpal joint and the carpometacarpal, we see at once the significance of the radial and ulnar flexors and extensors of the carpus being prolonged down to their insertion into the base of metacarpus, for they produce the combined effect of motion at each of the three transverse articulations:—(1) at the wrist; (2) at the intercarpal; (3) at the carpometacarpal joints.

Muscles which act upon the intercarpal joint.—The muscles which act upon this joint are the same as those which act upon the radiocarpal joint.

9. THE CARPOMETACARPAL JOINTS

These [articulationes carpometacarpeæ] may be divided into two sets:

(*a*) The **carpometacarpal joints of the four medial fingers.**

(*b*) The **carpometacarpal joint of the thumb.**

The inferior surfaces of the bones of the distal row of the carpus, present a composite surface for the four medial metacarpal bones; the greater multangular presents in addition a distinct and separate saddle-shaped surface for the base of the metacarpal bone of the thumb.

(*a*) The Four Medial Carpometacarpal Joints

These joints exist between the greater and lesser multangular, capitate, and hamate bones above, and the bases of the four medial metacarpal bones below (fig. 351). The articular surfaces are regarded by Fick as modified saddle contours, best marked in the case of the fifth finger. The ligaments which unite them are, articular capsule, dorsal and volar carpometacarpal and interosseous carpometacarpal.

The **articular capsule** is attached at the margins of the articular surfaces and is connected with the intercarpal capsules. It is lax for the fifth digit, restricted for the other joints.

The dorsal carpometacarpal ligaments [ligg. carpometacarpea dorsalia] (fig. 349).—Three dorsal ligaments pass to the second metacarpal bone: one from each of the carpal bones with which it articulates, viz., the greater and lesser multangular, and capitate. Two dorsal bands pass from the capitate to the third metacarpal bone. Two dorsal bands pass to the fourth bone: viz., one from the hamate, and another from the capitate; the latter is sometimes wanting. The fifth bone has only one band passing to it from the hamate.

The volar carpometacarpal ligaments [ligg. carpometacarpea volaria] (fig. 348).—One strong band passes from the second metacarpal bone to the greater multangular medial to the ridge for the transverse carpal ligament; it is covered by the sheath of the flexor carpi radialis.

Three bands pass from the third metacarpal: one laterally to the greater multangular, a middle one upward to the capitate, and a third medially over the fourth to reach the fifth metacarpal and the hamate bones.

One ligament connects the fourth bone to the hamate.

One ligament connects the fifth bone to the hamate, the fibers extending medially, and connecting the dorsal and volar ligaments. The ligament to the fifth bone is strengthened in front by the prolonged fibers of the flexor carpi ulnaris and the strong medial slip of the ligament of the third metacarpal bone; and posteriorly, by the tendon of the extensor carpi ulnaris.

The **interosseous carpometacarpal ligament** (fig. 350) is limited to one part of the articulation, and consists of short fibers connecting the contiguous angles of the hamate and capitate with the third and fourth metacarpal bones toward their volar aspect. There is, however, a thick strong ligament connecting the edge of the greater multangular with the lateral border of the base of the second metacarpal bone; it helps to separate the carpometacarpal joint of the thumb from the common carpometacarpal joint, and to close in the radial side of the latter joint.

The **articular cavity** is a continuation of that of the intercarpal joint; occasionally there is a separate space between the hamate and fourth and fifth metacarpal bones (fig. 350); while that between the fourth and capitate is continuous with the common joint.

The **arteries** to the four medial carpometacarpal joints are as follows:—

(1) For the index finger: twigs are supplied by the trunk of the radial on the dorsal and volar aspects, and by the dorsal and volar metacarpal branches. (2) For the middle finger: the first dorsal metacarpal by the branch which passes upward to join the dorsal carpal arch, and a

branch from the deep volar arch which joins the volar carpal arch. (3) For the ring finger: the deep volar arch and recurrent twigs from the second dorsal metacarpal in the same manner as for the middle finger. (4) For the little finger: the ulnar and its deep branch; also twigs from the second dorsal metacarpal.

The **nerves** are supplied to these joints by the deep volar branch of the ulnar, the dorsal interosseous of the radial, and the median.

Relations.—In front of the four medial carpometacarpal joints are the flexors of the fingers with their synovial sheath. The flexor carpi radialis crossing in front of the lateral part of the joint and the fibers of the oblique adductor pollicis which spring from the capitate and lesser multangular are also anterior relations. Behind the joints are the extensors of the wrist and fingers with their synovial sheaths and the dorsal metacarpal arteries. At the lateral border of the joint between the index and lesser multangular lies the radial artery.

The **movements** permitted at these joints (cf. p. 577), though slight, serve to increase those of the intercarpal and wrist-joints. The joint between the fifth metacarpal and the hamate bones approaches somewhat in shape and mobility the first carpometacarpal joint; it has a greater range of flexion and extension, but its side-to-side movement is nearly as limited as that of the three other metacarpal bones; the process of the hamate bone limits its flexion. Motion toward the ulnar side is checked by the strong palmar band which unites the base of the fifth metacarpal to the base of the third, and the strong transverse ligament at the head of the bones. The mobility of the second, third, and fourth metacarpal bones is very limited, and consists almost entirely of a slight gliding upon the carpal bones, i. e., flexion and extension; that of the third and fourth bones is extremely slight, as there is no long carpal flexor attached to either; but, owing to the close connection of the bases of the metacarpal bones, the radial and ulnar flexors and extensors of the carpus act on all by their pull on the particular bones into which they are inserted.

Abduction, or movement toward the radial side, is prevented by the impaction of the second bone against the greater multangular; a little adduction is permitted, and is favored by the slope given to the hamate and fifth metacarpal bones.

There is also a slight gliding between the fourth and fifth bones, when the concavity they present toward the palm is deepened to form the 'cup of Diogenes.'

Muscles which act upon the four medial carpometacarpal joints are the flexors and extensors of the wrist and fingers (cf. p. 577).

(*b*) The Carpometacarpal Joint of the Thumb

[Articulatio carpometacarpea pollicis]

The bones entering into this joint are the base of the first metacarpal and the greater multangular presenting cartilage covered saddle-shaped reciprocal surfaces (fig. 351). The first metacarpal bone diverges from the other four, contrasting very strongly in this respect with the position of the great toe. It is due to this divergence that the thumb is able to be opposed to each and all the fingers. The ligament which unites the bones is the articular capsule.

The **articular capsule** (figs. 348, 349) consists of fibers which pass from the margin of the articular facet on the greater multangular, to the margin of the articular facet at the base of the first metacarpal bone.

The fibers are stronger on the dorsal than on the volar aspect. They are not tense enough to hold the bones in close contact, so that while they restrict they do not prevent motion in any direction. The medial fibers are stronger than the lateral.

The articular cavity is capacious, and distinct from the other synovial cavities of the carpus.

The **arteries** of the carpometacarpal joint of the thumb are derived from the trunk of the radial, the first volar metacarpal, and the first dorsal metacarpal.

The **nerves** are supplied by the branches of the median to the thumb.

Relations.—Behind are the long and short extensor tendons of the thumb, and behind and laterally the tendon of the abductor pollicis longus. The tendon of the flexor pollicis longus is in front and fibers of the flexor pollicis brevis and opponens pollicis muscles are also anterior relations. To the medial side is the radial artery as it passes forward into the palm of the hand.

The **movements** of this joint (cf. p. 577) are regulated by the shape of the articular surfaces (saddle joint, two axes of movement), rather than by the ligaments, and consist of flexion, extension, abduction, adduction, and circumduction, but not rotation. In flexion and extension the metacarpal bone slides to and fro, upon a transverse axis through the base of the metacarpal, upon the multangular; in abduction and adduction it slides from side to side or more correctly, revolves upon the anteroposterior axis though the greater multangular. The power of opposing the thumb to any of the fingers is due to the forward and medial obliquity of its flexion movement, which is by far its most extensive motion. Abduction is very free, while adduction is limited on account of the proximity of the second metacarpal bone. The movement of the greater multangular upon the rest of the carpus somewhat increases the range of all the movements of the thumb.

Muscles which act upon the carpometacarpal joint of the thumb (cf. p. 577).—*Flexors.*—Flexor pollicis brevis, flexor pollicis longus, adductor pollicis. *Extensors.*—Extensores pollicis brevis and longus. *Abductors.*—Abductores pollicis longus and brevis. *Adductors.*—The transverse and oblique adductor pollicis, opponens, first dorsal interosseous. *Muscles producing opposition.*—Opponens, flexor brevis, oblique adductor.

10. THE INTERMETACARPAL JOINTS

[Articulationes intermetacarpeæ]

The metacarpal of the thumb is not connected with any other metacarpal bone. The second, third, fourth, and fifth metacarpal bones are in actual side-to-side contact at their bases, where special articular surfaces, cartilage covered, are developed (fig. 350). The bones are held firmly together by articular capsules and by the following ligaments.

Dorsal basal, interosseous basal and volar basal.

The **articular capsules** are connected with those of the carpometacarpal joints.

The **dorsal basal ligaments** [ligg. basium oss. metacarp. dorsalia] (fig. 349) are layers of variable thickness of strong, short fibers, which pass transversely from bone to bone, filling up the irregularities on the dorsal surfaces.

The **volar basal ligaments** [ligg. basium oss. metacarp. volaria] are transverse layers of ligamentous tissue passing from bone to bone; they cannot be well differentiated from the other ligaments and fibrous tissue covering the bones.

The **interosseous basal ligaments** [ligg. basium oss. metacarp. interossea] (fig. 350) pass between the apposed surfaces of the bones, and are attached to the distal sides of the articular

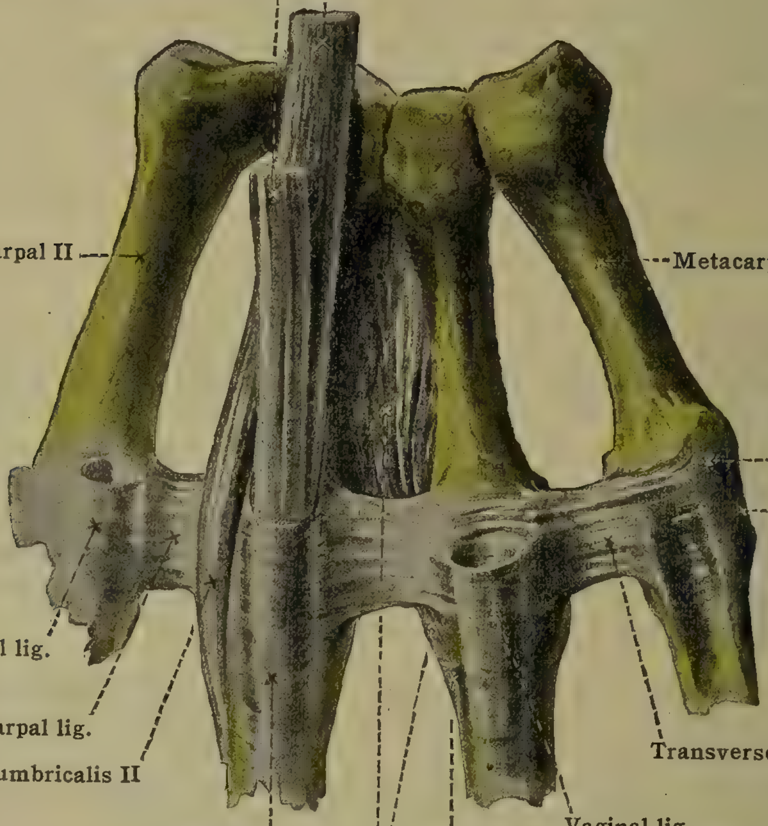


Fig. 354.—Transverse Metacarpal Ligament. (Volar aspect.) (Fick.)

facets, so as to close in the articular cavities on this aspect; where there are two articular facets, the fibers extend upward between them nearly as far as their carpal facets. That between the fourth and fifth is the weakest.

The **articular cavities** are prolonged downward from the common carpal articular space.

The **arteries** to the intermetacarpal joints are twigs from the volar and dorsal metacarpal arteries; the twigs pass upward between the interosseous muscles.

The **nerves** are derived from the ulnar and the dorsal interosseous branch of the radial.

The Union of the Heads of the Metacarpal Bones

The distal extremities of these bones are connected together on their volar aspects by what are called the **transverse capitular ligaments** [ligg. capitulorum oss. metacarpalium transversa] (fig. 354). These consist of three short fibrous bands, which unite the second and third, third and fourth, and the fourth and fifth bones. They are rather more than 6 mm. deep, and rather less in width, and limit the distance to which the metacarpal bones can be separated. They are continuous above with the fascia covering the interosseous muscles; below, they are connected with the subcutaneous tissue of the web of the hand. They are on a level with the front surface of the bones, and are blended on either side with the edges of the

glenoid ligament in front, with the lateral ligaments of the metacarpophalangeal joint, and also with the sheaths of the tendons. In front, a lumbrical muscle passes with the digital arteries and nerves; whereas behind, the interossei muscles pass to their insertions.

11. THE METACARPOPHALANGEAL JOINTS

(a) The Metacarpophalangeal Joints of the Four Medial Fingers

In these joints the oval concavity of the base of the first phalanx fits on to the rounded head of the metacarpal bone (fig. 355). These cartilage-covered surfaces provide for a biaxial joint. Union is made by an articular capsule and by the collateral and volar accessory ligaments.

The **articular capsule** is loose, and in its attachment to the bones approaches closer to the articular cartilage on the dorsal than on the volar surface.

The **volar accessory** (or glenoid) **ligament** [lig. accessorium volare] (fig. 355) is a fibrocartilaginous plate which increases the depth of the phalangeal articular facet in front. It is much more firmly attached to the margin of the phalanx than to the metacarpal bone, being only loosely connected with the volar surface of the latter by some loose areolar tissue which covers in the synovial stratum, here prolonged some little distance upon the surface of the bone. At the sides, it is connected with the collateral ligaments and with the transverse

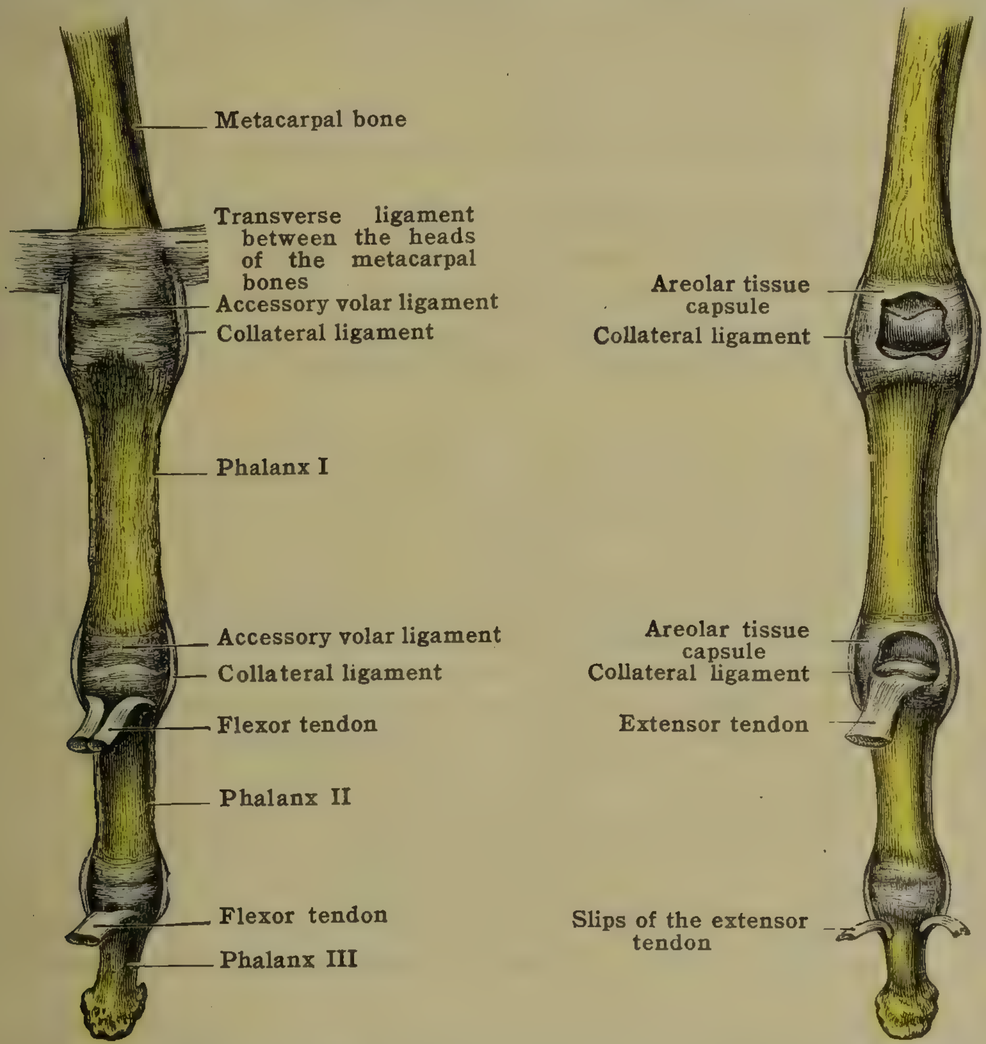


Fig. 355.—Anterior and Posterior Views of Ligaments of the Fingers.

metacarpal ligament. A sesamoid bone sometimes exists at the medial border of the joint of the little finger.

The **collateral ligaments** [ligg. collateralia] (figs 354, 355) are exceedingly strong and firmly connect the bones with one another; each is attached above to the corresponding tubercle, and to a depression in front of the tubercle, of the metacarpal bone. From this point the fibers spread widely as they descend on either side of the base of the phalanx; the anterior fibers are connected with the accessory volar ligament; the posterior blend with the tendinous expansion at the back of the joint.

The joint is covered in **posteriorly** by the expansion of the extensor tendon, and some loose areolar tissue passing from its under surface to the bones (fig. 355).

The **articular cavity** is capacious.

The **arteries** come from the digital or volar metacarpal vessels of the deep arch.

The **nerves** are derived from the digital branches, or from twigs of the branches of the ulnar to the interosseous muscles.

Relations.—1. The metacarpophalangeal joints of the middle three digits. In front, the tendons of the flexor digitorum profundus and flexor digitorum sublimis. On the radial side, a lumbrical, and interosseous muscle, and digital nerves and vessels; on the ulnar side, an interosseous muscle and digital vessels and nerves. Behind, the common extensor tendon and in the case of the index digit the tendon of the extensor indicis.

2. The metacarpophalangeal joint of the little finger. In front, the flexor digiti quinti brevis and the tendons of the flexor digitorum profundus and sublimis muscles which go to this digit. Behind, the extensor digti quinti to a slip of the extensor digitorum communis sometimes. On the radial side, a lumbrical, the third volar interosseous muscle, digital vessels and nerves. On the ulnar side, digital vessels and nerves.

The **movements** permitted at these joints (cf. p. 578) are flexion, extension, abduction, adduction, and circumduction. Flexion and extension take place on a transverse axis, abduction and adduction on an anteroposterior axis both passing through the head of the metacarpal bone. Flexion is the most free of all and may be continued until the phalanx is at a right angle with the metacarpal bone. This is in accord with the fact that the articular surface of the head of the bone is prolonged so much further on the volar aspect, and that the synovial membrane is here so loose and ample. Extension is the most limited of the movements, and can only be carried to a little beyond the straight line. Abduction and adduction are fairly free, but not so free as flexion. Flexion is associated with adduction, and extension with abduction. This may be proved by opening the hand, when the fingers involuntarily separate as they extend, while in closing the fist they come together again. The free abduction, adduction, and circumduction which are permitted at these joints are due to the fact that the long axes of the articular facets are at right angles to one another.

Muscles acting on the middle three digits.—*Flexors.*—Flexor digitorum profundus, flexor digitorum sublimis, lumbricales. *Extensors.*—Extensor digitorum communis and on the index digit the extensor indicis. *Abductors.*—Dorsal interossei. *Adductors.*—Volar interossei.

Muscles acting on the metacarpophalangeal joint of the little finger.—*Flexors.*—Flexor digiti quinti brevis, flexor digitorum sublimis, flexor digitorum profundus, lumbricalis. *Extensors.*—Extensor digitorum communis, extensor digiti quinti. *Abductor.*—Abductor digiti quinti. *Adductor.*—Third volar interosseous.

(b) The Metacarpophalangeal Joint of the Thumb

The head of the metacarpal bone of the thumb differs considerably from the corresponding ends of the metacarpal bones of the fingers. It is less convex, wider from side to side, the volar edge of the articular surface is raised and irregular, and here on either side of the median line are the two facets for the sesamoid bones (see p. 223). The ligaments are the collateral, the articular capsule, and the dorsal.

The **collateral ligaments** are short, strong bands of fibers, which radiate from depressions on either side of the head of the metacarpal bone to the base of the first phalanx and sesamoid bones. As they descend they pass a little forward, so that the greater number are inserted in front of the center of motion.

The **dorsal ligament** consists of fibers which pass across the joint from one collateral ligament to the other, completing the **articular capsule** and enclosing the articular cavity.

The **sesamoid bones** are two in number, situated on either side of the middle line, and connected together by strong transverse fibers which form the floor of the groove for the long flexor tendon; they are connected with the base of the phalanx and head of the metacarpal bone by strong fibers. Anteriorly they give attachment to the short muscles of the thumb, and posteriorly are smooth where they glide over the facets. The collateral ligaments are partly inserted into their sides.

The **arteries and nerves** come from the digital branches of the thumb.

Relations.—Of the metacarpophalangeal joint of the thumb: In front and laterally abductor pollicis brevis and superficial head of flexor pollicis brevis. In front and medially oblique and transverse adductors and deep head of flexor pollicis brevis. Directly in front, flexor pollicis longus and terminal branches of first volar metacarpal artery. Behind, extensor pollicis brevis and longus tendons. On either side, the dorsal digital vessels and the digital nerves.

The **movements** (cf. p. 578) are chiefly flexion and extension, very little side-to-side movement being permitted, and that only when the joint is slightly bent. Thus this joint more nearly approaches the simple hinge character than the corresponding articulations of the fingers. The thumb gets its freedom of motion at the carpometacarpal joint; the fingers get theirs at the metacarpophalangeal, but they are not endowed with so much freedom as the thumb enjoys.

Muscles which act upon the metacarpophalangeal joint of the thumb—*Flexors.*—Flexor pollicis brevis, flexor pollicis longus. *Extensors*—Extensor pollicis brevis, extensor pollicis longus.

Metacarpophalangeal dislocation occurs in the thumb and the index-finger especially. The chief cause of the difficulty in reduction is the accessory volar (glenoid) ligament. This, in reality a fibrocartilaginous plate, is blended with the lateral ligaments on the palmar aspect of the joint, and is firmly attached to the phalanx, but more loosely to the metacarpal. Thus when dislocation occurs in violent hyperextension, the metacarpal attachment of the glenoid ligament gives way and it is carried by the phalanx over the head of the metacarpal bone. In the case of the thumb, the buttonhole-like slit with which the two heads of the flexor brevis, now displaced, embrace the head of the metacarpal, renders reduction difficult. The contraction of the other short muscles, and, occasionally, a displaced long flexor, are additional causes of difficult reduction. In the case both of the thumb and finger, tilting the phalanx well back on the dorsum of the metacarpal and then combined pressure with the thumbs forward against the base of the phalanx, when this is sharply flexed, will, with an anesthetic, be usually successful in effecting reduction. The thumb should be, first, adducted into the palm.

12. THE INTERPHALANGEAL JOINTS

[Articulationes digitorum manus]

The peculiar articular surfaces, cartilage covered, which enter into the interphalangeal joints and largely determine their ginglymoid movements will be found described on p. 226. The ligaments which unite the phalanges of the thumb and of the fingers are the articular capsule, the accessory volar, and the collateral.

The **accessory volar ligament** (fig. 354), sometimes called the sesamoid body, is very firmly connected with the base of the distal bone, and loosely, by means of fibroareolar tissue, with the head of the proximal one. It blends with the collateral ligaments at the sides, and over it pass the flexor tendons. Occasionally a sesamoid bone is developed in the cartilage of the interphalangeal joint of the thumb.

The **collateral ligaments** (figs. 350, 355) are about the strongest bands, in proportion to the size of the joint, found any where in the body. They are attached to the rough depressions on the sides of the proximal phalanx, and to the projecting margins of the distal phalanx of each joint. They are tense in every position, and entirely prevent any side-to-side motion; they are connected posteriorly with the expansion of the extensor tendon.

Dorsally (fig. 355) the joint is covered in by the deep surface of the extensor tendon, and by a little fibroareolar tissue extending from the tendon, completing the **articular capsule**.

The **articular cavity** is ample, and extends upward a little way along the shaft of the proximal bone.

The **arteries** and **nerves** come from their respective digital branches.

In **relation** to the interphalangeal joints are the flexor and extensor tendons and the digital vessels and nerves.

The **movements** are limited to flexion and extension, hinge movements which take place around a single transverse axis, through the head of the corresponding phalanx. Flexion is more free, and can be continued till one bone is at a right angle to the other, and is most free at the junction of the first and second bones; the second phalanx can be flexed on the first through 110° to 115° when the latter is not flexed. The greater freedom of flexion is due to the greater extent of the articular surface in front of the heads of the proximal bones, and to the direction of the fibers of the collateral ligaments, which pass a little forward to their insertion into the distal bone.

The muscles which act upon the interphalangeal joints are the extensors and flexors of the digits and the lumbricales and interossei.

THE ARTICULATIONS OF THE LOWER LIMB

The articulations of the lower limb are the following:—

1. The **articulations of the pelvis.**
2. The **hip-joint.**
3. The **knee-joint.**
4. The **tibiofibular union.**
5. The **ankle-joint.**
6. The **intertarsal joints.**
7. The **tarsometatarsal joints.**
8. The **intermetatarsal joints.**
9. The **metatarsophalangeal joints.**
10. The **interphalangeal joints.**

1. THE ARTICULATIONS OF THE PELVIC GIRDLE

(*a*) The Sacroiliac Articulation

It is now generally admitted that the **sacroiliac joint** [articulatio sacroiliaca] is a diarthrosis. The auricular surfaces of the sacrum and ilium are covered with a layer of cartilage, whilst the cavity of the joint is a narrow cleft and the capsule is extremely thick posteriorly. The cartilage on the sacrum (hyalin in its deeper parts) is much thicker than that on the ilium (mostly fibrocartilage) and the cartilages are sometimes bound together here and there by fibrous strands. The different character of the joint in the two sexes should be noted. Briefly, the female joint has strong ligamentous bonds with but little bony apposition, whereas the male joint gains its strength by virtue of extensive areas of bony contact and a slighter development of ligaments. This structural difference is the basis of a physiological one; for some laxity of the joint occurs in pregnancy and labor. The bones are bound together by a tight capsule attached to the paraglenoid sulcus, the anterior sacroiliac, long posterior sacroiliac, short posterior sacroiliac, and interosseous ligaments.

The **anterior sacroiliac ligaments** [ligg. sacroiliaca anteriora] (figs. 356, 362) consist of well-marked glistening fibers which unite the base and lateral part of the sacrum to the ilium, blending with the periosteum of the pelvic surface and, on the ilium, reaching the arcuate line and attaching in the paraglenoid groove.

The **posterior sacroiliac ligament** (fig. 357) is extremely strong and consists essentially of two sets of fibers, deep and superficial, forming the short and long posterior sacroiliac ligament, respectively. The **short posterior sacroiliac ligament** [lig. sacroiliacum posterius breve], the deeper stratum, passes downward and medialward from the rough area of the ilium behind the auricular surface and posterior inferior iliac spine to the back of the lateral part of the sacrum, and to the upper sacral articular process, and the area between it and the first sacral foramen. The **long posterior sacroiliac ligament** [lig. sacroiliacum posterius longum] passes downward, partly covering the short ligament, from the posterior superior iliac spine to the second third, and fourth articular tubercles on the back of the sacrum, and is continuous below with the sacrotuberous ligament.

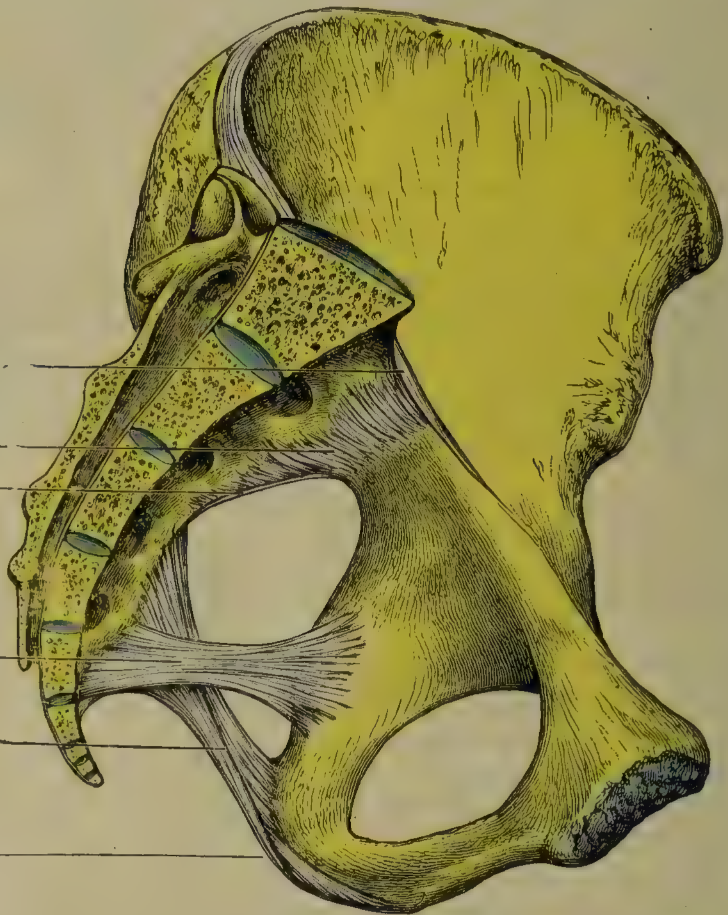


FIG. 356.—MEDIAN SAGITTAL SECTION OF THE PELVIS, SHOWING LIGAMENTS.

The **interosseous ligaments** [ligg. sacroiliaca interossea] are the strongest of all, and consist of fibers of different lengths passing in various directions between the two bones. They extend from the rough surface of the iliac tuberosity to the corresponding surface on the lateral aspect of the sacrum above and behind the auricular surface. Immediately above the interspinous notch of the ilium the fibers of these ligaments are very strong, and form an open network, in the interstices of which is a quantity of fat in which the articular vessels ramify.

The ear-shaped **cartilaginous plate,** which unites the bones firmly, is accurately applied to the auricular surfaces of the sacrum and ilium. It is about 2 mm. thick in the center, but becomes thinner toward the edges. Though closely adherent to the bones, it tears away from one entirely, or from both partially, on the application of violence, sometimes breaking irregularly so that the greater portion remains connected with one bone, leaving the other bone rough and bare. It consists of two layers of fibrocartilage, separated by a more or less extensive imperfect synovial cavity. Testut mentions certain folds of synovial membrane filling up gaps which here and there occur at the margin of the fibrocartilage but they are not usually seen.

LIGAMENTS OF THE PELVIC GIRDLE

The **obturator membrane** [membrana obturatoria], composed of fibers having various directions, fills the obturator foramen, its attachment being upon the pelvic side of the bony margin of the opening. Superiorly, it is deficient and a notch remains, which, together with the obturator groove, forms the **obturator**

canal, traversed by the obturator vessels and nerve in their course from the pelvis into the thigh. Through this canal, the membrane is continuous with the pelvic fascia covering the obturator internus muscle. Both obturator muscles in large part arise from the membrane, one from its outer, the other from its inner surface.

The **sacrotuberous** (great sciatic) **ligament** [lig. sacrotuberosum] (figs. 356–357) is attached above to the posterior extremity of the crest of the ilium and the lateral aspect of the posterior iliac spines, in common with the long posterior sacroiliac ligament. From this attachment some of its fibers pass downward and backward to be attached to the lateral borders and posterior surfaces of the lower three sacral vertebræ and upper two segments of the coccyx; while others, after passing for a certain distance backward, curve forward and downward to the ischium, forming the anterior free margin of the ligament where it limits posteriorly the sciatic foramina. These fibers are joined by others which arise from the posterior surfaces of the lower three sacral vertebræ and upper pieces of the coccyx. At the ischium it is fixed to the medial border of the tuberosity, and sends a thin sharp process upward along the ramus of the ischium which is called the **falciform process** [processus falciformis] (fig. 357), and is a prolongation of the posterior edge of the ligament.

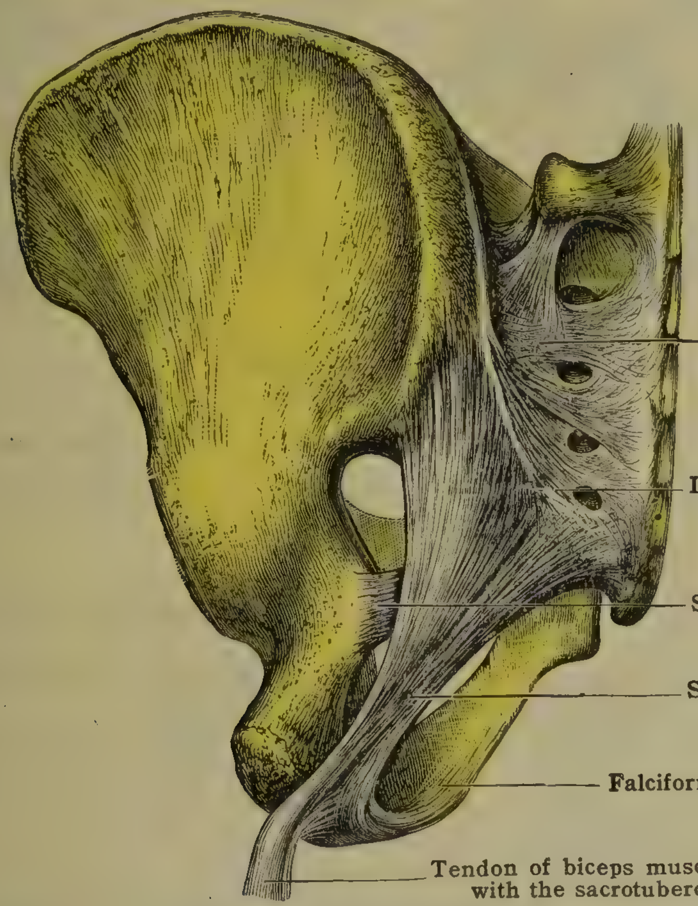


FIG. 357.—POSTERIOR SACROILIAC, SACROTUBEROUS AND SACROSPINOUS LIGAMENTS.

A great many fibers pass on directly into the tendon of the biceps muscle, so that traction on this muscle braces up the whole ligament, and the coccyx is thus made to move on the sacrum. The ligament may not unfairly be described as a tendinous expansion of the muscle, whereby its action is extended and a more advantageous leverage given. It is broad and flat at its attached ends, but narrower and thicker in the center, looking like two triangular expansions joined by a flat band, the larger triangle being at the ilium, and the smaller at the ischium. The fibers of the ligament are twisted upon its axis at the narrow part, so that some of the superior fibers pass to the lower border.

The posterior surface gives origin to the gluteus maximus muscle, and on it ramify the loops from the posterior branches of the sacral nerves; its anterior surface is closely connected at its origin with the sacrospinous ligament, and some fibers of the piriformis muscle arise from it; below, the obturator internus passes out of the pelvis under its cover, and the internal pudendal vessels and nerve pass into the perineum. At the ilium, its posterior edge is continuous with the vertebral aponeurosis; while to the anterior edge is attached the thick fascia covering the gluteus medius. The obturator fascia is attached to its falciform edge. It is pierced by the coccygeal branches of the inferior gluteal (sciatic) artery and the inferior clunial (perforating cutaneous) nerve from the second and third sacral.

The **sacrospinous** (small sciatic) **ligament** [lig. sacrospinosum] (figs. 356–357) is triangular and thin, springing by a broad base from the lateral border of the sacrum and coccyx, from the front of the sacrum both above and below the level of the fourth sacral foramen, and from the coccyx nearly as far as its

tip. By its apex it is attached to the front surface and the borders of the sciatic spine as far outward as its base. Its fibers decussate so that the lower ones at the coccyx become the highest at the sciatic spine; muscular fibers are often seen intermingled with the ligamentous.

The sacrospinous ligament is situated in front of the sacrotuberous ligament, with which it is closely connected at the sacrum, and separates the greater from the lesser sciatic foramen [foramen ischiadicum majus; foramen ischiadicum minus]. These are subdivisions of a large space intervening between the sacrotuberous ligament and the hip-bone. The piriformis muscle passes out of the pelvis into the thigh by way of the greater sciatic foramen, and is accompanied by the gluteal and sciatic vessels and nerves. The internal pudendal vessels and nerve and the nerve to the obturator internus muscle also leave the pelvis by this foramen to enter the perineal region through the lesser sciatic opening, by which also the obturator internus muscle passes from the pelvis to its insertion on the femur.

Anteriorly, the sacrospinous ligament gives attachment to the coccygeus muscle, which overlies it. Behind, it is connected with, and hidden by, the sacrotuberous ligament, so that only the lateral inch or less (2 cm.) and a small part of its attachment to the coccyx can be seen; the internal pudendal nerve also passes over the posterior surface.

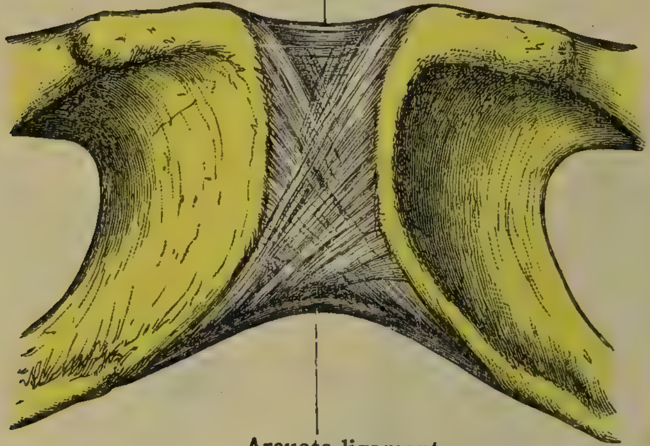


FIG. 358.—ANTERIOR VIEW OF THE MALE SYMPHYSIS PUBIS, SHOWING THE DECUSSATION OF THE FIBERS OF THE ANTERIOR LIGAMENT.

FIG. 359.—ANTERIOR VIEW OF THE FEMALE SYMPHYSIS PUBIS, SHOWING GREATER WIDTH.

The **arterial supply** of the sacroiliac joint comes from the superior gluteal, iliolumbar, and lateral sacral.

The **nerve-supply** is from the superior gluteal, sacral plexus, and external twigs of the posterior divisions of the first and second sacral nerves.

Movements.—Investigations have shown that in spite of the interlocking of the articular surfaces and the strong ligaments connecting the bones together a slight amount of movement both a gliding and rotatory, does occur at the sacroiliac joint. The gliding movement is both up and down, and forward and backward, and the latter is associated with a slight rotation round a transverse axis which passes through the upper articular tubercles on the back of the sacrum. The movement is but small in extent, nevertheless as the base of the sacrum moves downward and forward the conjugate (anteroposterior) diameter of the pelvic inlet is diminished and at the same time, as the coccyx moves up and back, the conjugate diameter of the outlet is increased. This rotatory movement is limited principally by the sacrosciatic (sacrotuberous and sacrospinous) ligaments which prevent any extensive upward and backward movement of the coccyx and lower part of the sacrum.

Downward displacement of the sacrum when the body is in the sitting posture is prevented not only by the surrounding ligaments, but also by the wedge-like character of the sacrum in the frontal plane, which is broader above than below. Downward and forward displacement of the sacrum in the erect posture is prevented by the ligaments and more particularly by the posterior sacroiliac bands, while backward displacement would be hindered by the breadth of the anterior as contrasted with the posterior part of the sacrum as well as by the anterior ligaments.

Relations.—The sacroiliac joint is in relation above with psoas and iliacus. In front it is in relation at its upper part with the hypogastric vessels and obturator nerve, and at its lower part with the piriformis muscle.

THE SYMPHYSIS PUBIS

The bones entering into this joint (symphysis pelvis NK) are the symphyseal surfaces of the pubic bones. This joint is shorter and broader in the female than in the male. The ligaments of the articulation, are the superior pubic, arcuate of the pubis, anterior pubic, and interpubic fibrocartilage.

The **superior pubic ligament** [lig. pubicum superius] (figs. 358, 359) is a well-marked stratum of yellowish fibers which extends lateralward along the crest

of the pubis on each side to the pubic tubercle, blending in the middle line with the interpubic cartilage. It gives origin to the rectus abdominis tendon.

The **anterior pubic ligament** (figs. 358, 359) is thick and strong, and is closely connected with the fascial covering of the muscles arising from the conjoined rami of the pubis. It consists of several strata of thick, decussating fibers of different

Fig. 360.—Section of Symphysis to show the Rudimentary Articular Cavity.

degrees of obliquity, the superficial being the most oblique, and extending lowest over the joint.

The **arcuate** (inferior or subpubic) **ligament of the pubis** [lig. arcuatum pubis] (figs. 358, 359) is a thick, arch-like band of closely packed fibers which fills up the angle between the pubic rami, and forms a smooth, rounded summit to the pubic arch. It is yellowish in color and is inseparably connected with the interpubic cartilage.

Both on the front and back aspects of the joint it gives off decussating fibers, which, by their interlacement add very materially to the strength of the joint.

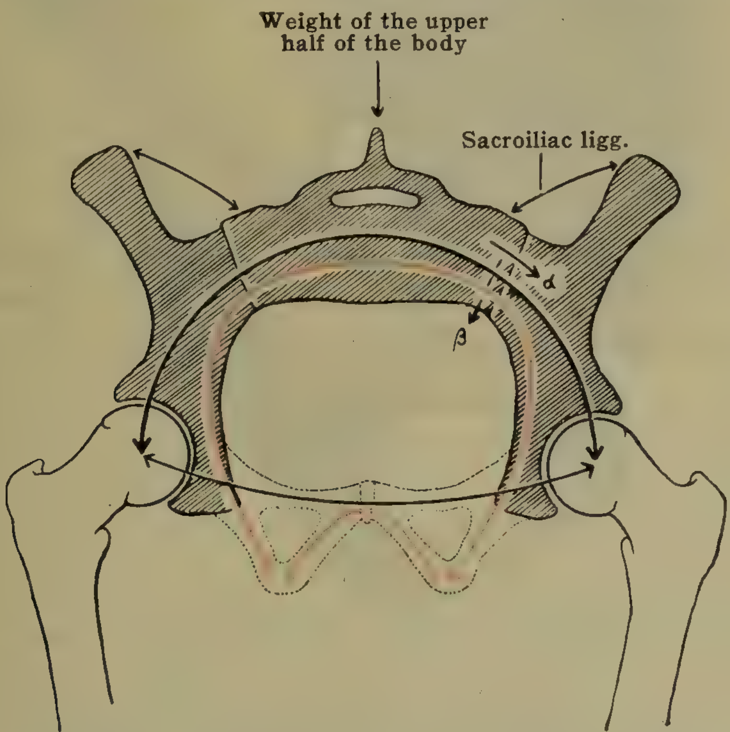


Fig. 361.—Mechanics of the Pelvic Arch.

Black semi-circular line represents the distribution of the weight of the upper part of the body, in the standing position, to the heads of the femora and the resistance offered by the latter. The red semicircle indicates the transmission of body weight to the ischial tuberosities in sitting and the resistance from them. Transverse tension in standing is shown by the black line from one femoral head to the other; between the ischial tuberosities by the red line. (Braus, Anatomie des Menschen.)

The **interpubic fibrocartilage** [lamina fibrocartilaginea interpubica] varies in different subjects, but is thicker in the female than in the male. It is thicker in front than behind, and projects beyond the edges of the bones, especially on the posterior aspect, blending intimately with the ligaments at its margins. It is sometimes uninterruptedly woven throughout, but often presents an elongated narrow fissure, partially dividing the cartilage into two plates, with a little

fluid in the interspace (fig. 360). This rudimentary articular cavity generally extends about half the length of the cartilage.

When this cavity is large, especially if it reaches or approaches very near to the circumference of the cartilage (which, however, it very rarely does), the joint is thought by some to resemble a diarthrodial joint, and it is then classed with the sacroiliac joint under similar conditions. The interpubic cartilage is intimately adherent to the layer of hyalin cartilage which covers the medial surface of each pubic bone; the osseous surface is ridged, giving a firmer attachment; and, on forcing the bones apart, it does not frequently split into two plates, but is torn from the bone on one side or the other.

The **arterial supply** of the interpubic joint is from twigs of the internal pudendal, pubic branches of the obturator and epigastric, and ascending branches of the medial circumflex and superficial external pudendal.

The **movements** amount only to a slight yielding of the cartilage; neither muscular force nor extrinsic forces produce any appreciable movement in the ordinary condition. Occasionally, as the result of child-bearing, the joint becomes unnaturally loose, and then walking and standing are painfully unsteady. It is known that, during pregnancy and parturition, the symphyseal cartilage becomes softer and more vascular, so as to permit the temporary enlargement of the pelvis; but it must be remembered that the fibers of the oblique muscles decussate and thus, during labor, while they force the head of the fetus down, they strengthen the joint by bracing the bones more tightly together.

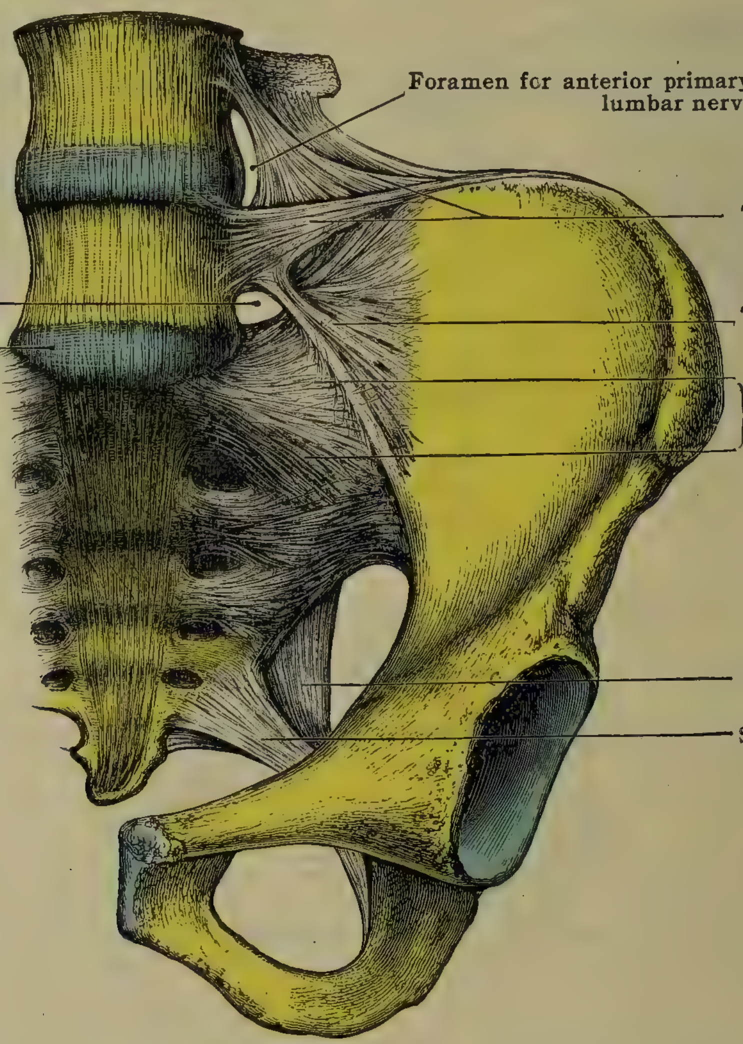


Fig. 362.—Ligaments of the Sacrovertebral and Sacroiliac Joints. (Anterior view.)

Mechanically the pelvis is an arch which receives the weight of the body above on its keystone, the sacrum, from which it is transmitted equally by the hip-bones to the femora in standing and to the ischial tuberosities in sitting. The piers of the arch are tied together by the pubic rami joined at the symphysis (fig. 361).

Relations.—The symphysis pubis is in relation above with the linea alba; behind with the prostate and the anterior aspect of the bladder; in front with the suspensory ligament of the penis or clitoris; and below with the dorsal vein of the penis or clitoris and the upper border of the urogenital diaphragm (triangular ligament).

UNION OF THE PELVIS WITH THE FIFTH LUMBAR VERTEBRA

As in the intervertebral articulations, so in the union of the sacrum with the fifth lumbar vertebra, there are two sets of joints, viz., a synchondrosis between the bodies, and a pair of diarthrodial joints between the articular processes. Two special accessory ligaments on either side, the iliolumbar and the sacrolumbar, connect the pelvis with the fifth and fourth lumbar vertebræ.

The **iliolumbar ligament** [lig. iliolumbale] (fig. 362) is a strong, dense, triangular ligament connecting the fourth and fifth lumbar vertebræ with the iliac crest.

It springs from the front surface of the transverse process of the fifth lumbar vertebra as far as the body, by a strong fasciculus from the posterior surfaces of the process near the tip, and also from the front surface and lower edge of the transverse process and pedicle of the fourth lumbar vertebra, as far medialward as the body. Between these two lumbar vertebræ it is inseparable from the intertransverse ligament.

At its origin from the transverse process of the fifth lumbar vertebra it is closely interwoven with the sacrolumbar ligament, and some of its fibers spread downward on to the body of the fifth vertebra, while others ascend to the disk above. At the pelvis it is attached to the inner lip of the crest of the ilium for about two inches (5 cm.). The anterior surface forms part of the posterior boundary of the major (false) pelvis; the posterior surface forms part of the floor of the spinal groove, and gives origin to the multifidus muscle. Of the borders, the upper is oblique, has the anterior lamella of the lumbar fascia attached to it, and gives origin to the quadratus lumborum; the lower is horizontal, and is adjacent to the upper edge of the sacrolumbar ligament; while the medial is crescentic, and forms the lateral boundary of a foramen through which the fourth lumbar nerve passes.

The **sacrolumbar ligament** is generally inseparable from the iliolumbar and has been regarded as part of it. It consists of a fan shaped expansion of fibers attached above to the transverse process, root and body of the fifth lumbar vertebra, and below in the iliac fossa, to the base and pelvic surface of the

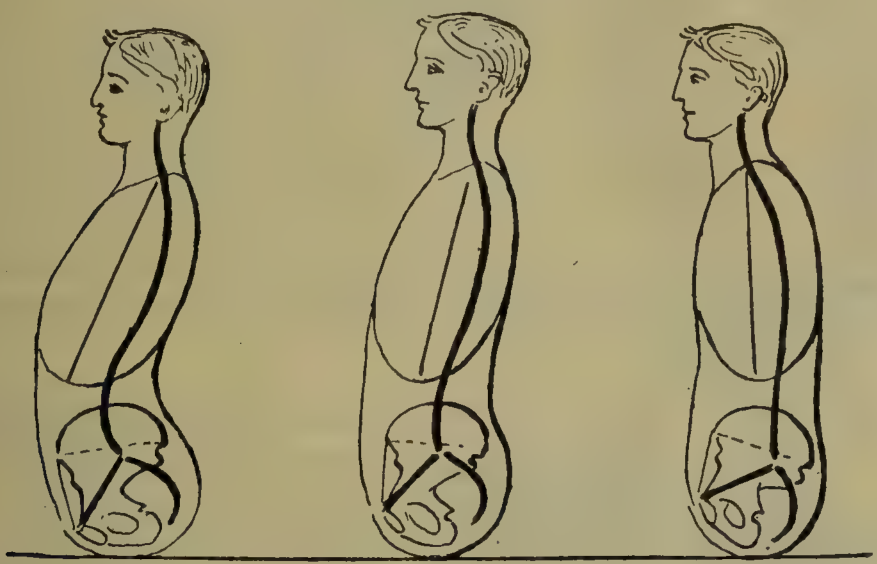


Fig. 363.—Pelvic Inclination.

Showing the relation of the pelvic inclination to the curve of the lumbar spine; also to the curves in the thoracic and cervical regions and to the axis of the thorax, in different postures in standing. (Strasser, Lehrbuch der Muskel- und Gelenkmechanik.)

sacrum. By its sharp medial border it limits laterally the foramen for the passage of the last lumbar nerve.

Movements (Cf. p. 579.)—The movements at the lumbosacral joint are of the same sort as obtain between lumbar vertebræ, but their results, affecting the pelvis, are far more extensive and of the highest importance in contributing to the mechanism of the erect posture, of walking and sitting (fig. 363). Owing to the greater thickness of the intervertebral disk here than elsewhere, the movements permitted at this joint are very free, being freer than those between any two lumbar vertebræ. As the diameter of the two contiguous bones is less in the sagittal than in the frontal plane, the forward and backward motions are much freer than from side to side. The backward and forward motions take place every time the sitting is exchanged for the standing position, and the standing for the sitting posture; in rising, the back is extended on the sacrum at the sacrolumbar union; in sitting down it is flexed.

The articular processes provide for the gliding movement incidental to the extension, flexion, and lateral movements; they also allow some horizontal movement, necessary for the rotation of the vertebral column on the pelvis, or pelvis on the column. The inferior articular processes of the fifth differ considerably from the inferior processes in the rest of the lumbar vertebræ, and in direction they resemble somewhat those of the cervical vertebræ; while the superior articular processes of the sacrum differ in a similar degree from the superior processes of the lumbar vertebræ. This difference allows for the freer rotation which occurs at this joint.

In the erect posture the sacrovertebral angle averages 117° in the male, and 130° in the female; while the pelvic inclination averages 55° in the male, and 60°–65° in the female (p. 236).

The muscles which produce the movements are those mentioned in the preceding groups which cross the axes of the articulation (see p. 301).

2. THE HIP-JOINT

The **hip-joint** [articulatio coxæ] is a typical example of a ball-and-socket joint, the round head of the femur being received into the cup-shaped cavity

of the acetabulum with very close approximation of curvatures (figs. 368, 369). Both articular surfaces are coated with cartilage, that covering the head of the femur, about two-thirds of a sphere, being thicker above where it has to bear the weight of the body, and thinning out to a mere edge below; the pit for the ligamentum teres is the only part uncoated, but the cartilage is somewhat heaped up around its margin. Covering the acetabulum, the cartilage is horseshoe-shaped, limited and corresponding to the lunate surface, and thicker above than below. In the acetabular fossa a mass of fatty tissue—the so-called synovial or Haversian gland—is lodged.

The ligaments of the joint are the articular capsule, transverse acetabular ligament, zona orbicularis, iliofemoral, ischiocapsular, pubocapsular, ligamentum teres, and glenoid lip.

The **articular capsule** is one of the strongest ligaments in the body. It is large and somewhat loose, so that in every position of the body some portion of it is relaxed. At the pelvis it is attached, superiorly, to the base of the anterior inferior iliac spine; curving backward, it becomes blended with the deep surface

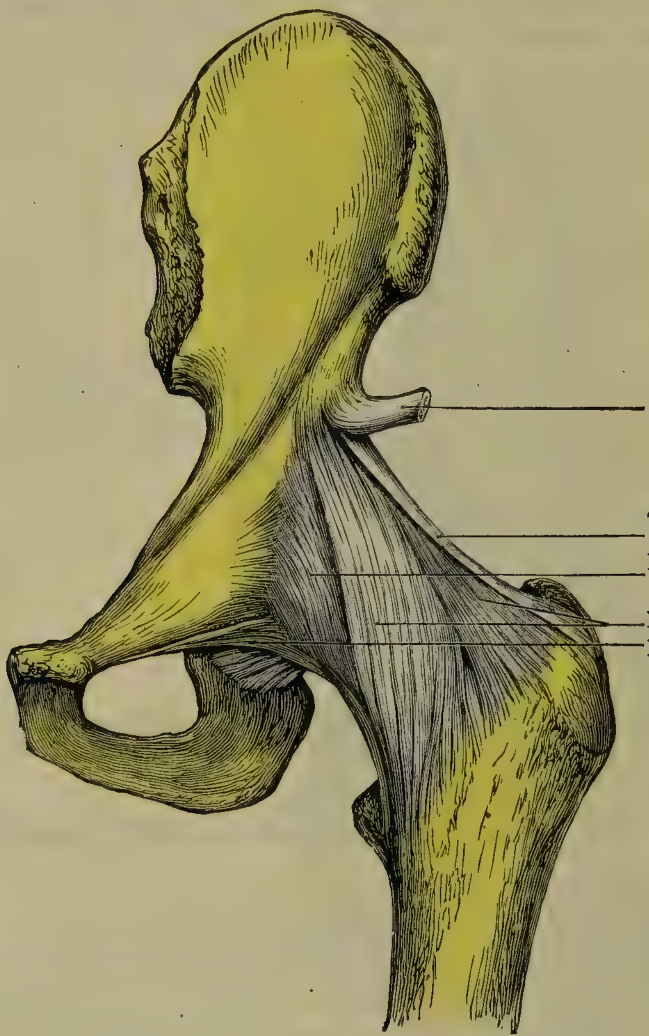


FIG. 364.—ANTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.

of the reflected tendon of the rectus femoris; posteriorly, it is attached a few millimeters from the acetabular rim; and below, to the upper edge of the groove between the acetabulum and tuberosity of the ischium. Thus it reaches the transverse ligament of the acetabulum, being firmly blended with its outer surface, and frequently sends fibers beyond the acetabular notch to blend with the obturator membrane. Anteriorly it is attached to the pubis near the obturator groove, to the iliopectineal eminence and thence backward to the base of the inferior iliac spine. (See figs. 365, 366, 368.)

A thin strong stratum (tendinotrochanteric band, fig. 364) is given off from its superficial aspect behind; this extends beneath the gluteus minimus and lateral rotator muscles, to be attached above to the dorsum of the ilium higher than the reflected tendon of the rectus, and posteriorly to the ilium and ischium nearly as far as the sciatic notch.

At the femur, the capsule is fixed to the anterior portion of the upper border of the greater trochanter and to the cervical tubercle. Thence it runs down the intertrochanteric line as far as the medial aspect of the femur, where it is on a

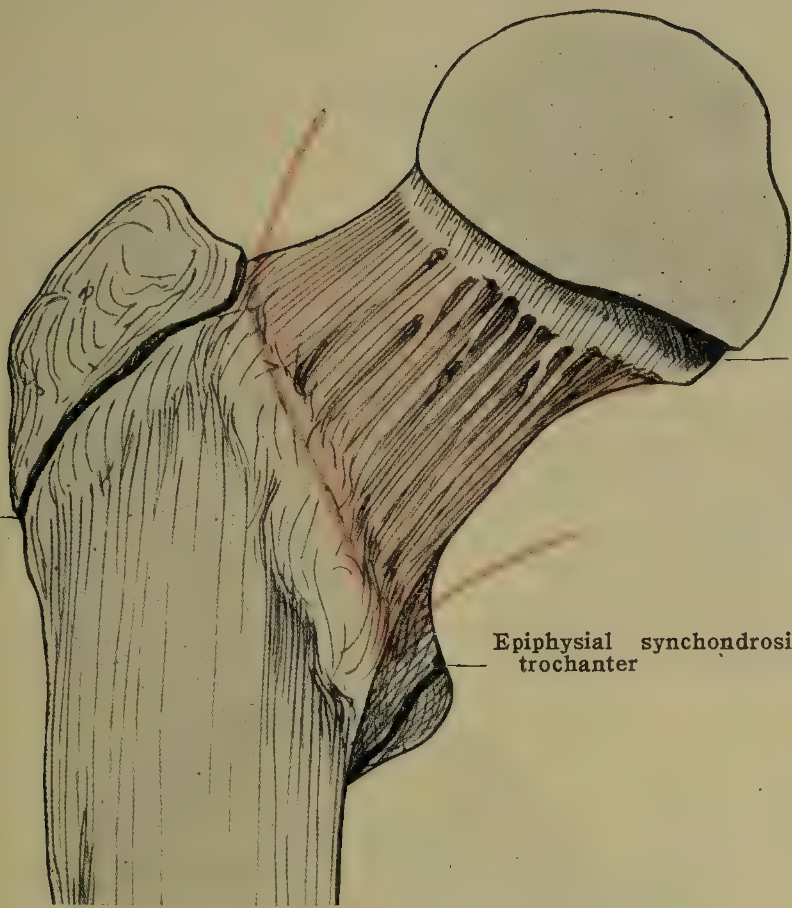


FIG. 365.—UPPER EXTREMITY OF THE FEMUR (ANTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSIAL LINES.

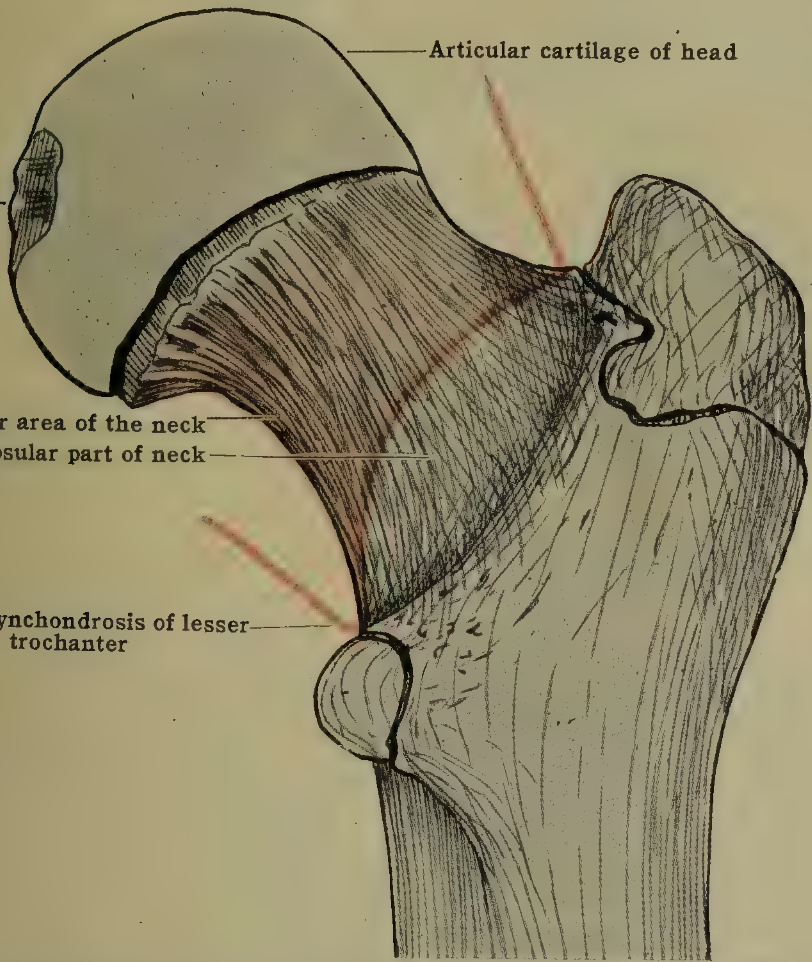


FIG. 366.—UPPER EXTREMITY OF THE FEMUR (POSTERIOR VIEW), TO SHOW THE RELATION OF THE ARTICULAR CAPSULE OF THE HIP-JOINT (IN RED) TO THE EPIPHYSIAL LINES.

level with the lower part of the lesser trochanter. It then runs upward and backward along an oblique line about 1.6 cm. in front of the lesser trochanter, and continues its ascent along the back of the neck nearly parallel to the intertrochanteric crest, and from 12 to 16 mm. above it; finally, it passes along the medial side of the trochanteric fossa to reach the anterior superior angle of the greater trochanter. It follows, therefore, that a considerable part of the neck of the femur posteriorly is extracapsular (figs. 365, 366).

On laying open the capsule, some of the deeper fibers are seen reflected upward long the neck of the femur, to be attached much nearer the head: these are the **retinacula.** One corresponds to the upper, and another to the lower, part of the intertrochanteric line; a third is seen at the upper and back part of the neck. They form flat bands, covered by the synovial layer, which lie on the femoral neck.

Superadded to the capsule, and considerably strengthening it, are three auxiliary bands, whose fibers are intimately blended with, and in fact form part of, the capsule, viz., the iliofemoral, ischiocapsular, and pubocapsular ligaments.

The **iliofemoral ligament** [lig. iliofemorale] (fig. 364) is the longest, widest, and strongest of the bands. Located at the front of the capsule, it is of triangular shape, with the apex attached above to a curved line on the ilium immediately below and behind the anterior inferior spine, and its base below to the anterior edge of the greater trochanter and to the spiral line as far as the medial border of the shaft. The highest or most lateral fibers are coarse, almost

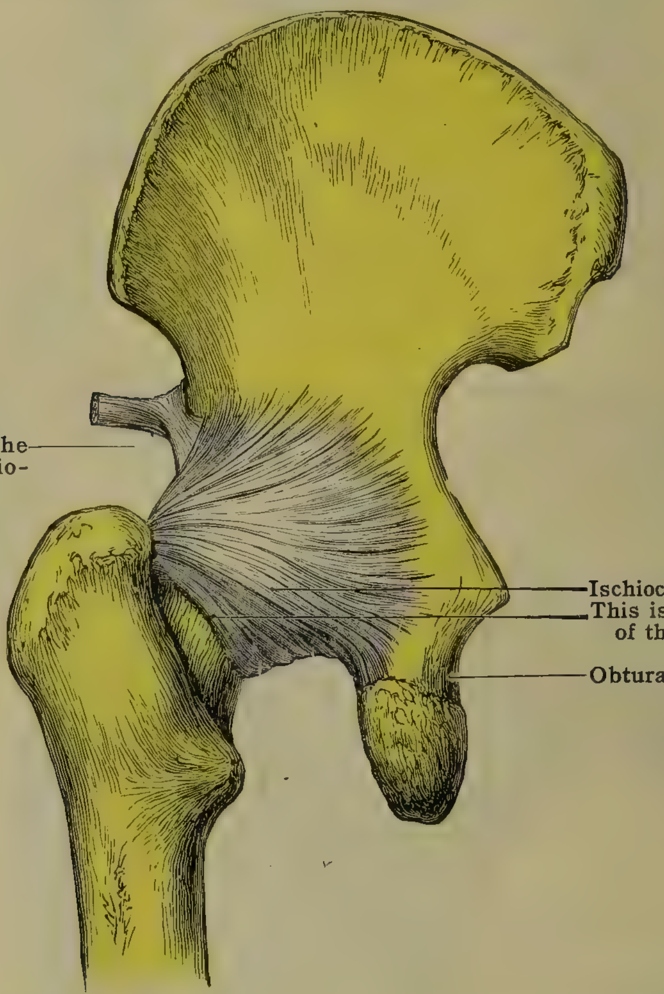


FIG. 367.—POSTERIOR VIEW OF THE ARTICULAR CAPSULE OF THE HIP-JOINT.

straight, and shorter than the rest; the most medial fibers are also thick and strong, but oblique. This varying obliquity of the fibers, and their accumulation at the borders, explain why this band has been described as the Y-shaped ligament; but it should be noted that the Y is inverted. About the center of its base, near the femoral attachment, is an aperture transmitting an articular twig from the ascending branch of the lateral circumflex artery.

The **ischiocapsular ligament** [lig. ischiocapsulare] (fig. 367) on the back of the capsule, is formed of very strong fibers attached all along the upper border of the notch for the external obturator muscle, and to the ischial margin of the acetabulum above the notch. The highest of these incline a little upward as they pass laterally to be fixed to the greater trochanter in front of the insertion of the piriformis tendon, while the other fibers curve more and more upward as they pass laterally to their insertion at the inner side of the trochanteric fossa, blending with the capsule and with the insertion of the external rotator tendons.

The deeper fibers of the capsule lying next to the synovial stratum take a circular course. They may be seen at the back and lower part of the capsule where the longitudinal fibers are deficient, forming a ring, the **orbicular zone** [zona orbicularis], embracing the neck of the femur.

The **pubocapsular ligament** [lig. pubocapsulare] (fig. 364) is a distinct but narrow set of fibers which are individually less marked than the fibers of the other two bands; they are fixed

above to the obturator crest and to the anterior border of the iliopectineal eminence, reaching as far down as the pubic end of the acetabular notch. Below, they reach the neck of the femur, and are fixed above and behind the lowermost fibers of the iliofemoral band, with which they blend.

In **thickness** and strength the capsule varies greatly; thus, if two lines be drawn, one from the anterior inferior spine to the medial border of the femur near the lesser trochanter, and the other from the anterior part of the notch for the external obturator to the trochanteric fossa, all the ligament between these lines on the lateral and upper aspects of the joint is very thick and strong, while that below and to the medial side, except at the narrow pubocapsular ligament, is thin and weak. The capsule is thickest in the course of the iliofemoral ligament, toward the lateral part of which it may measure over 10 mm. Between the iliofemoral and ischiocapsular ligaments the capsule is very strong, and with it here, near the acetabulum, is incorporated the reflected tendon of the rectus, and here also a triangular band of fibers runs downward and forward to be attached by a narrow insertion to the ridge on the front border of the great trochanter near the gluteus minimus (the **iliotrochanteric band,** fig. 367).

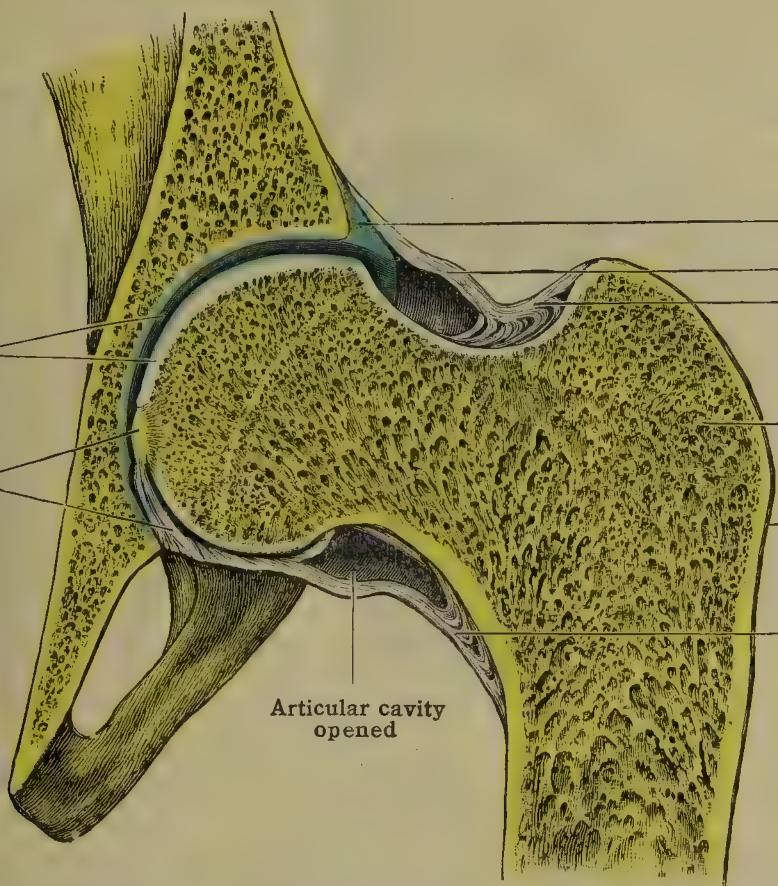


FIG. 368.—SECTION THROUGH THE HIP-JOINT, SHOWING THE GLENOID LIP, LIGAMENTUM TERES, AND RETINACULA. (The synostosis of the epiphysis of the head appears as a curving line in the section.)

The capsule is strengthened also at this point by a strong band from the under surface of the gluteus minimus, and by the **tendinotrochanteric band** which passes down from the reflected tendon of the rectus to the vastus lateralis (fig. 364).

The thinnest part of the capsule is between the pubocapsular and iliofemoral ligaments; this is sometimes perforated, allowing the bursa beneath the psoas to communicate with the joint. The capsule is also very thin at its attachment to the back of the femoral neck, and again opposite the acetabular notch.

The **ligamentum teres** (figs. 368, 369) is an interarticular flat band which extends from the acetabular fossa to the head of the femur, and is usually about 3.7 cm. long. It has two bony attachments, one on either side of the acetabular notch immediately below the articular cartilage, while intermediate fibers spring from the lower surface of the transverse ligament. The ischial portion is the stronger, and has fibers arising outside the cavity, below and in connection with the origin of the transverse ligament, where it is also continuous with the capsule and periosteum of the ischium. At the femur it is fixed to the front part of the fovea capitis, and to the cartilage round the margin of the depression.

The **transverse ligament of the acetabulum** [lig. transversum acetabuli] passes across the acetabular notch and converts it into a foramen; it supports part of the glenoid lip, and is connected with the ligamentum teres and the capsule. It is composed of decussating fibers, which arise from the margin of the acetabulum on either side of the notch, those coming from the pubis being more superficial, and passing to form the deep part of the ligament at the ischium, while those superficial at the ischium are deep at the pubis. It thus completes the rim of the acetabulum.

The **glenoid lip** [labrum glenoidale] (figs. 368, 369) is a fibrocartilaginous structure, which deepens the acetabulum by surmounting its margin. It varies in strength and thickness, but is stronger at its iliac and ischial portions than elsewhere. Its base is broad and fixed to the bony rim as well as to the articular cartilage of the acetabulum on the inner, and the periosteum on the outer, side of it, and blends inseparably with the transverse ligament which supports it over the acetabular notch.

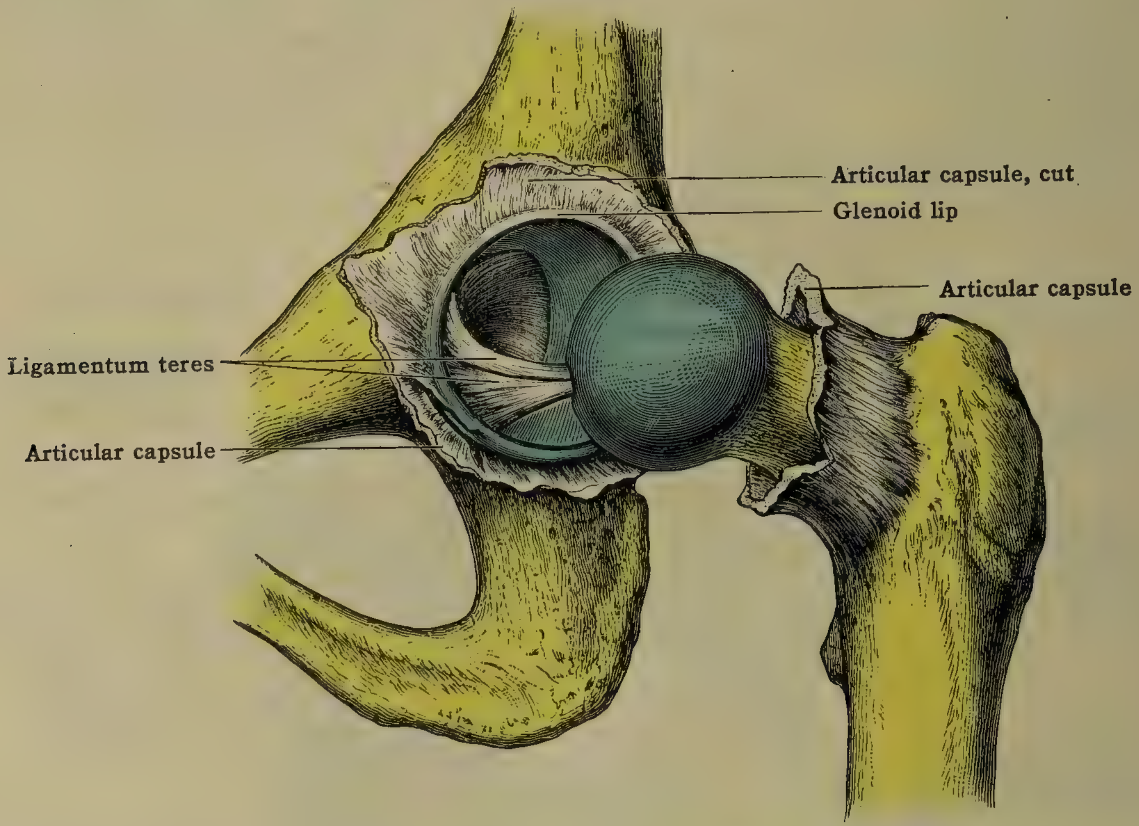


Fig. 369.—Hip-joint after Dividing the Articular Capsule and Disarticulating the Femur.

The free margin of the glenoid lip is thin; on section it is somewhat lunated, having its outer surface convex and its articular face concave and very smooth in adaptation to the head of the bone, which it tightly embraces a little beyond its greatest circumference. It somewhat contracts the aperture of the acetabulum, and gives to that socket a depth exceeding a hemisphere. This enarthrosis is in marked contrast to the conditions of the shoulder joint where the head of the humerus is merely in contact, not enclosed, in the shallow glenoid cavity. The glenoid lip is covered on both its extra- and intra-articular surfaces by the synovial layer.

The **synovial stratum** of the fibrous capsule continues upon both surfaces of the glenoid lip, and passes over the transverse acetabular ligament to reach and cover the fatty tissue of the acetabular fossa. The part covering the fatty cushion is unusually thick, and is attached round the edges of the rough bony surface on which the cushion rests. The membrane is loosely reflected off this on to the ligamentum teres, along which it is prolonged to the head of the femur; thus the fibers of the round ligament are shut out from the joint cavity. The synovial layer is also reflected below on to the neck of the femur, whence it passes over the retinacula to the margin of the articular cartilage.

The **arterial supply** comes from—(*a*) the transverse branches of the medial and lateral circumflex arteries; (*b*) the lateral branch of the obturator, by a branch through the acetabular notch beneath the transverse ligament, which ramifies in the fat at the bottom of the acetabulum, and travels down the round ligament to the head of the femur; (*c*) the inferior branch of the deep division of the superior gluteal; and (*d*) the inferior gluteal (sciatic) artery.

The superior and inferior gluteal arteries send several branches through the coxal attachment of the articular capsule: these anastomose freely beneath the capsule around the outer aspect of the acetabulum, and supply some branches to enter the bone, and others which enter the substance of the glenoid lip. There is quite an arterial crescent upon the posterior and postero-

superior portions of the acetabulum; but no vessels are to be seen on the inner aspect of the glenoid lip. A fold of the synovial layer on the lower aspect of the neck often conveys to the head of the femur a branch of an artery—generally a branch of the medial circumflex.

Lymph-vessels drain to the hypogastric, obturator and external iliac nodes.

The **nerve-supply** comes from—(*a*) femoral, (*b*) anterior division of the obturator, (*c*) the accessory obturator (when present), and (*d*) the sacral plexus, by a twig from the nerve to the quadratus femoris, or from the upper part of the great sciatic, or from the lower part of the sacral plexus.

Relations.—In *front* and in contact with the capsule are the iliopectineal bursa, the tendinous part of the psoas major, and the iliacus. Still more anteriorly and not in contact are the femoral artery, the femoral nerve, the rectus femoris, the sartorius, and the tensor fasciæ latæ muscles.

Above and in close relation with the capsule are the piriformis, the obturator internus, the gemelli, and the reflected head of the rectus femoris, whilst more superficially lie the gluteus minimus and medius.

Behind and in close relation with the capsule are the obturator externus, the gemelli and obturator internus, and the piriformis. More superficially lie the quadratus femoris, the sciatic and posterior femoral cutaneous nerves, and the gluteus maximus.

Below, the obturator externus, the pectineus, and the medial circumflex artery are in close relation with the capsule.

The **movements** (cf. p. 579).—The hip-joint, like the shoulder, is a ball-and-socket joint, but with a much more complete socket and a corresponding limitation of movement. Each variety of movement is permitted, viz., flexion, extension, abduction, adduction, circumduction, and rotation; and any two or more of these movements not being antagonistic can be combined, i. e., flexion or extension associated with abduction or adduction can be combined with rotation lateral or medial.

The three axes about which these movements take place, transverse, anteroposterior and vertical, intersect in the center of the head of the femur. The transverse axis lies in a plane anterior to the line of gravity of the body and if extended laterally would cut Nelaton's line (see below) at about its mid-point. The antero-posterior axis of abduction and adduction passes through the margins of the acetabulum to traverse the head of the femur. In the standing posture the shaft of the femur is inclined from above downward and medially and lies for the greater part lateral to the vertical axis of rotation which falls from the center of the femoral head above through the center of the knee joint.

It results from the obliquity of the neck of the femur that the movements of the head in the acetabulum are always more or less of a rotatory character. This is more especially the case during flexion and extension, and two results follow from it. First, the bearing surfaces of the femur and acetabulum preserve their apposition to each other, so that the amount of articular surface of the head in the acetabulum does not sensibly diminish *pari passu* with the transit of the joint from the extended to the flexed position, as would necessarily be the case if the movement of the femoral head, like that of the thigh itself, was simply angular, instead of rotatory and angular. Secondly, as rotation of the head can continue until the ligaments are tight without being checked by contact of the neck of the thigh bone with the rim of the acetabulum, flexion of the thigh so far as the joint is concerned is practically unlimited. Flexion is the most important and most extensive movement, and in the dissected limb, before the ligaments are disturbed, can be carried to 160°, and is then checked by the lower fibers of the ischiocapsular ligament. In the living subject simple flexion can continue until checked by the contact of the soft parts at the groin, if the knee be bent; if the knee be straight, flexion of the hip is checked in most persons by the hamstring muscles at nearly a right angle. This is very evident on trying to touch the ground with the fingers without bending the knees, the chief strain being felt at the popliteal space. This is due to the shortness of the hamstrings. Extension is limited by the iliofemoral ligament. Measurements of the range of flexion and extension in the living (men, mostly in the third decade) have shown a total of 146° on both sides, average flexion 114°, average extension 32° (Moore and Vaughn, Jour. Bone and Joint Surg., 10, 1928).

Abduction and lateral rotation can be performed freely in every position of flexion and extension—abduction being limited by the pubocapsular ligament; lateral rotation by the iliofemoral ligament, especially its medial portion, during extension; but by the lateral portion, as well as by the ligamentum teres, during flexion.

Adduction is very limited in the extended thigh on account of the contact with the opposite limb. In the slightly flexed position adduction is more free than in extension, and is then limited by the lateral fibers of the iliofemoral band and the superior portion of the capsule. In flexion the range is still greater, and limited by the ischiocapsular ligament, the ligamentum teres being also rendered nearly tight. Medial rotation in the extended position is limited by the lower fibers of the iliofemoral ligament; and in flexion by the ischiocapsular ligament and the portion of the capsule between it and the iliofemoral band.

The iliofemoral band also prevents the tendency of the trunk to roll backward on the thigh bones in the erect posture, and so does away with the necessity for muscular power for this purpose; it is put on stretch in the stand-at-ease position (fig. 370).

The ligamentum teres is of little use in resisting violence or in imparting strength to the joint. It assists in checking lateral rotation, and adduction during flexion. A ligament can only be of use when it is tight, and it was found by trephining the bottom of the acetabulum, removing the fat, and threading a piece of whip cord round the ligament, that the ligament was slack in simple flexion, and very loose in complete extension, but that its most slack condition was in abduction. It is tightest in flexion combined with adduction and lateral rotation.

Muscles which act upon the hip-joint (cf. p. 579ff.).—*Flexors.*—The psoas and iliacus, the rectus femoris, the pectineus, the adductors longus, brevis, the sartorius, obturator externus, the tensor fasciæ latæ, and the gluteus minimus. *Extensors.*—The gluteus maximus, the posterior fibers of the glutei medius and minimus, the biceps, the semitendinosus, the semimembranosus, and the ischial fibers of the adductor magnus; also (slightly) the piriformis, obturator

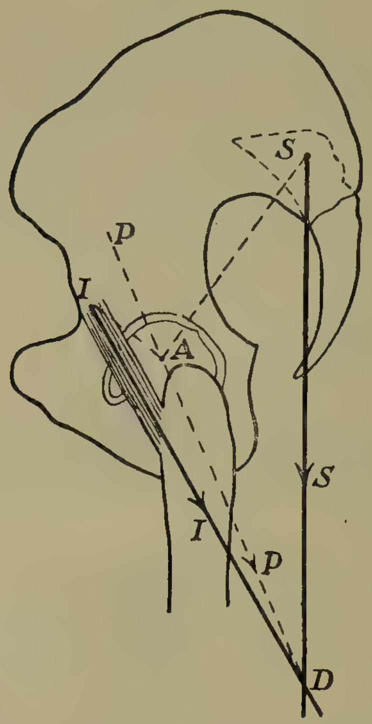


FIG. 370.—SCHEME OF THE MECHANICS OF THE PELVIS.

Upper *S*, center of gravity of the body standing erect; lower *S*, the line of gravity; *A*, mid-point of femoral head and projection of the axis of the hip-joint; II, iliofemoral ligament and extension of its direction to the line of gravity at *D*; *PP*, line of axis pressure; *IA*, lever arm of the iliofemoral ligament; *SA*, lower arm of the body weight. (H. Meyer, in Rauber-Kopsch, Lehrbuch der Anatomie.)

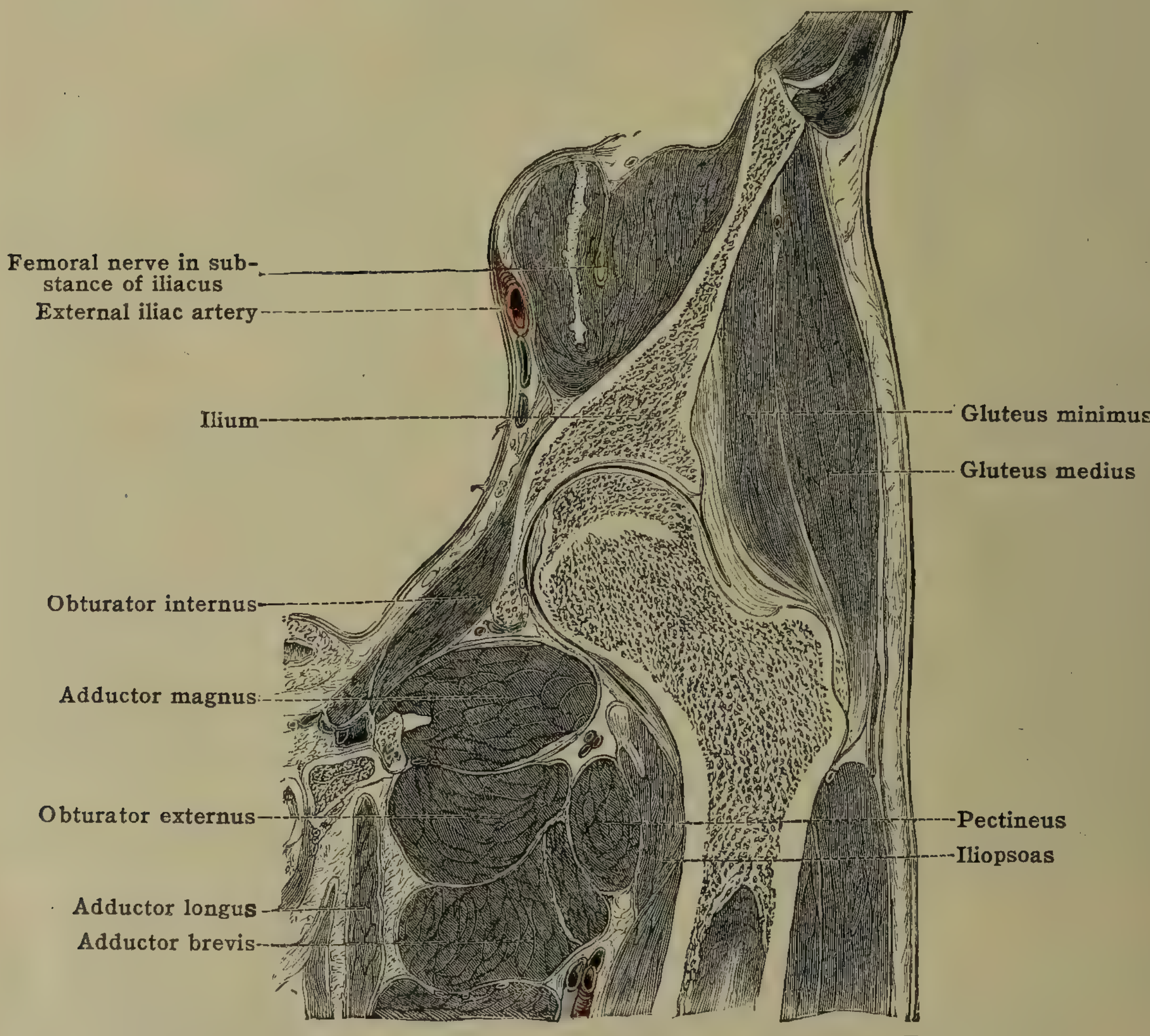


FIG. 371.—FRONTAL SECTION OF THE HIP-JOINT AND ITS RELATIONS. ($\times \frac{1}{3}$) (Braune.)

internus and gemelli. *Abductors.*—Tensor fasciæ latæ, gluteus medius, gluteus minimus, and, when the joint is flexed, the piriformis, obturator internus, the gemelli, and the sartorius also become abductors. *Adductors.*—Adductores magnus, longus, brevis, and minimus, semitendinosus, biceps, the gracilis, the pectineus, obturator externus, the quadratus femoris, and the lower fibers of the gluteus maximus. *Medial rotators.*—Psoas, semimembranosus, semitendinosus, the anterior fibers of the gluteus medius and minimus, and the tensor fasciæ latæ, adductors longus and brevis. *Lateral rotators.*—Gluteus maximus, posterior fibers of gluteus medius, the biceps, the adductor magnus (lower part), obturator externus, quadratus femoris, obturator internus, the gemelli, and the piriformis when the joint is extended.

Clinical relations (figs. 364, 366, 369, 371).—The chief points of surgical importance for the hip-joint are the following. The capsule shows fibers chiefly longitudinal in front, circular behind. Of the former, the iliofemoral or inverted Y-shaped ligament descends from the base of the anterior inferior spine to the two extremities of the anterior intertrochanteric line. It not only checks extension and strengthens the front of the joint, but it keeps the pelvis and trunk from rolling backward on the heads of the femurs, thus preventing waste of muscular action. It is joined on the medial side by the pubocapsular ligament, which checks abduction. Between the two is the mid-part of the front of the capsule, and here the iliopsoas

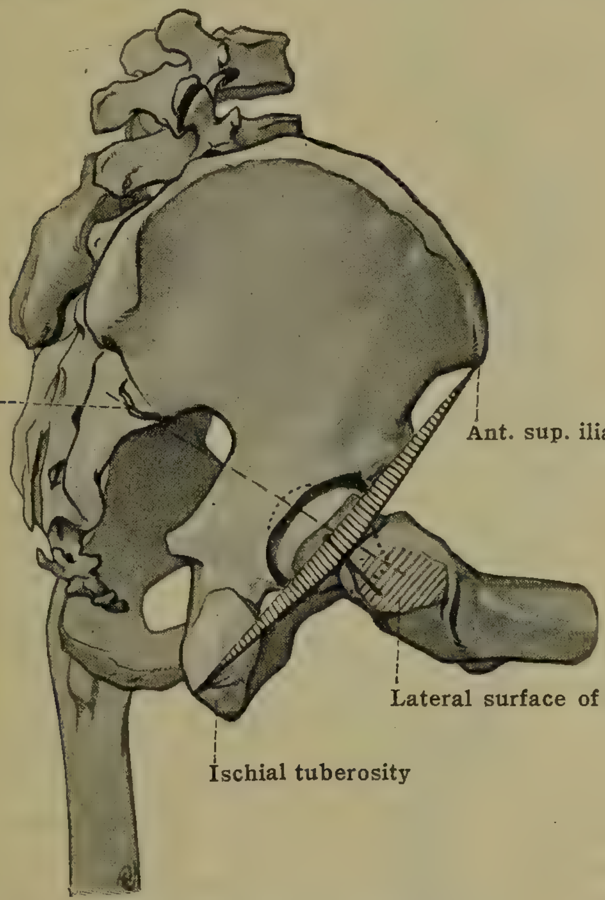


Fig. 372.—Nelaton's Line.

Nelaton's line (modified by Roser) extends from the anterior superior iliac spine to the middle of the tuberosity of the ischium and passes slightly above the summit of the greater trochanter. It forms the base of an obtuse triangle (shaded) whose apex is at the trochanter. (Braus, Anatomie des Menschen.)

bursa may communicate with the joint. This fact must be remembered in tuberculous disease of the psoas, and the presence of this bursa explains certain deep-seated swellings in the front of the joint in adults. Behind, the ischiofemoral ligament is the strongest part of the capsule, its fibers blending with the circular and weaker part of the capsule here. Dislocation usually occurs at the posterior, lower and medial part of the joint. It is to be noted that in full extension and flexion the head of the femur is in contact with the weakest spot in the capsule, in front and behind, respectively. From the deep aspect of the capsule fibers pass up at the line of reflection of the synovial membrane on to the neck—the retinacula (cervical ligaments of Stanley). In intracapsular fracture these fibers keep the fragments together; hence one need of gentle handling; their softening may explain, a little later, an increase in the shortening.

Nélaton's line (fig. 372).—This useful guide is a line drawn from the anterior superior spine of the ilium to the most prominent part of the tuberosity of the ischium. In normal limbs, the top of the great trochanter just touches this line. In dislocation, fractures of the neck, and in wasting of the neck, as in osteoarthritis, the relation of the trochanter to Nélaton's line becomes altered.

The top of the great trochanter is a guide in Adams's operation for division of the neck of an ankylosed femur, the puncture being made and the saw entered 2.5 cm. (1 in.) above and about the same distance in front of this point. Owing to the fact that in many cases of ankylosis the neck is destroyed, the above operation has been largely replaced by the simpler and more widely applicable Gant's osteotomy just below the great trochanter, from the lateral side.

Bryant's triangle.—Bryant makes use of the following in deciding the position of the great trochanter. The patient being flat on his back (1) a line is dropped vertically on to the couch from the anterior superior spine; (2) from the top of the great trochanter a straight line in the

long axis of the thigh is drawn to meet the first; (3) to complete the triangle, a line is drawn from the anterior superior spine to the top of the trochanter. This line is practically Nélaton's. The second line will be found diminished on the damaged or diseased side.

3. THE KNEE-JOINT

The **knee-joint** [articulatio genus] is the largest joint in the body. It is rightly described as a ginglymoid joint; but there are also other elements, for flexion and extension are modified by the spiral contour of the femoral condyles; in addition there is a sliding backward and forward of the tibia upon the femoral condyles, as well as slight rotation round a vertical axis. The knee is one of the most superficial, and, because of the incongruity of the bony surfaces, one of the weakest joints; in no position are the bones in more than partial contact. Its strength lies in the number, size, and arrangement of the ligaments, and the powerful muscles and fascial expansions which pass over the articulation and enable it to withstand the leverage of the two longest bones in the body. It may be said to consist of two articulations (compound joint) with a common articular cavity—the patellofemoral and the tibiofemoral, the latter being double. The articular surfaces entering into the knee-joint are the condyles and patellar surface of the femur, the superior articular surface of the tibia, and the patella.

Regarding the articular surfaces, the condyles of the femur are in the form of rollers or thick wheels, not exactly parallel but diverging backward and downward. The sagittal curves change gradually from a circle of longer radius to one of smaller radius, giving a spiral curve. The spiral curves of the two condyles differ in that the medial is of shorter radii than the lateral; also the medial condylar surface is longer than the lateral. The patellar articular surface is more projecting laterally than medially and is demarcated from the condylar surfaces by the condylopatellar lines. On the tibia the superior articular surface is divided into two quite separate cartilage-covered surfaces by the intercondyloid areas. The medial surface is slightly concave and approximates an oval outline, whereas the lateral is slightly convex and circular. (For the contour of the articular surface of the patella see p. 244.) The articular cartilage measures in thickness 2.6–3.2 mm. maximum on the femoral condyles, 3.5 mm. in the middle of the trochlear surface, but 5.4–6.4 mm. deep at the longitudinal ridge of the patellar articular surface. The cartilage of the lateral articular surface on the tibia is thicker than that of the medial surface (4–5 mm. in the central part).

The bones are united by the following ligaments, which may be divided into an external and an internal set:—

External	Internal
Articular capsule.	Anterior cruciate.
Patellar retinacula.	Posterior cruciate.
Ligamentum patellæ.	Medial meniscus.
Oblique popliteal ligament.	Lateral meniscus.
Arcuate popliteal ligament.	Transverse.
Fibular collateral.	
Tibial collateral.	

External Ligaments

Superficial to the fibrous expansion of the quadriceps extensor tendons the fascia lata of the thigh covers the front and sides of the knee-joint.

The deep fascia of the thigh, as it descends to its attachment to the tuberosity and oblique lines of the tibia, not only overlies but blends with the fibrous expansion of the extensor tendons. The oblique ridges of the tibia curve upward and backward from the tuberosity on each side to the posterolateral part of the condyles. The process of fascia, iliotibial band, attached to the lateral ridge of the tibia and to the head of the fibula, descends from the tensor fasciæ latæ and is very thick and strong. It is firmly blended with the tendinous fibers of the vastus lateralis. The fascia lata, on the medial side of the patella, besides being attached to the medial oblique ridge of the tibia, sends some longitudinal fibers lower down to become blended with the fibrous expansion of the sartorius. The fascia is much thinner on the medial side of the patella than on the lateral, and blends much less with the tendon of the vastus medialis than the lateral part of the fascia does with the vastus lateralis. A thin layer of the fascia lata in the form of transverse or arciform fibers passes over the front of the joint. These fibers are specially well marked over the ligamentum patellæ.

The **patellar retinacula** [retinaculum patellæ mediale; laterale] consist—(1) of a central portion, densely thick and strong, derived from the rectus tendon, which is inserted into the upper border of the patella, many of its superficial fibers, passing over the subcutaneous surface of the bone into the ligamentum

patellæ; (2) of two thinner lateral portions, derived from the tendons of the vastus medialis and lateralis.

The lateral portions are attached to the patella along its upper border on either side of the central portion and also into its medial and lateral borders, nearer the anterior than the posterior surface, as low down as the attachment of the ligamentum patellæ; passing thence along the sides of the ligamentum patellæ to the tibia, they are inserted into the oblique ridges, and reach as far as the tibial and fibular collateral ligaments. On the lateral side, the fibers of the lateral patellar retinaculum blend with the iliotibial band of the fascia lata, and on the medial, those of the medial patellar retinaculum extend below the oblique line to blend with the periosteum of the shaft. Thus there is a large hood spread over the whole of the front of the joint, investing the patella, and reaching from the sides of the ligamentum patellæ to the collateral ligaments, attached below to the tibia, and separated everywhere from the synovial stratum by a layer of fatty tissue. (See fig. 479.)

FIG. 373.—POSTERIOR VIEW OF THE KNEE-JOINT.

The **ligamentum patellæ** (fig. 377) is the continuation of the central portion of the quadriceps tendon, some fibers of which are prolonged over the front of the patella into the ligament. It is an extremely strong, flat band, attached above to the lower border of the patella; below, it is inserted into the lower part of the tuberosity and upper part of the crest of the tibia, somewhat obliquely, being prolonged downward further on the lateral side, so that this border is fully 2.5 cm. longer than the medial, which measures about 6.7 cm. in length. Behind, it is in contact with a mass of fat which separates it from the synovial layer, and the small deep infrapatellar bursa intervenes between it and the head of the tibia. In front, the large subcutaneous prepatellar bursa separates it from the integument, and at the sides it is continuous with the patellar retinacula.

The **tibial collateral ligament** [lig. collaterale tibiale] (fig. 373) is a strong, flat band, which extends from the tubercle on the medial epicondyle of the femur, to the medial border and medial surface of the shaft of the tibia, about 3.7 cm. below the condyle. It is about 8.7 cm. long, well defined anteriorly, where it blends with the expansion of the medial patellar retinaculum; but not so well defined posteriorly, where it merges into the oblique popliteal ligament.

Some of the lower fibers blend with the descending portion of the semimembranosus tendon. Its deep surface is firmly adherent to the edge of the medial meniscus and coronary ligament,

while part of the semimembranosus tendon and inferior medial articular vessels and nerve pass between it and the bone. Superficially, the bursa anserina separates it from the tendons of the gracilis and semitendinosus muscles and from the aponeurosis of the sartorius muscle.

The **fibular collateral ligament** [lig. collaterale fibulare] (fig. 373), is a strong, rounded cord, about 5 cm. long, attached above to the tubercle on the lateral epicondyle of the femur, just below and in front of the origin of the lateral head of the gastrocnemius, whilst the tendon of the popliteus arises from the groove below and in front of it. Below, it is fixed to the middle of the lateral surface of the head of the fibula, 1.2 cm. (or more) anterior to the apex.

Superficially is the tendon of the biceps, which splits to embrace its lower extremity; while beneath it pass the popliteus tendon in its sheath, and the inferior lateral articular vessels and nerve.

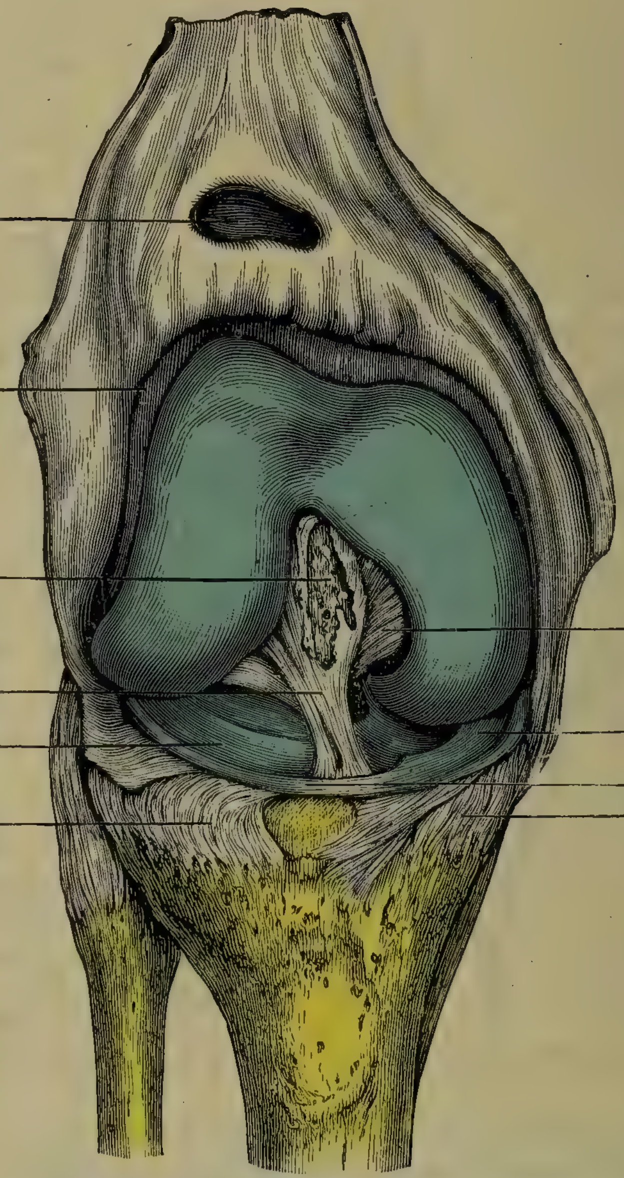


Fig. 374.—Anterior View of the Internal Ligaments of the Knee-joint.

The **arcuate popliteal ligament** [lig. popliteum arcuatum] (fig. 373) at the posterolateral side of the knee, is fixed below to the apex of the fibula, inclines upward and somewhat backward, and ties down the popliteus against the lateral epicondyle of the tibia to which it is attached, blending beneath the lateral head of the gastrocnemius with the oblique popliteal ligament of the knee, of which it is really a portion.

The **oblique popliteal ligament** [lig. popliteum obliquum] (ligament of Winslow) (fig. 373) is a dense structure of interlacing fibers, with large orifices for vessels and nerves, at the back of the knee. It is an oblique fasciculus from the semimembranosus tendon of insertion, passing upward and laterally from near the back part of the medial condyle of the tibia to the lateral epicondyle of the femur, where it joins the lateral head of the gastrocnemius, a sesamoid plate being sometimes developed at the point of junction.

The **articular capsule** (fig. 374) is thin but strong, inclosing the articular cavity, and forming a loose sac. It is attached to the femur near the articular margin on the medial side, but further away on the lateral; it encapsulates each condyle posteriorly and is traceable into the intercondyloid fossa to the attach-

ments of the cruciate ligaments, covered posteriorly by the oblique popliteal ligament. Laterally it passes beneath the fibular collateral ligament to join the sheath of the popliteus. Medially it joins the tibial collateral ligament. Below,

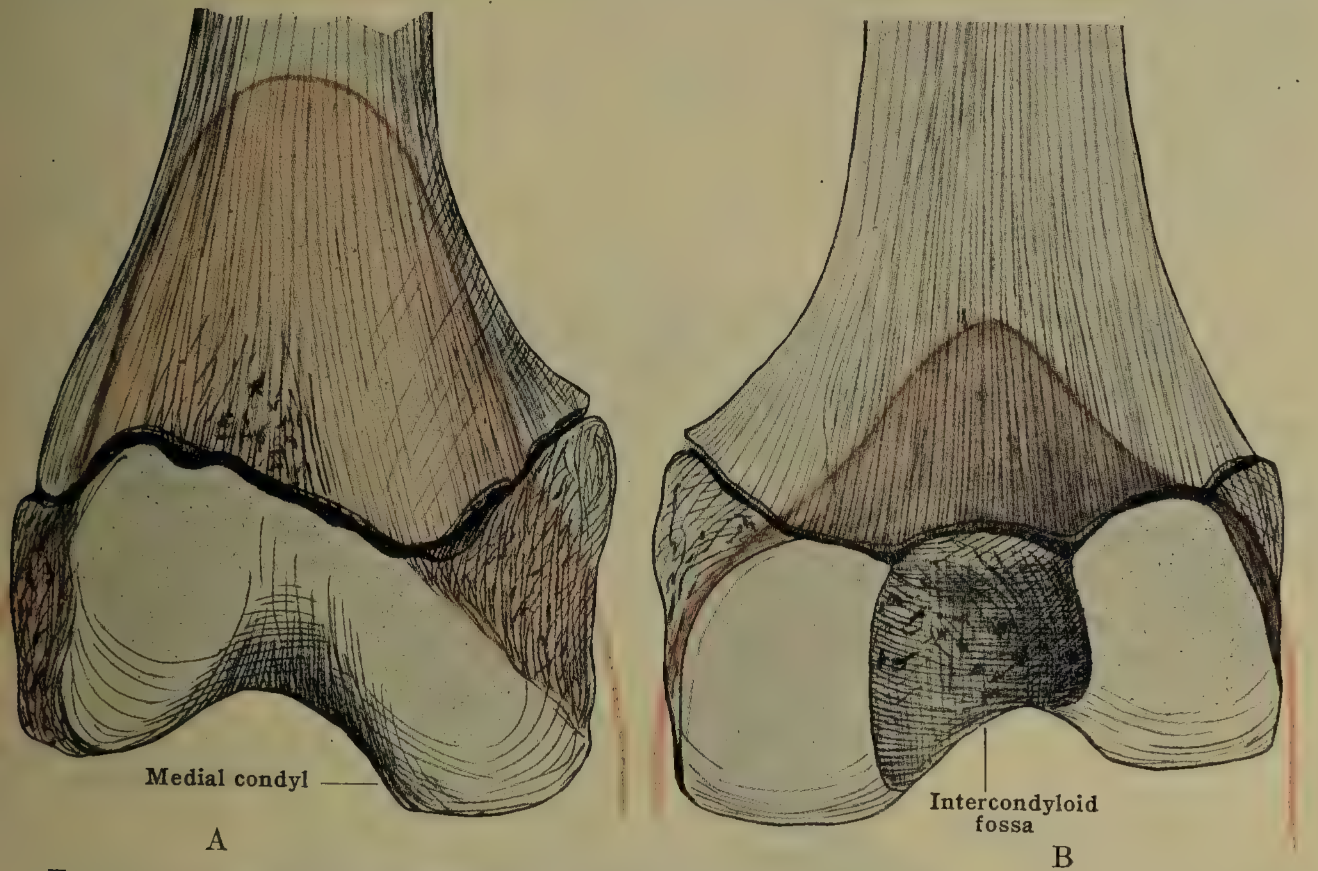


Fig. 375.—The Lower Extremity of the Femur, (A) Anterior, (B) Posterior view; to show the Relation of the Articular Capsule of the Knee-joint (in red) to the Epiphysial Line.

it is fixed to the upper as well as the medial and lateral borders of the patella and the anterior border of the head of the tibia. It is strengthened superficially between the femur and patella by an expansion from the articularis genus (sub-

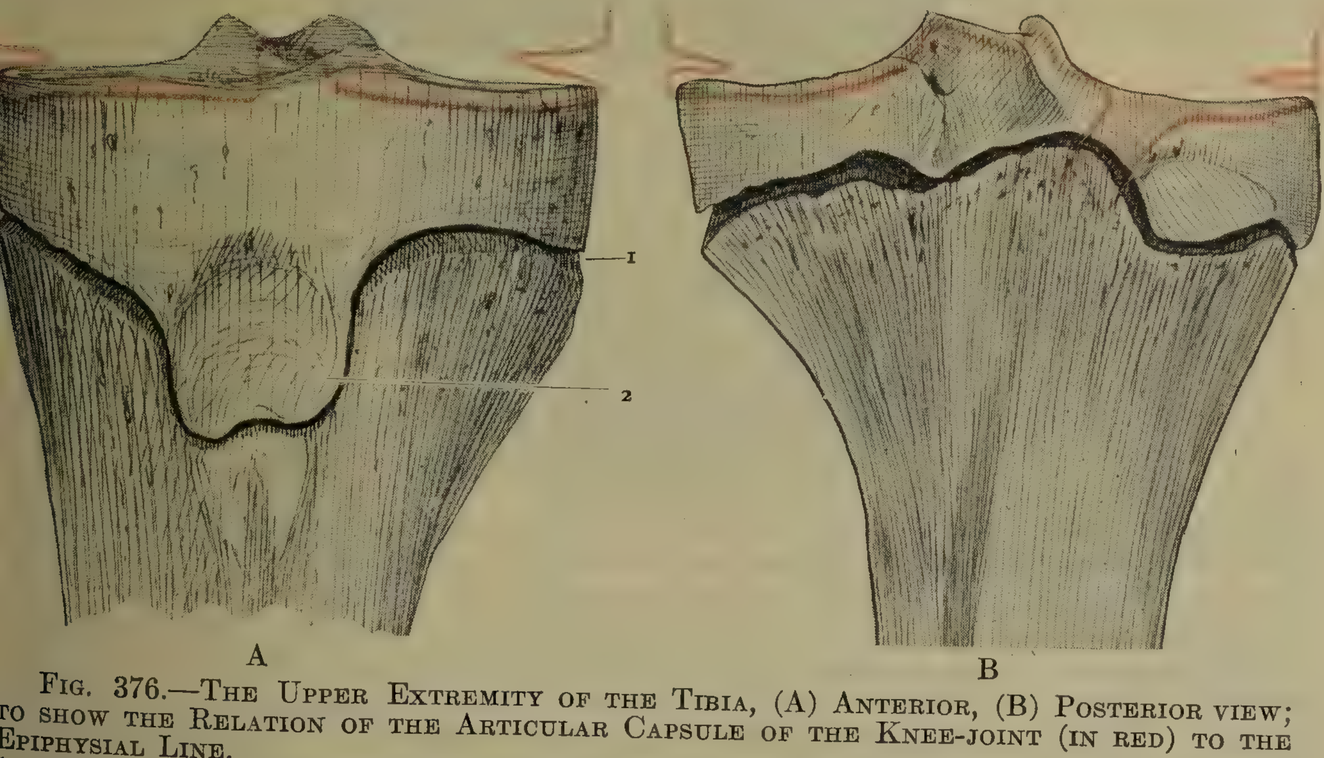


Fig. 376.—The Upper Extremity of the Tibia, (A) Anterior, (B) Posterior view; to show the Relation of the Articular Capsule of the Knee-joint (in red) to the Epiphysial Line.
1, synchondrosis of superior tibial epiphysis; 2, tuberosity of tibia. The shelf-like indentations of the red line above indicate the reflexions of the synovial layer upon the menisci.

crureus) and by the patellar retinacula and the fibrous expansions of the extensor tendons. By its deep surface it is connected with the borders of the menisci and, considerably thickened (coronary ligaments), goes to an attachment below to the straight margins of the tibial condyles (figs. 375, 376).

Internal Ligaments

The **anterior cruciate ligament** [lig. cruciatum anterius] (lig. decussatum laterale NK) (figs. 374, 377) is strong and cord-like. It is attached to the medial half of the anterior intercondyloid fossa of the tibia, and to the lateral border of the medial articular facet as far back as the medial intercondyloid tubercle. It passes upward, backward, and laterally to the back part of the medial surface of the lateral condyle of the femur.

To the tibia, it is fixed behind the anterior extremity of the medial semilunar meniscus. Behind and to the lateral side it has the anterior extremity of the lateral meniscus, a few fibers of which blend with the lateral edge of the ligament.

The **posterior cruciate ligament** [lig. cruciatum posterius] (lig. decussatum mediale NK) (figs. 374, 377, 383) is stronger and less oblique than the anterior. It is fixed below to the greater portion of the fossa behind the intercondyloid eminence of the tibia, especially the lateral and posterior portion, and then medially along the posterior intercondyloid fossa; being joined by fibers, which arise between the intercondyloid tubercles, it ascends to the anterior part of the lateral surface of the medial condyle of the femur, having a wide crescentic attachment, 1.5 cm. in extent, just above the articular surface.

Behind, it is connected at the tibia directly with the oblique ligament, and a little higher up by means of a quantity of interposed areolar tissue. In front it rests upon the posterior

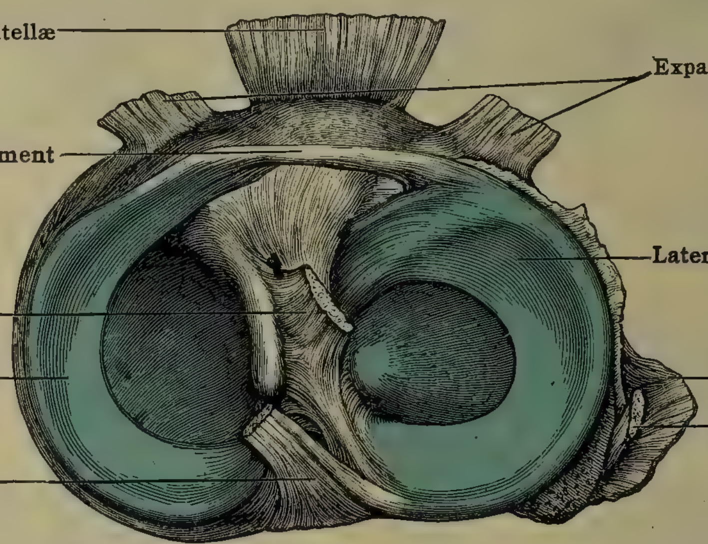


Fig. 377.—Articular Structures on the Head of the Right Tibia.

horn of the medial semilunar meniscus, and receives a large slip from the lateral meniscus, which ascends along it, either in front or behind, to the femur; higher up in front it is connected with the anterior cruciate ligament.

Until they rise above the intercondyloid eminence of the tibia the two cruciate ligaments are closely bound together, so that no interspace exists between their tibial attachments and the point of decussation; the only space between them is therefore a V-shaped one corresponding to the upper half of their X-shaped arrangement, and this is a mere chink in the undissected state. An intercruciate bursa has been described by Fick.

The interarticular **menisci** (semilunar fibrocartilages) (figs. 377, 378) are two crescentic disks resting upon the circumferential portions of the articular facets of the tibia, and moving with the tibia upon the femur. They somewhat deepen the tibial articular surfaces, and are dense and compact in structure, becoming looser and more fibrous near their extremities, where they are firmly fixed in front of and behind the intercondyloid eminence of the tibia. The circumferential border of each is convex, thick, and somewhat loosely attached to the borders of the condyles of the tibia by the coronary ligaments and the reflexion of the synovial stratum. The inner border is concave, thin, and free. About 1.3 cm. broad at the widest part, they taper somewhat toward their extremities, and cover rather less than two-thirds of the articular facets of the tibia. Their upper surfaces are slightly concave, and fit on to the femoral condyles, while the lower are flat and rest on the head of the tibia; both surfaces are smooth and covered by the synovial stratum.

The **lateral meniscus** [meniscus lateralis] (fig. 377) is nearly circular in form and less firmly fixed than the medial, and consequently slides more freely upon the tibia. Its anterior cornu is attached to a narrow depression along the lateral articular facet, just in front of the lateral

intercondyloid tubercle of the tibia, close to, and on the lateral side of, the anterior cruciate ligament. The posterior cornu is firmly attached to the tibia behind the lateral intercondyloid tubercle, blending with the posterior cruciate ligament, and giving off a well-marked fasciculus, which runs up along the anterior border of the ligament to be attached to the medial condyle (ligament of Wrisberg, fig. 382). It also sends a narrow slip into the back part of the anterior cruciate ligament. Its outer border is grooved toward its posterior part by the popliteus tendon, which is held to it by fibrous tissue and the synovial layer, and separates it from the fibular collateral ligament. From its anterior border is given off the transverse ligament.

The **medial meniscus** [meniscus medialis] (fig. 377) is a segment of a larger circle than the lateral, and has an outline more oval than circular. Its anterior cornu is wide, and has a broad and oblique attachment to the anterior margin of the head of the tibia. It reaches from the margin of the condyle toward the middle of the anterior intercondyloid fossa, being altogether

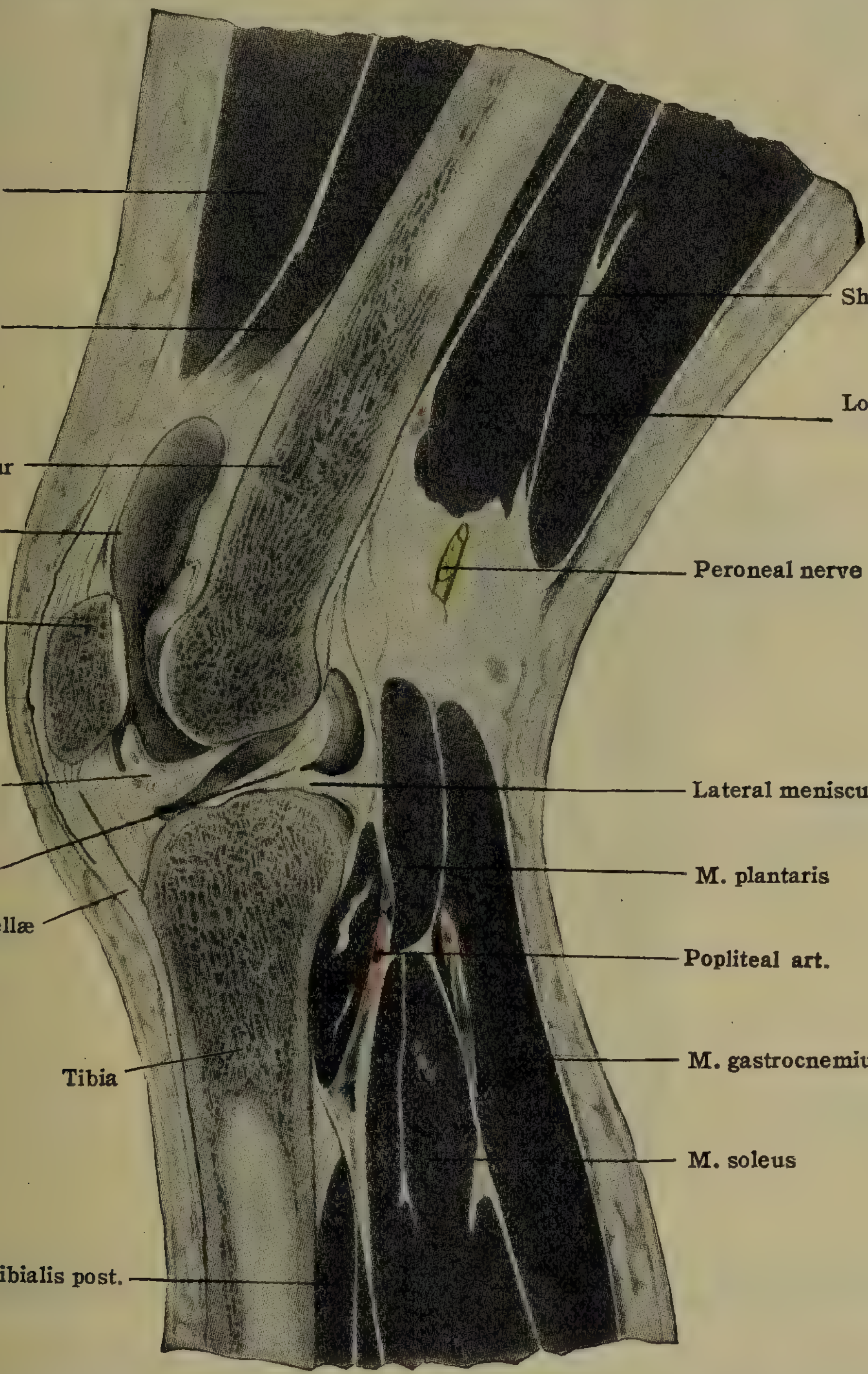


FIG. 378.—SAGITTAL SECTION OF THE KNEE-JOINT. (The bones are drawn somewhat apart. The suprapatellar bursa above the upper synovial *cul-de-sac* is not shown.) (After Braune.)

in front of the anterior cruciate ligament. The posterior cornu is firmly fixed by a broad insertion in an anteroposterior line along the medial side of the posterior intercondyloid fossa, from the medial tubercle to the posterior margin of the head of the tibia. Its convex border is connected with the tibial collateral ligament and the semimembranosus tendon.

The **transverse ligament of the knee** [lig. transversum genus] (figs. 374, 377) is a rounded, slender, short cord, which extends from the convex border of the lateral meniscus to the concave border or anterior cornu of the medial, near which it is sometimes attached to the bone. It is an accessory band of the lateral meniscus, and is situated beneath the synovial stratum.

The **articular cavity** (figs. 374, 378, 379, 380, 384) of the knee forms the largest joint space in the body. Bulging upward from the patella, it follows

the capsule of the joint into a large *cul-de-sac* beneath the tendon of the extensor muscles on the front of the femur. It reaches some distance beyond the articular surface of the bone, and communicates very frequently with the large suprapatellar bursa interposed between the tendon and the femur above the line of attachment of the articular capsule. An extension of the synovial layer invests the circumference of the lower end of the femur and is continuous with the layer upon the fibrous envelope of the articular capsule. The cavity may communicate with that of the superior tibiofibular joint.

The synovial stratum covers a great portion of the cruciate ligaments, but leaves uncovered the back of the posterior cruciate where the latter is connected with the posterior ligament, and the lower part of both cruciate ligaments where they are united. Thus the ligaments are completely shut out of the articular cavity. Along the fibrous envelope the synovial layer is conducted down to the semilunar menisci, over both surfaces of which it passes, and is reflected off the under surface on to the fibrous capsule, and thence down to the head of the tibia around the circumference of which it extends a short way. It dips down between the lateral meniscus and the head of the tibia as low as the superior tibiofibular ligament, reaching inward nearly as far as the intercondyloid notch, and forming the bursa of the popliteus muscle for the play of the popliteal tendon (fig. 376).

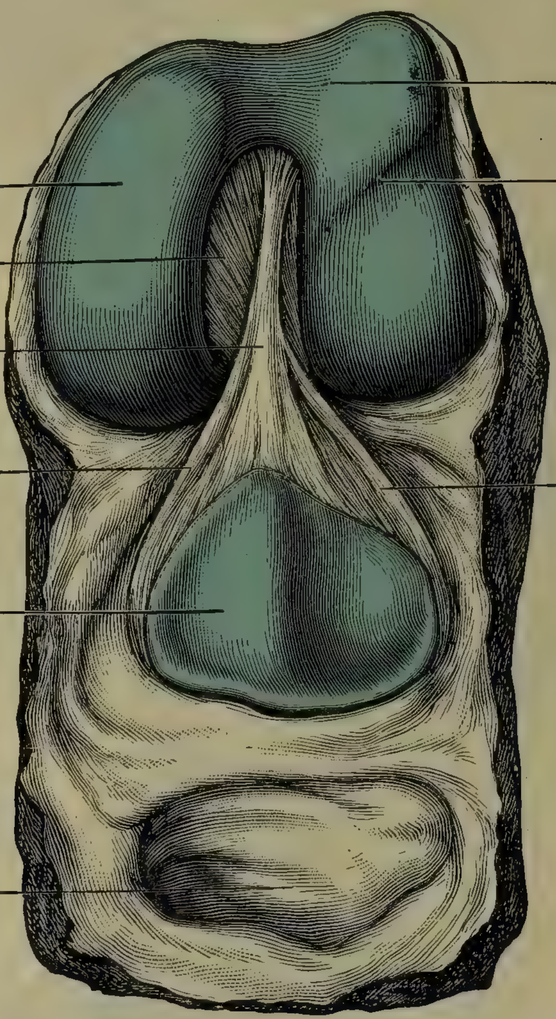


FIG. 379.—INTERIOR VIEW OF THE KNEE-JOINT, SHOWING THE SYNOVIAL FOLDS. (Anterior portion of capsule with the extensor tendon thrown downward.)

At the back of the joint two pouches of the articular cavity are prolonged beneath the muscles, one on each side between the condyle of the femur and the origin of the gastrocnemius. Large processes of synovial membrane also project into the joint, and being occupied by fat, serve as padding to fill up spaces and so aid in reducing incongruity. The chief of these processes, the **patellar synovial fold** [plica synovialis patellaris] (rudimentum septi genus NK) (figs. 379 and 380), springs from the infrapatellar fatty mass. This is the central portion of the large process of synovial membrane, of which the alar folds form the free margins. It extends from the fatty mass, below the patella, backward and upward to the intercondyloid fossa of the femur, where it is attached in front of the anterior cruciate, and lateral to the posterior cruciate ligament. Near the femur it is thin and transparent, consisting of a double fold of synovial membrane, but near the patella it contains some fatty tissue. Its anterior or upper edge is free, and fully 2.5 cm. long; the posterior or lower edge is half the length, and is attached to the cruciate ligaments above, but is free below.

Passing backward from the articular capsule on each side of the patella is a prominent crescentic fold formed by reduplications of the synovial membrane—these are the **alar folds** [plicæ alares] (fig. 379). Their free margins are concave and thin, and are lost below in the patellar fold. There is a slight fossa above and another below each ligament.

The **arterial supply** of the knee-joint is derived from the a. genus suprema (anastomotica) the superior and inferior medial and lateral articular; the middle articular; the descending

branch of the lateral circumflex; the anterior recurrent branch from the anterior tibial; and the posterior tibial recurrent.

Lymph-vessels drain to the popliteal, subinguinal and deep inguinal nodes.

The **nerve-supply** comes from the great sciatic, femoral, and obturator sources. The **great sciatic** gives off the tibial and common peroneal; the tibial sends two, sometimes three branches—one with the middle articular artery; one with the inferior medial, and sometimes one with the superior medial articular artery; the common peroneal gives a branch which accompanies the superior, and another accompanying the inferior lateral articular artery, and a recurrent branch which follows the course of the anterior recurrent branch of the anterior tibial artery. The **femoral** sends an articular branch from the nerve to the vastus lateralis;

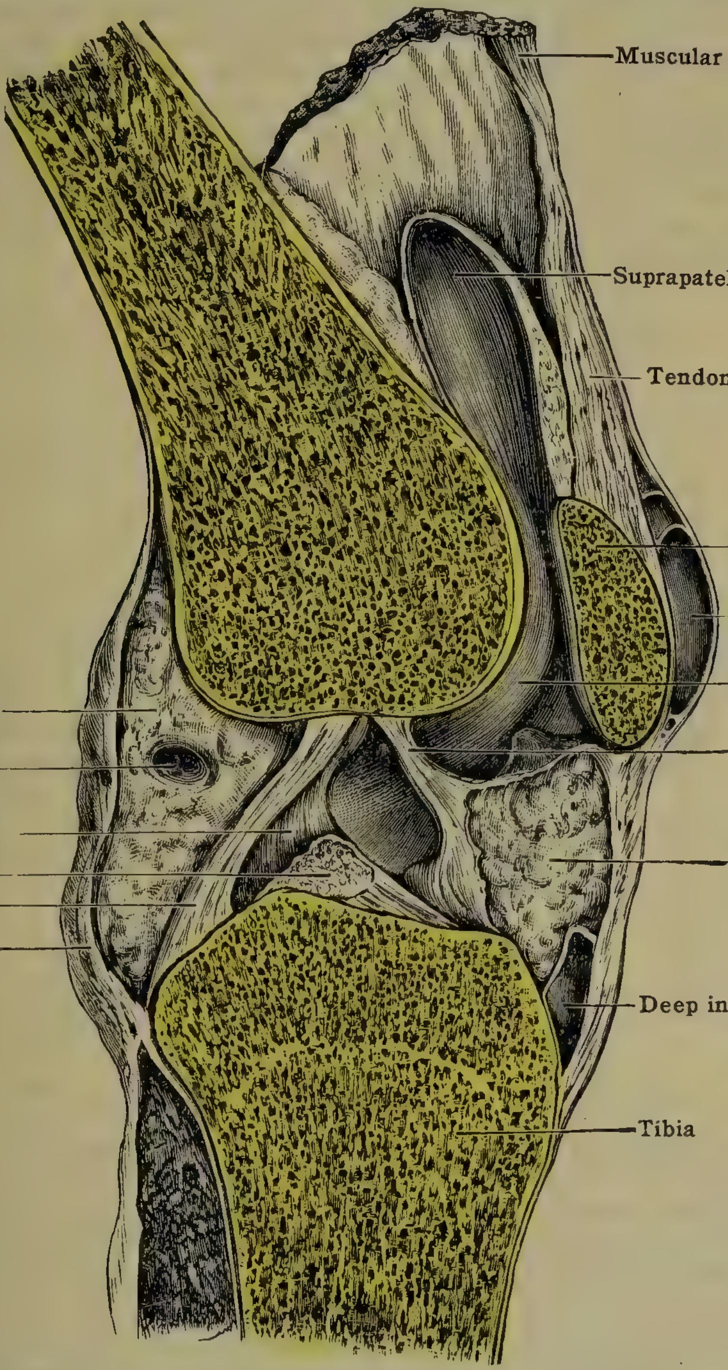


Fig. 380.—Sagittal Section of the Right Knee-joint.
(The bones are drawn somewhat apart.)

a second from the nerve to the vastus medialis; and sometimes a third from that to the vastus intermedius. Thus there are three articular twigs to the knee derived from the muscular branches of the femoral. The **obturator** by its posterior division sends a branch through the adductor magnus on to the popliteal artery, which enters the joint posteriorly.

Relations.—Anteriorly and at the sides the knee-joint is merely covered and protected by the integuments, fascia, and the tendinous expansions of the quadriceps extensor muscle. Laterally and posteriorly it is crossed by the biceps tendon. Medially and posteriorly lie the sartorius and the tendons of the gracilis and semitendinosus muscles. Posteriorly it is in relation with the popliteal vessels and nerves, the semimembranosus, the two heads of the gastrocnemius, and the plantaris. The tendon of the popliteus pierces the capsule behind and medial to the biceps tendon.

The following **bursæ** communicate with the knee-joint: suprapatellar, semimembranosus, medial gastrocnemius, popliteus. Other bursæ in relation to the joint are: three prepatellar bursæ, variable; two infrapatellar and the subcutaneous bursa over the tuberosity of the tibia.

The **movements** which occur at the knee-joint are flexion and extension, with a certain amount of rotation in the bent position (cf. also p. 580). These movements are not simple rolling on a transverse axis and rotation on a vertical axis. In addition to and complicating these movements, shifting or gliding motion of the joint surfaces upon each other, is intro-

duced. The transverse axis of hinge movement is affected in its position by the spiral contour of the condylar surfaces. The vertical axis of rotation passes near the middle of the joint, but in a plane nearer the medial condyle.

The movements of the knee-joint can be studied to advantage in a preparation from which all surrounding soft parts, including the articular capsule, have been removed; in which the collateral ligaments and internal joint structures remain intact.

Holding the tibia fixed and moving the femur from a position of half flexion to one of complete extension, i. e., with the tibia and femur in a straight line, and observing the movement of the femoral condyles, it will be seen that there is (1) a rolling forward, accompanied by (2) a gliding backward of the condyles on the superior articular surfaces of the tibia; as the femur is nearly in the extended position it undergoes (3) medial rotation, and when extension is complete, no further excursion of the bone is possible. It should be considered that these movements which occur naturally in the living are to be accounted for solely by the parts in the preparation and by the motive force supplied from without. Further observation reveals (4) that the lateral meniscus moves forward, adjusting itself to the larger curve of the lateral condyle as it glides and rolls to the close of extension; (5) that at this moment the cartilage becomes wedged between the tibial surface and the condylopatellar groove of the lateral condyle; (6) that rotation now takes place on the vertical axis in which the medial condyle moves backward until its oblique part adjacent to the patellar surface, is pressed in contact with the tibial articular surface; (7) in the rotation the lateral condyle turns on the lateral tibial articular surface; (8)

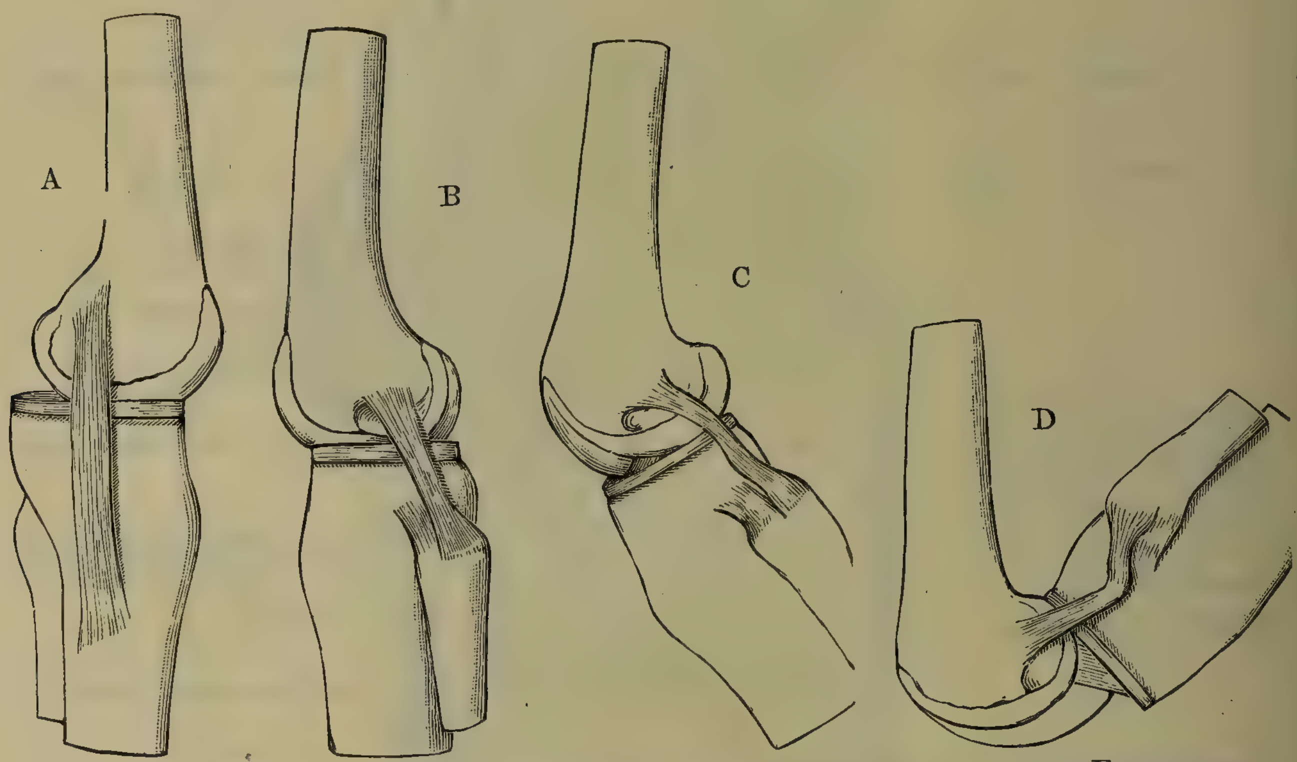


Fig. 381.—The Collateral Ligaments of the Knee in Flexion and Extension.

the condylopatellar groove of the medial condyle is pressed against the edge of the medial meniscus. Regarding the ligaments: in the semiflexed joint it will be found, (9) that both collateral ligaments are relaxed, but that as extension proceeds, (10) they tighten because the greater curves of the fore part of the condyles are exerting leverage upon their posteriorly located attachments; (11) the cruciate ligaments in the semiflexed joint are moderately stretched; (12) the anterior cruciate tightens towards the close of extension and terminates the rolling of the lateral condyle; (13) it remains stretched during the rotation of the femur, but is slightly relaxed at the end of rotation; (14) from their attachments and directions the cruciate ligaments in the fully extended joint prevent further rotation of the condyles.

With the femur fixed and the tibia movable, the latter rotates outward at the close of extension. The beginning of flexion is marked by an unwinding of the knee-joint, the femur rotating laterally or the tibia medially. It has been observed that rotation in the fully extended joint is brought to an end; rotatory movement to a range of 50° is permitted in the semiflexed knee.

Regarding the movements of the patella: in extreme flexion the medial articular facet rests on the lateral part of the medial condyle of the femur; in nearly complete flexion the upper pair of facets rests on the lower part of the patellar surface of the femur; in midflexion the middle pair rests on the middle of the patellar surface; while in extension the lower pair of facets on the patella rests on the upper portion of the patellar surface of the femur. This difference may be described as the shifting of the points of contact of the articular surface.

Incongruity of the joint surfaces, which is extreme in the knee, is compensated for by the menisci and by the extensive synovial folds and fat pads. The menisci give some support in steadying the knee from side to side. Side-to-side stability is offered by the collateral ligaments and the patellar retinacula, also by the cruciate ligaments. The latter are chiefly responsible for the anteroposterior stability of the knee, the anterior cruciate preventing backward displacement, the posterior ligament checking anterior dislocation of the condyles of the femur.

In the standing position the line of gravity falls in front of the transverse axis of flexion and extension and therefore the weight of the body is a factor in keeping the collateral ligaments on

the stretch and so maintaining the rigidity of the knees. Further support to the stability of the extended joint is given by the pull of the iliotibial band on the lateral condyle of the tibia, in a plane slightly posterior to that of the line of gravity, given by the tonic contraction of the tensor fasciæ latæ and anterior part of the gluteus maximus muscles. In the account above, it was pointed out that the several phenomena in the movements of the joint structures that occur in life can be largely accounted for in the absence of muscular influence. Whereas this seems to be true, there is much evidence of the participation of special muscle action in the phenomenon of rotation on the vertical axis. Medial rotation of the leg is associated with beginning flexion and these movements in combination are brought about by the sartorius, gracilis and semitendinosus; that is, the peculiar contour of articular surfaces and the passive influence of ligaments insure the path of rotatory movement and limit its range; but the initiation and progress of the movement are given in the living by muscles specially adapted to the mechanism. It is of much interest to find that the three muscles named are members of three topographically different muscle groups of the thigh and are supplied by branches from the three different nerve trunks of the thigh.

In **extension** of the knee-joint all the ligaments are on the stretch with the exception of the ligamentum patellæ and front of the capsule. Extension is checked by both the cruciate ligaments and the collateral ligaments (figs. 381, A, B, and 382).

FIG. 382.—SECTION OF KNEE, SHOWING CRUCIATE LIGAMENTS IN EXTENSION.

In **flexion** the ligamentum patellæ and anterior portion of the capsule are on the stretch; so, also, is the posterior cruciate in extreme flexion, though it is not quite tight in the semiflexed state of the joint. All the other ligaments are relaxed (fig. 381, C, D), although the relaxation of the anterior cruciate ligament is slight in extreme flexion (fig. 383). Flexion is only checked during life by the contact of the soft parts, i. e., the calf with the back of the thigh.

Rotation of the leg medially is checked by the anterior cruciate ligament; the collateral ligaments being loose. Rotation laterally is checked by the collateral ligaments; the cruciate ligaments have no controlling effect on it, as they are untwisted by it.

Sliding movements are checked by the cruciate and collateral ligaments—sliding forward especially by the anterior, and sliding backward by the posterior cruciate.

Muscles which act upon the knee-joint (cf. p. 533ff; 580).—*Flexors.*—Biceps, semimembranosus, semitendinosus, sartorius, gracilis, gastrocnemius, and popliteus. *Extensor.*—Quadriceps femoris. *Medial Rotators.*—Sartorius, gracilis, semitendinosus, semimembranosus, popliteus. *Lateral Rotators.*—Biceps, tensor faciæ latæ.

CLINICAL RELATIONS AT THE KNEE-JOINT

Bony landmarks.—The patella, the condyles and epicondyles of the femur, the condyles and tuberosity of the tibia, the head of the fibula, are all easily examined.

The patella (figs. 272, 378, 384).—The limb being supported in the straight position, and the extensor muscles relaxed, the natural range of mobility laterally of the patella can be estimated. This is interfered with by muscular action in inflammatory conditions, or by early tuberculous ulceration of the contiguous cartilages. The numerous longitudinal striæ or sulci on the anterior surface of this bone can now also be detected. In these are embedded tendinous bundles of the rectus. The fact that these fibers, thus tied down, are liable after stretching and tearing to fold in between the ends of the bone after fracture, is a ready explanation of the difficulty of ensuring bony union here. (Macewen.) Owing to the lowest part of

the patella being separated from the joint by synovial folds containing fat, fracture here does not, necessarily, open the joint.

Reviewing the patella's *relation to the femur* in different positions:—(1) In **extension**, the patella rises over the condyles, and in full extension only the lower third of its articular surface rests upon that of [the condyles; its upper two-thirds lies upon the bed of fat which covers the lower and front part of the femur. (2) In extreme **flexion**, as the prominent anterior surface of the condyles affords leverage to the quadriceps, the patella projects very little; thus, only its upper third is in contact with the femur, its lower two-thirds now resting on the pad of

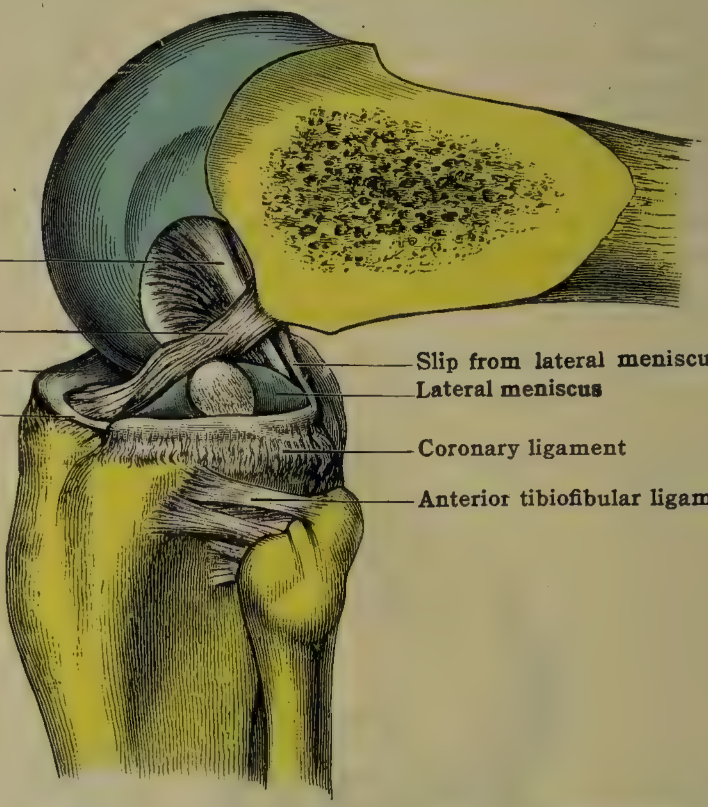


FIG. 383.—CRUCIATE LIGAMENTS IN FLEXION.

fat between it and the tibia. (3) In **semiflexion** the middle third of the patella rests upon the most prominent part of the condyles. (Humphry.) While the bone now affords the greatest amount of leverage to the quadriceps, it is also submitted to the greatest amount of strain from this muscle, which is acting almost at a right angle to the long axis of the patella. This position may therefore be called the 'area of danger,' as, in a sudden and violent contraction, the patella may be snapped across by muscular action, aided by the resistance given by the condyles, in the same way as a stick is snapped across the knee. The amount of separation of the fragments

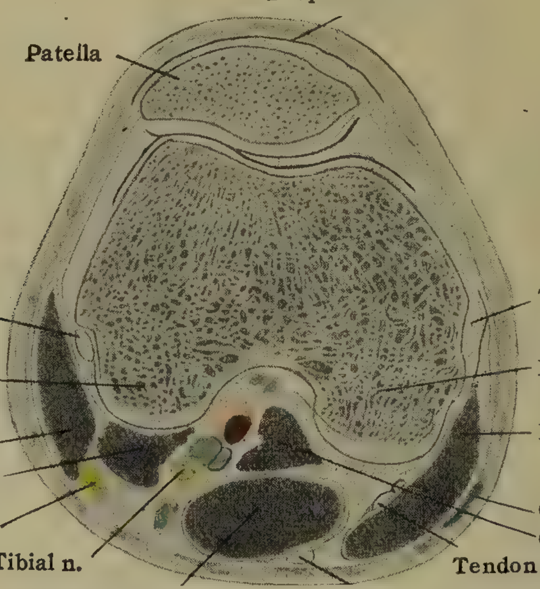


FIG. 384.—HORIZONTAL SECTION OF THE KNEE-JOINT. (× ½.) (Braune.)

in a fracture of the patella is due chiefly to the extent to which the lateral tendinous expansions of the vasti are torn; to a less degree to the hemorrhage from the numerous articular vessels (p. 692) and synovial effusion. Thel ower fragment is usually the smaller, and its fractured surface will be tilted forward; that of the upper one usually looks backward.

The rareness with which necrosis and caries occur here, when the exposed situation of the bone is remembered, is partly explained by the density of its tissue, especially in front, and the intimate blending of the rectus fibers with its periosteum. When the knee-joint is bent, the

patellar surface of the femur can be made out, with some difficulty, underneath the quadriceps expansion. The upper and lateral angle of this surface forms a useful landmark (Godlee) as a line drawn from it to the adductor tubercle marks the level of the lower epiphysis of the femur.

Dislocation of the patella.—The following anatomical facts account for lateral dislocation taking place most frequently:—(1) The medial edge of the patella is more prominent, and thus more exposed to injury; it is also well supported, as is seen when, the parts being relaxed, the fingers are insinuated beneath each border. (2) The pull of the quadriceps upon the patella, ligamentum patellæ, and tibia is somewhat lateral; the femora being directed medially here, bringing the knee-joints nearer the center of gravity, and, so, counterbalancing their wide separation above at the pelvis. The lateral pull of the quadriceps upon the patella is, in all normal actions of the muscle, counteracted by the space taken in the patellar surface by the lateral condyle, this being wider and creeping up higher, and having a more prominent and thus protective lip. In violent contraction, however, these counteracting points may be overcome.

FIG. 385.—KNEE-JOINT AS SHOWN BY THE RÖNTGEN-RAYS, ANTEROPOSTERIOR VIEW. Epiphyses of the femur, tibia and fibula are visible. (Cf. fig. 275.)

The condyles of the femur and tibia.—It should be noted that on the medial side the prominence of the medial epicondyle of the femur is well marked, and the condyle of the tibia is less so, while on the lateral side this condition is reversed. Descending to the lateral condyle of the tibia, the iliotibial band of the fascia lata can be traced. The more distinct lateral condyle is a good landmark for opening the joint in amputation and excision. It also indicates the lower level of the synovial membrane of the knee-joint.

Farther back are the biceps and fibular collateral (long external lateral) ligament. The gap on the medial side between the femoral and tibial condyles is the place for feeling for a displaced medial meniscus (fibrocartilage) in 'internal derangement' of the knee, and also for 'lipping' in suspected osteoarthritis. On each femoral epicondyle, posteriorly, in a thin subject, can be felt its tubercle, which gives attachment to the collateral ligament. Owing to their being placed behind the center of the bone, these ligaments become tight in extension. On the upper and posterior part of the medial femoral epicondyle the adductor tubercle and the vertical tendon of the adductor magnus can be felt during flexion. This bony point is a guide to the lower epiphysis, the ossification of which and its occasional exostosis have been mentioned. The medial aspect of this epicondyle faces practically in the same direction as the head of the femur. The relations of the epiphyses as they appear with the X-rays are shown in fig. 385.

A *sesamoid bone*, the fabella (fig. 275), is frequently found in the lateral head of the gastrocnemius posterior to the joint. The X-ray shadow cast by such a bone has occasionally been interpreted as a floating cartilage.

Ligamentum patellæ and tuberosity of tibia.—These, in a well-formed leg, should, with the center of the ankle-joint, be all in the same straight line, a useful point in the adjustment

of fractures. (Holden.) Behind the upper half of the ligament is the infrapatellar pad of fat; below, the lower half is separated from the tibia by the deep infrapatellar bursa. The tuberosity (tubercle) of the tibia is on a level with the head of the fibula.

Occasionally, the ligamentum patellæ pulls upon the tuberosity of the tibia to such an extent that the epiphysial cartilage becomes greatly widened. The tuberosity may even be separated. This widening of the cartilage is associated with marked pain and enlargement of the tuberosity.

Prepatellar and infrapatellar bursæ.—These usually protect the lower part of the patella and the ligamentum patellæ. They are liable to be enlarged in those who habitually kneel much, the enlargement being either fluid or solid; enlargement occasionally occurs in tertiary syphilis. Their close relation with the patella and, at the sides, with the joint itself, is to be remembered in infective inflammations of these bursæ. Usually the deep fascia, passing off from the sides of the patella upward to the thigh and downward to the leg, serves to conduct inflammation away from the joint.

Synovial membrane (fig. 378).—This the largest of the synovial membranes, forms a short *cul-de-sac* above the patella, between the quadriceps extensor and the front of the femur, this process reaching about 2.5 cm. (1 in.) above the patellar surface of the femur. At its highest point this *cul-de-sac* communicates with the suprapatellar bursa lying between the quadriceps and front of the femur. Thus, synovial membrane will usually be met with 6.2 cm. (2½ in.) or more above the patellar surface or the upper border of the patella when the limb is extended. Flexing the joint draws the membrane down very slightly.

During extension, the above pouch is supported by the articularis genus (subcrureus). Traced downward, the synovial layer reaches the level of the head of the tibia, being separated in the middle line from the upper part of the ligamentum patellæ by fat. It here gives off to the intercondyloid notch the patellar synovial fold (ligamentum mucosum), with its free lateral prolongations, the alar folds (ligamenta alaria).

The enlargement of these folds, under conditions not yet understood, may sometimes be a cause of 'internal derangement,' and simulate a loosened meniscus. But the synovial membrane of this joint is not only the largest: it is also the most complicated, a fact accounting for the grave peril of infective arthritis, and the well-known difficulty of effective drainage and cleansing this joint. Thus "it passes over the greater portion of the crucial ligaments, but the posterior surface of the posterior crucial, which is connected by means of fibroareolar tissue to the front of the ligamentum posticum, and the lower portions of both crucial ligaments, where they are united together, of course cannot receive a complete covering from the membrane" (Morris).

Finally, amid the complications of this synovial membrane, its communication with some of the bursæ mentioned below, and occasionally with the superior tibiofibular joint, is to be borne in mind. In effusion the bony prominences are obliterated, and the patella 'floats.' The knee-joint is easily opened by free lateral incisions lying midway between the margins of the patella and the tuberosities and condyles.

Menisci.—The menisci serve as buffer-bonds and cushions between the contiguous bones, as well as important apparatus in the mechanism of the movements of the joint. The more frequent displacement of the medial meniscus is explained by—(*a*) its greater fixity, and, therefore, its greater reaction to strains. Thus, in addition to weaker attachments of the meniscus to the transverse ligament, it is connected all along its convex border with the inside of the capsule, and strongly with the tibial collateral ligament. The lateral meniscus, on the other hand, is more weakly attached to the capsule, especially opposite to the popliteus tendon, and has no tie to the fibular collateral ligament. (*b*) When, in the erect position, the femur is rotated laterally and slightly flexed, a common position, an especial strain is thrown upon the very important tibial collateral ligament, and from the above-mentioned connection, on the medial meniscus also.

Position of knee-joint in disease.—In inflammatory effusion, the position which best accommodates the collection of fluid is one of moderate flexion, the ligaments being now mainly relaxed. Later on, when the ligaments are softened, the hamstrings obstinately displace the leg backward, the tibia being rotated laterally by the biceps. The anteroposterior displacement is always more marked than the lateral. In straightening an ankylosed joint, the resistance of the shortened lateral, cruciate, and posterior ligaments, and the facility with which a softened upper epiphysial plate of the tibia may give way, must never be forgotten. **Erasion and excision.**—The extent and complications of the synovial layer render attention to the following points imperative:—(1) Free exposure of the joint usually by an anterior curved incision, the medial extremity of which must not damage the great saphenous vein. (2) The extent of the pouch under the quadriceps, it may be for 5 cm. (2 in.) above the patella, and the lateral recesses under the vasti. The pouches at the back of the joint are far more difficult to deal with, viz., the partial covering of the posterior cruciate ligament, the proximity of the popliteal artery, the pouches in relation to the popliteus, gastrocnemii, and back of the femoral condyles. In **erasion**, the cartilage and bone, where diseased, are removed with a gouge. Owing to the removal, in addition to the synovial layer, of the menisci and cruciate ligaments, and the damage to lateral and patellar ligaments, there is a most obstinate tendency to flexion afterward. In **excision**, to avoid injury to the epiphysis, the section of the femur should not pass higher than through the upper third of the patellar surface. Of the tibia, only 12 mm. (½ in.) should be removed.

Genu valgum.—Here the natural angle at which the femur inclines medially to the tibia is increased. As shown by v. Mikulicz, this is due to an abnormal growth downward of the medial part of the femoral diaphysis, the epiphysial line being gradually altered from one at right angles to the shaft to one which runs obliquely from without downward and medially. The femur is not only elongated on its medial side, but bent at its lower end, the concavity of the curve being lateral. Other changes have to be remembered. Pes valgus very commonly coexists, and in the tibia there may be a compensatory curve, the concavity being medial, in the lower third, or an analogous alteration in the line of the upper epiphysis may be present

its direction being no longer at a right angle with the shaft, but oblique. In Sir W. Macewen's supracondyloid osteotomy, a longitudinal incision, about 3.7 cm. (1½ in.) long is made where the following lines meet, viz., one transverse, a finger's breadth above the upper margin of the lateral condyle, and one longitudinal, 1.2 cm. (½ in.) in front of the adductor magnus tendon. The bone is divided in front of the genu suprema and above the superior medial articular artery above the epiphysial line and behind the upward extension of the synovial membrane under the quadriceps.

The following **bursæ about the knee-joint** must be remembered. Some are much more constant than others.

A. **In front.**—(1) The prepatellar bursæ found here have been mentioned above (p.) 364.

B. **On the medial side.**—(1) The medial gastrocnemial bursa often extending between the above muscle and the semimembranosus. After adult life, it usually communicates with the knee-joint. But, owing to the narrow communication, it is rarely possible, when the parts are relaxed by flexion of the joint, to empty a bursal cyst. For its removal a straight incision is made over the most prominent part of the swelling, its neck found by drawing aside the tendons. A ligature is then pushed high up around the neck, and the cyst cut away. (2) The bursa anserina to the tibial collateral ligament, between it and the tendon of the sartorius, gracilis, and semitendinosus. (3) The double bursa of the semimembranosus, between the medial condyle of the tibia and the semimembranosus, and between the latter and the medial head of the gastrocnemius.

C. **On the lateral side.**—(1) One between the lateral head of the gastrocnemius and the condyle; (2) one superficial to the fibular collateral ligament between it and the biceps tendon; (3) one under the ligament between it and the popliteus tendon; (4) one between the popliteus tendon and the lateral condyle of the femur. This is usually a diverticulum from the synovial membrane of the knee-joint, and may enlarge to form a swelling (hygroma) in the popliteal fossa.

The following explanations may be given of an inflamed knee-joint usually taking the flexed position:—(1) By experimental injections, Braune found that the capacity of the synovial sac reaches its maximum with a definite degree of flexion, i. e., at an angle of twenty-five degrees. (2) As the same nerves supply the synovial membrane and the muscles which act upon the joint, reflex spasm of the flexors will help to explain the flexed position. (Hilton.)

4. THE TIBIOFIBULAR UNION

The fibula is connected with the tibia throughout its length by an interosseous membrane, and at the upper and lower extremities by means of two joints. Very little movement is permitted between the two bones.

(*a*) The Tibiofibular Joint

The **tibiofibular joint** [articulatio tibiofibularis] is formed between the cartilage covered fibular articular surface of the tibia and the articular surface of the head of the fibula, united by an articular capsule inclosing the joint cavity and strengthened by accessory bands. The articular surfaces are incongruent. At its upper and anterior part, the tibiofibular articulation is about 6 mm. below, and quite distinct from, the knee; but at its posterior and superior aspect, where the border of the lateral condyle of the tibia is bevelled by the popliteus muscle, the joint is in the closest proximity to the bursa from the knee-joint beneath the tendon of that muscle. The ligaments uniting the bones are the articular capsule, the anterior capitular, and the posterior capitular.

The **articular capsule** is a well-marked fibrous structure; it is attached close round the margins of the articular surfaces of the tibia and fibula. In front it is shut off completely from the knee-joint by the capsule of the knee; but behind, it is often very thin, and may communicate with the knee-joint through the bursa under the popliteus tendon (according to Fick, in about ⅛ of the cases).

The **capitular ligaments** [ligg. capituli fibulæ] are two, anterior and posterior. The **anterior capitular ligament** (fig. 382) consists of a few fibers which pass almost horizontally medially from the fibula to the tibia. It lies beneath the anterior portion of the tendon of the biceps. The **posterior capitular ligament** (fig. 373) consists of a few fibers which pass nearly straight upward between the adjacent bones, from the head of the fibula to the lateral condyle of the tibia.

The **biceps tendon** is divided by the fibular collateral ligament of the knee; of the two divisions the anterior is by far the stronger, and is inserted into the lateral condyle of the tibia as well as to the front of the head of the fibula, and thus the muscle, acting on both bones, tends to brace them more tightly together; indeed, it holds the bones strongly together after all other connections have been severed.

The **arterial supply** is from the inferior lateral articular and recurrent tibial arteries.

Lymphatics drain to the poplitial nodes.

The **nerve-supply** is from the tibial (nerve to the popliteus), and also from the recurrent branch of the common peroneal.

Relations.—In front, the upper ends of the tibialis anterior, the extensor digitorum longus, and the peroneus longus. Behind, the tendon of the popliteus overlapped by the lateral head of the gastrocnemius. Laterally, the biceps tendon and the common peroneal nerve. Below and medially, the anterior tibial vessels.

The **movements** are but slight, and consist merely of a gliding of the two bones upon each other. The joint is so constructed that the fibula gives some support to the tibia in transmitting the weight to the foot. The articular facet of the tibia overhangs, and is received upon the articular facet of the head of the fibula in an oblique plane. This joint allows of slight yielding of the lateral malleolus during flexion and extension of the ankle-joint, the whole fibula gliding slightly upward in flexion, and downward in extension, of the ankle.

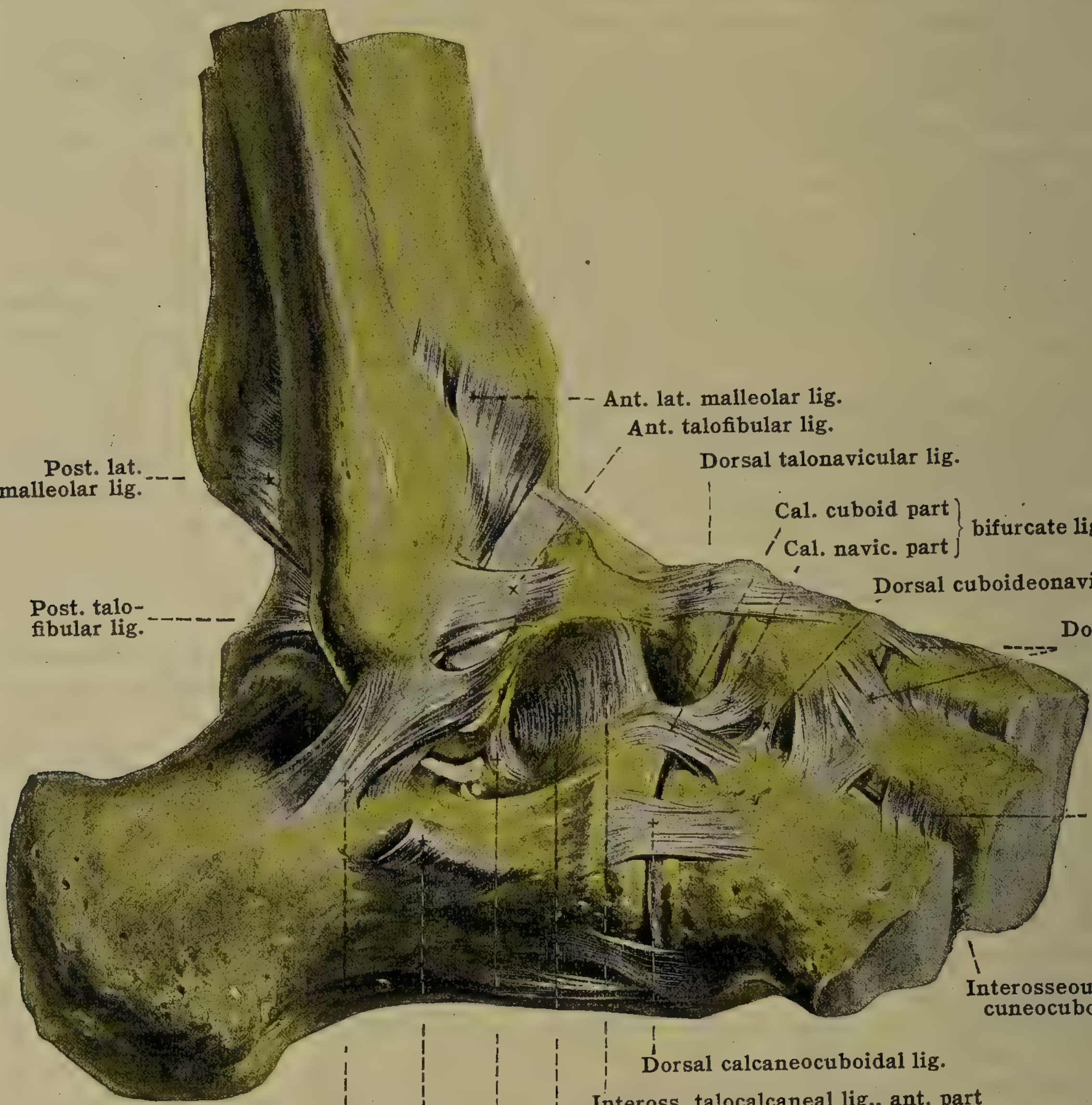


Fig. 386.—Ligaments of the Right Foot (Lateral Aspect). (Fick.)

The Interosseous Membrane of the Leg

The **interosseous membrane of the leg** [membrana interossea cruris] is attached along interosseous crests of the tibia and fibula. It is deficient above for about 2.5 cm. or more. Its upper border is concave, and over it pass the anterior tibial vessels to gain the front of the leg.

The membrane consists of a thin aponeurotic and translucent lamina, formed of oblique fine fibers, inclined downward and laterally. They are best marked at their attachment to the bones, and gradually grow denser and thicker as they approach the inferior interosseous ligament. A small opening in the inferior part gives passage to the perforating branch of the peroneal artery. The interosseous membrane establishes a syndesmotic union between the bones of the leg. It gives support to the slender fibula which is reacted upon by the pull of many muscles and the movements and pressure exerted at the ankle joint. It also affords a surface for the origin of muscles. It is continuous below with the inferior interosseous ligament.

Nerves.—The crural interosseous branch of the tibial nerve gives numerous twigs to the membrane. Vater's corpuscles are richly distributed.

In front of the interosseous membrane lie the tibialis anterior, the extensor digitorum longus, the extensor hallucis longus, and the anterior tibial vessels and deep peroneal nerve. Behind it is in relation with the tibialis posterior, the flexor hallucis longus, and the peroneal artery.

(c) The Tibiofibular Syndesmosis

The **tibiofibular syndesmosis** [syndesmosis tibiofibularis] is formed by the lower ends of the tibia and fibula. The rough triangular surface of the fibula and the fibular notch of the tibia are covered by periosteum and firmly united by ligaments. The fibula is in actual contact with the tibia by an articular facet, which is small in size, crescentic in shape, and continuous with the articular facet of the malleolus (see p. 250).

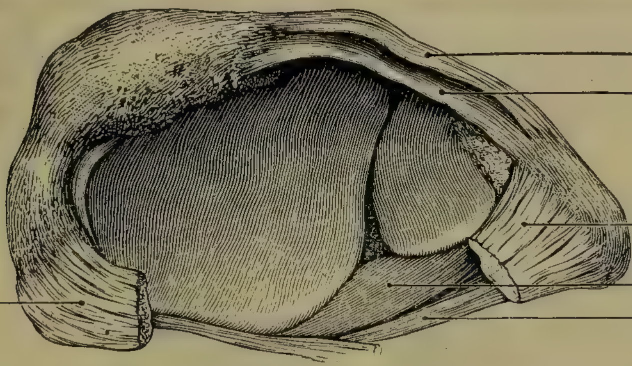


Fig. 387.—Lower Ends of Left Tibia and Fibula, showing the Ligaments. The synovial fold between these bones has been removed to show the transverse ligament, and the deeper fibers of the anterior lateral malleolar ligament which come into contact with the talus. (From a dissection by Mr. W. Pearson, of the Royal College of Surgeons' Museum.)

The ligaments which unite the bones are the anterior lateral malleolar ligament, posterior lateral malleolar ligament, inferior interosseous ligament and transverse ligament.

The **anterior lateral malleolar ligament** [lig. malleoli lateralis anterius] (tibiofibulare dorsale NK) (figs. 386 and 387) is a strong triangular band about 2 cm. wide, attached to the lower extremity of the tibia at its anterior and lateral angle, close to the margin of the facet for the talus and passes downward and laterally to the anterior border and contiguous surface of the lower end of the fibula, some fibers passing along the edge nearly as far as the origin of the anterior talofibular ligament.

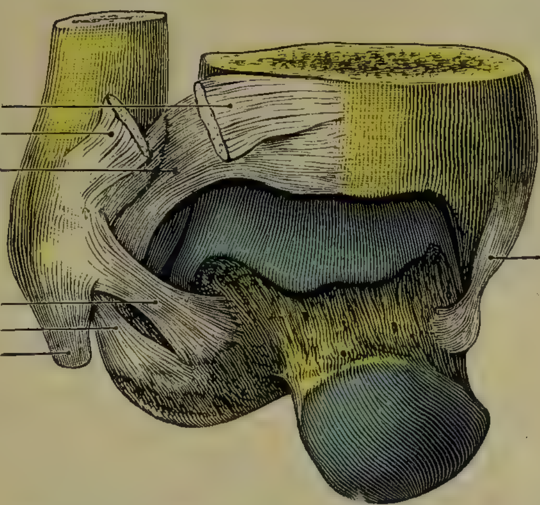


Fig. 388.—Right Ankle-joint, showing the Ligaments. (Anterior view.) (From a dissection by Mr. W. Pearson, of the Royal College of Surgeons' Museum.)

In front it is in relation with the peroneus tertius and deep fascia of the leg, and gives origin to fibers of the anterior ligament of the ankle-joint. Behind, it lies in contact with the interosseous ligament, and comes into contact with the articular surface of the talus (see figs. 387 and 388).

The **posterior lateral malleolar ligament** [lig. malleoli lateralis posterius] (tibiofibulare plantare NK) (figs. 386 and 387) is very similar to the anterior, extending from the posterior and lateral angle of the lower end of the tibia downward and laterally to the lowest 1.5 cm. of the border separating the medial from the posterior surface of the shaft of the fibula, and to the upper part of the posterior border of the lateral malleolus. It is in relation in front with the interosseous ligament; below, it touches the transverse ligament.

The **inferior interosseous ligament** is a dense mass of short, felt-like fibers, continuous with the interosseous membrane of the leg, passing transversely

between and firmly uniting the opposed rough triangular surfaces at the lower ends of the tibia and fibula, except for 1 cm. at the extremity, where there is a synovial cavity. It extends from the anterior to the posterior lateral malleolar ligaments, reaching upward 4 cm. in front, but only half this height behind.

The **transverse tibiofibular ligament** (fig. 387, 389) is a strong rounded band, attached to nearly the whole length of the inferior border of the posterior surface of the tibia, just above the articular facet for the talus. It then inclines a little forward and downward, to be attached to the medial surface of the lateral malleolus, and into the digital fossa.

Sometimes the lower part of each articular surface is cartilage covered and bounds the fissure continuous with the articular cavity of the ankle joint below. A small pouch of **synovial membrane,** continuous with that of the ankle-joint, projects upward between the bones as high as the inferior interosseous ligament.

The **nerve-supply** is the same as that of the ankle-joint; the **arterial** supply is from the peroneal and the anterior peroneal, and sometimes from the anterior tibial, or its lateral malleolar branch. **Lymphatic vessels** convey to the popliteal nodes.

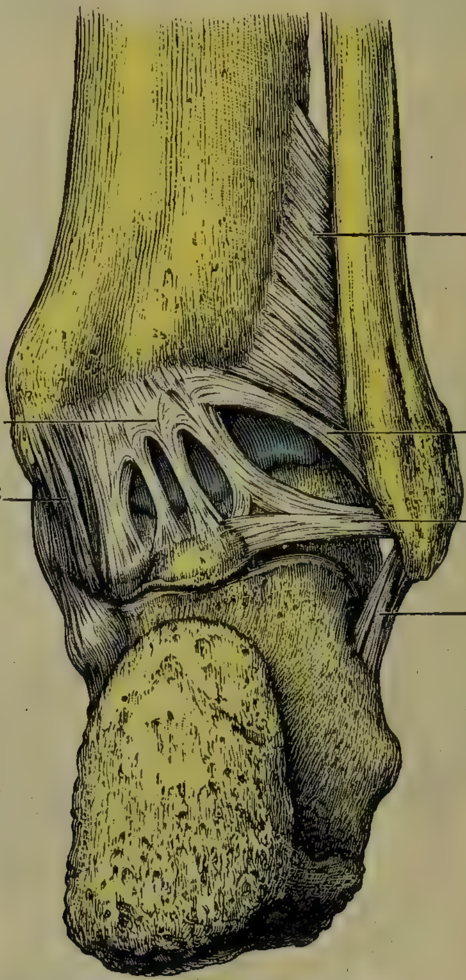


Fig. 389.—Ligaments seen from the Back of the Ankle-joint.

Relations.—In front of the inferior tibiofibular joint are the anterior peroneal artery and the tendon of the peroneus tertius, and behind it are the posterior peroneal artery and the pad of fat which lies in front of the tendo Achillis.

The **movement** permitted at this joint is a slight gliding, chiefly in an upward and downward direction, of the fibula on the tibia. The bones are firmly braced together and yet form a slightly yielding arch, thus allowing a slight side to side expansion during extreme flexion, when the broad part of the talus is brought under the arch, by the upward gliding of the fibula on the tibia. The direction of the fibers of the lateral malleolar ligaments is downward from tibia to fibula. This mechanical arrangement secures perfect contact of the articular surfaces of the ankle-joint in all positions of the foot.

JOINTS OF THE FOOT

These joints [articulationes pedis] include those of the ankle, the tarsus, the metatarsus and the phalanges.

5. THE ANKLE-JOINT

The **ankle** [articulatio talocruralis] is a perfect ginglymus or hinge-joint. The bones which enter into its formation are: the lower extremity and medial malleolus of the tibia, and the lateral malleous of the fibula, above; and the talus

(astragalus) below. The articular surfaces, cartilage covered, are the inferior and malleolar articular surfaces of the tibia, the malleolar articular surface of the fibula, the superior surface of the talus, and its medial and lateral malleolar articular surfaces (see pp. 249, 254). The bones are united by an articular capsule inclosing the joint cavity. The ligaments (supplementing the articular capsule) uniting the bones are the deltoid, (comprising tibionavicular, calcaneotibial, anterior talotibial, and posterior talotibial), anterior talofibular, posterior talofibular, and calcaneofibular.

The **articular capsule** (fig. 389) is a thin, membranous structure surrounding the joint. It is attached above to the anterior border of the medial malleolus, to a crest of bone just above the transverse groove at the lower end of the tibia, to the anterior lateral malleolar ligament, and to the anterior border of the lateral

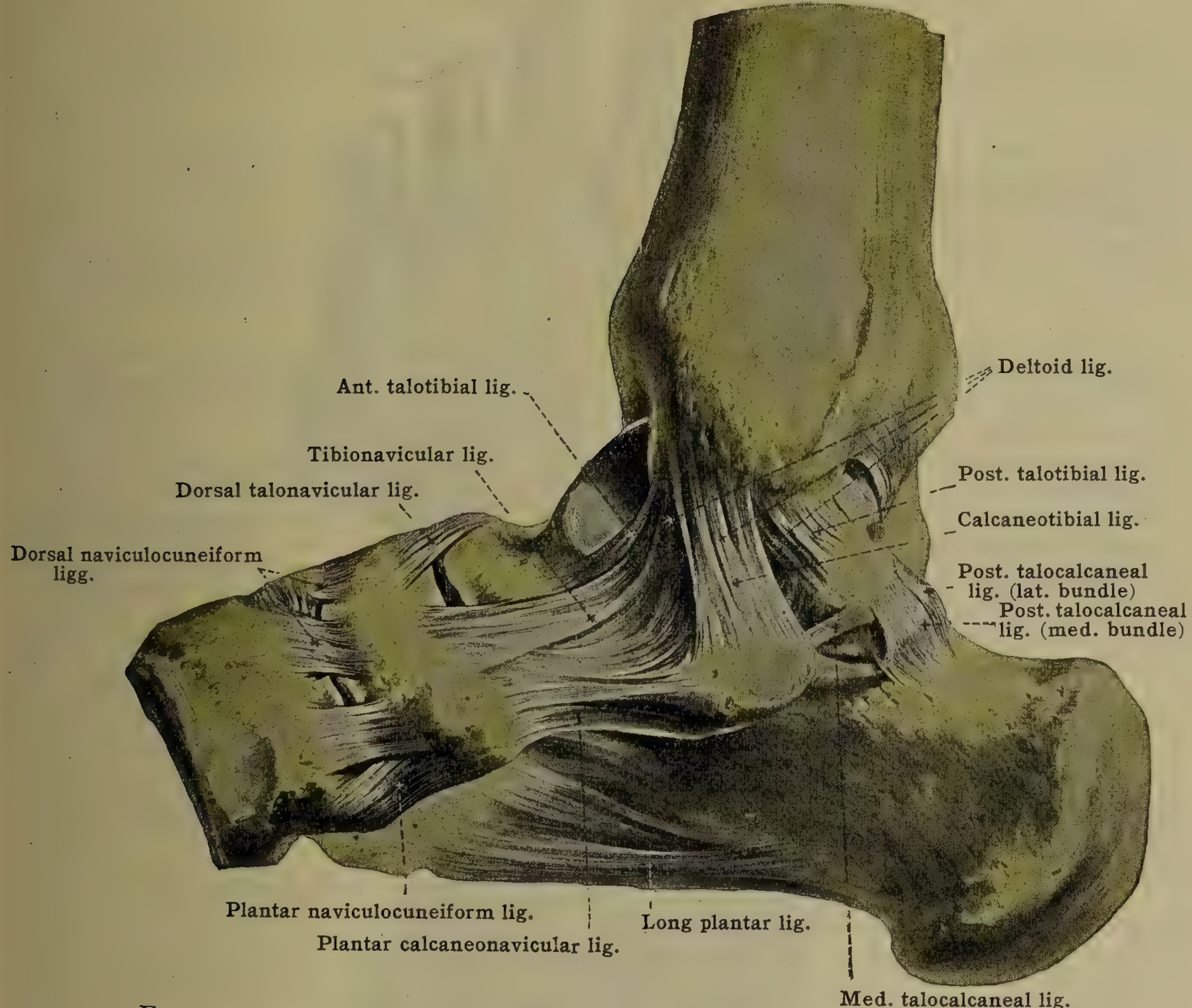


Fig. 390.—Ligaments of the Right Foot (Medial Aspect). (Fick.)

malleolus. Below, it is attached to the rough upper surface of the neck of the talus (astragalus). Medially it is thicker, and is fixed to the talus close to the facet for the medial malleolus, being continuous with the deltoid ligament, and passing forward to blend with the talonavicular ligament. Laterally it is attached to the talus, just below and in front of the angle between the superior and lateral facets, close to their edges, and joins the anterior talofibular ligament.

It is in relation, in front with the tibialis anterior muscle, the anterior tibial vessels and deep peroneal nerve, the extensor tendons of the toes, and the peroneus tertius; and behind with a mass of fat and synovial membrane.

Posteriorly the capsule (fig. 389) is a very thin and disconnected membranous structure, attached above to the lateral malleolus, medial to the peroneal groove; to the posterior margin of the lower end of the tibia lateral to the groove for the tibialis posterior; and to the posterior lateral malleolar ligament. Below, it is attached to the posterior surface of the talus from the deltoid to the lateral ligaments. The passage of the flexor hallucis longus tendon over the back of the joint materially strengthens the posterior part of the articular capsule.

The **deltoid ligament** [lig. deltoideum] (fig. 390) is attached superiorly to the medial malleolus along its lower border, and to its anterior surface superficial to the capsule; some very strong fibers are fixed to the notch in the lower border of the malleolus, and, getting attachment below to the rough depression on the medial side of the talus, form a deep portion to the ligament. The ligament radiates. The posterior fibers constituting the **posterior talotibial ligament** [lig. talotibiale posterius] are short, and incline a little backward to be fixed to the rough medial surface of the talus, close to the superior articular facet, and into the tubercle to the medial side of the flexor hallucis longus groove.

Fig. 391.—Ligaments of the Right Foot (Dorsal Aspect). (Fick.)

The fibers next in front are numerous and form a thick and strong mass, filling up the rough depression on the medial surface of the talus, whilst some, the **calcaneotibial ligament** [lig. calcaneotibiale], pass over the talocalcaneal joint to the upper and medial border of the sustentaculum tali. The fibers which are connected above with the anterior surface of the malleolus, the **tibionavicular ligament** [lig. tibionaviculare], pass downward and somewhat forward to be attached to the navicular and to the margin of the calcaneonavicular ligament. The fibers springing from the anterior margin of the malleolus above the last named are attached to the anterior margin of the medial articular surface of the talus forming the **anterior talotibial ligament** [lig. talotibiale anterius].

The remaining ligaments are found on the lateral side of the joint and (figs. 388, 390, 391) consist of three distinct slips. The **anterior talofibular ligament** [lig. talofibulare anterius], is ribbon-like and passes from the anterior border of the lateral malleolus near the tip to the rough surface of the talus in front of the lateral facet, and overhanging the sinus tarsi. The **calcaneofibular ligament** [lig. calcaneofibulare], is a strong roundish bundle, which extends downward and somewhat backward from the anterior border of the lateral malleolus close to the attachment of the anterior fasciculus, and from the lateral surface of the malleolus, just in front of the apex, to a tubercle on the middle of the lateral surface of the calcaneus. The **posterior talofibular ligament** [lig. talofibulare posterius], is almost horizontal; it is a strong, thick band attached at one end to the posterior border of the malleolus, and slightly to the fossa on the medial surface; and at the other end to the talus, behind the articular facet for the fibula, as well as to the posterior process of the talus.

The middle fasciculus is covered by the tendons of the peronei longus and brevis; and in extension, the posterior fasciculus is received into the pit on the medial surface of the lateral malleolus.

The **articular cavity** is very extensive. Besides following the space inclosed within the articular capsule of the ankle, it extends upward between the tibia and fibula, forming a short *cul-de-sac* as far as the interosseous ligament. In the anterior and posterior parts of the joint it is capacious, and extends beyond the limits of the articulation. It is said to contain more synovia than any other joint.

The **nerve-supply** is from the saphenous, tibial, and the lateral division of the deep peroneal.

The **arterial supply** comes from the anterior tibial, the anterior peroneal, the lateral malleolar, the posterior tibial, and posterior peroneal.

Relations.—In front and in contact with the anterior ligament, from medial to lateral aspects, are the tendon of the tibialis anterior, the tendon of the extensor hallucis longus, the anterior tibial vessels, the deep peroneal nerve, the tendons of the extensor digitorum longus, and the tendon of the peroneus tertius. Behind and laterally to the ankle-joint are the tendons of the peroneus longus and brevis. Behind and medially, from medial to lateral side, are the tendon of the tibialis posterior, the tendon of the flexor digitorum longus, the posterior tibial vessels, the tibial nerve, and the tendon of the flexor hallucis longus. Directly behind is a pad of fat which intervenes between the tendo Achillis and the joint. Below and on the lateral side, crossing the middle fasciculus of the lateral ligament, are the tendons of the peroneus longus and brevis. Below and on the medial side, crossing the deltoid ligament, are the tendons of the tibialis posterior and the flexor digitorum longus.

Movements (cf. p. 582).—This being a true hinge-joint, movements on one axis are the only ones permitted, there being no side-to-side motion, except in extreme extension, when the narrowest part of the talus is thrust forward into the widest part of the tibiofibular arch. In flexion (elevation of the foot) the talus is tightly embraced by the malleoli, and side-to-side movement is impossible. Flexion of the ankle-joint is limited by:—(i) nearly the whole of the fibers of the deltoid ligament, none but the most anterior being relaxed; (ii) the posterior and middle portions of the lateral ligament, especially the posterior; (iii) the posterior part of the capsule. It is also limited by the neck of the talus abutting on the edge of the tibia.

In most European ankle-joints the anterior edge of the lower end of the tibia is kept from actual contact with the neck of the talus in positions of extreme flexion by the intervention of a pad of fat situated beneath the anterior extension of the capsule. In races which adopt a squatting posture, however, an actual articulation may be developed between these two bony surfaces, a facet being present both upon the anterior margin of the tibia and upon the neck of the talus. These facets are known as 'squatting facets' and are of common occurrence in ancient bones and in the bones of modern oriental people (see p. 249).

Extension of the ankle-joint (depression of the foot) is limited by:—(1) the anterior fibers of the deltoid ligament; (2) the anterior and middle portions of the lateral ligament; (3) the medial and stronger fibers of the anterior part of the capsule. It is also limited by the posterior portion of the talus meeting with the tibia. Thus the middle portion of the lateral ligament (calcaneofibular) is always on the stretch, owing to its obliquely backward direction, whereby it limits flexion; and its attachment to the fibula in front of the malleolar apex, whereby it prevents over-extension as soon as the foot begins to twist medialward. This medial twisting, or adduction of the foot, is partly due to the greater posterior length of the medial border of the superior articular surface of the talus, and to the less proportionate height posteriorly of the lateral border of that surface, but chiefly to the side-to-side movement in the talocalcaneal joints. The entire range of movement is about 50°. Flexion and extension take place round a transverse axis drawn through the body of the talus. In the normal position of the feet in standing, heels approximated, the two axes form an angle of about 130° open backward. The movement is not, therefore, in a direct anteroposterior plane, but on a plane inclined forward and laterally from the middle of the talus to the intermetatarsal joint of the second and third toes, a natural condition which helps stabilize the ankles in the standing position.

Muscles which act on the ankle-joint (cf. p. 582).—*Flexors.*—Tibialis anterior, peroneus tertius, extensor digitorum longus, extensor hallucis longus. *Extensors.*—Gastrocnemius, soleus, tibialis posterior, peroneus longus, peroneus brevis, flexor digitorum longus, flexor hallucis longus.

Clinical relations of the ankle. Bony landmarks.—The following are the differences between the two **malleoli**: The **medial** is the more prominent, shorter, and is placed more anteriorly than the lateral, being a little in front of the center of the joint. The **lateral** descends lower by about 1.2 cm. (½ in.), and thus securely locks in the joint on this side; it is opposite to the center of the ankle-joint, being placed about 1.2 cm. (½ in.) behind its fellow. Figure 392 shows the appearance of the ankle region with the X-rays.

Owing to the lateral malleolus descending lower than the medial, in Syme's and Pirogoff's amputations the plantar incision should run between the tip of the lateral malleolus and a point 1.2 cm. (½ in.) below that of the medial one. When a fracture is set, or a dislocation adjusted, the medial edge of the patella, the medial malleolus, and the medial side of the great toe are useful landmarks and should be in the same vertical plane, regard being paid at the same time to the corresponding points in the opposite limb. (Holden.)

Effusion or tuberculous thickening shows itself first in front, between the medial malleolus and tibialis anterior and between the peroneus tertius and lateral malleolus and then behind, where it fills up the hollow between the tendo Achillis and the two malleoli. Owing to the thinness of the transverse crural ligament, the extensor sheaths are easily affected in neglected

Fig. 392.—Lateral View of the Ankle Region, as Shown by the Röntgen-rays.

tuberculous disease. Owing to the way in which the joint is locked in, it is not easy to open and drain an infected ankle-joint satisfactorily. Removal of a portion of the lateral malleolus subperiosteally, saving the tip and calcaneofibular ligament, will admit of the insertion of a tube and good drainage if the foot is so slung as to keep its lateral aspect dependent.

6. THE INTERTARSAL JOINTS

The **intertarsal joints** [articulationes intertarseæ] may be divided into the following sub-groups:—(a)the **posterior talocalcaneal articulation**; (b) The **talocalcaneonavicular articulation**, comprising the two **talocalcaneal joints, middle** and **anterior** and the **talonavicular articulation**; (c) **calcaneocuboid articulation**; (d) **transverse articulation of the tarsus** (Chopart's joint); (e) **cuneonavicular articulation**; (f) **cuboideonavicular articulation**; (g) **intercuneiform articulations**; (h) **cuneocuboid articulation**.

(a) The Posterior Talocalcaneal Articulation

This joint is formed by the convex posterior articular facet of the calcaneus and the posterior calcanean articular facet on the lower surface of the talus, concave to correspond. Both articular surfaces are cartilage-covered (see pp. 254, 256). The two bones are united by an articular capsule and the anterior, the lateral, the posterior and the medial, talocalcaneal ligaments.

The loose thin walled **articular capsule** unites the two bones by attachment surrounding the articular surfaces.

The anterior **talocalcaneal ligament** [lig. talocalcaneum anterius] (fig. 386) connects the bones at the level of the posterior side of the entrance to the sinus tarsi.

The **posterior talocalcaneal ligament** [lig. talocalcaneum posterius] passes from the posterior process of the talus and lower edge of the groove for the flexor hallucis longus to the calcaneus, a variable distance from the articular margin (fig. 390).

The **medial talocalcaneal ligament** [lig. talocalcaneum mediale] (fig. 390) is a narrow well-marked band passing obliquely downward and forward from the medial tubercle of the talus, just behind the medial end of the sinus tarsi, to the calcaneus behind the sustentaculum tali, thus completing the floor of the groove for the flexor hallucis longus tendon.

The **lateral talocalcaneal ligament** [lig. talocalcaneum laterale] extends from the groove just below and in front of the lateral articular facet of the talus, to the calcaneus some little distance from the articular margin. Its fibers are nearly parallel with those of the calcaneo-

Fig. 393.—View of the Foot from Above, with the Talus removed to show the Plantar Calcaneonavicular and Bifurcate Ligaments.

fibular ligament of the ankle, which passes over it and adds to its strength. It fills up the interval between the calcaneofibular and anterior talofibular ligaments, a considerable bundle of its fibers blending with the anterior border of the calcaneofibular.

The **articular cavity** is distinct from any other.

The **nerve-supply** is from the tibial or one of its plantar branches.

The **arteries** are, a branch from the posterior tibial, which enters at the medial end of the sinus tarsi; and twigs from the tarsal, lateral malleolar, and the peroneal, which enter at the lateral end of the sinus.

(*b*) The Talocalcaneonavicular Articulation

This joint is formed by the cartilage-covered anterior and middle facets on the upper surface of the calcaneus and the cartilage-covered anterior and middle calcanean facets on the lower surface of the neck and head of the talus, including also the plantar calcaneonavicular ligament supporting the head of the talus, all participating in the anterior talocalcaneal joint; and, too, the head of the talus fitting the posterior concave surface of the navicular in the talonavicular articulation. An articular capsule binds the bones and envelopes the common articular cavity. There are, besides, the following ligaments: interosseous, plantar calcaneonavicular, dorsal talonavicular and the calcaneonavicular part of the bifurcate ligament.

The **interosseous ligament** [lig. talocalcaneum interosseum] (figs. 386 and 391) is a strong band connecting the apposed surfaces of the calcaneus and talus

along their oblique tarsal grooves. It is composed of several laminæ of fibers, with some fatty tissue in between.

The laminæ of the interosseous ligament extend from the roof of the sinus tarsi obliquely downward and laterally to the calcaneus immediately in front of the lateral facet, thus forming the anterior part of the capsule of the posterior joint.

The **plantar calcaneonavicular ligament** [lig. calcaneonaviculare plantare] (figs. 390 and 393) is an exceedingly dense, thick plate of fibroelastic tissue. It extends from the sustentaculum tali and the lower surface of the calcaneus, to the whole width of the inferior surface of the navicular, and also to the medial surface of the navicular behind the tuberosity. Medially it is blended with the anterior portion of the deltoid ligament of the ankle, and laterally with the lower border of the calcaneonavicular part of the bifurcate ligament. It is thickest along the medial border (4–5 mm.) Its upper surface loses the well-marked fibrous appearance which the ligament has in the sole, contains fibrocartilage (sometimes a sesamoid bone) and becomes smooth and faceted under the pressure of the head of the talus. In contact with the lower surface of the ligament the tendon of the tibialis posterior passes, giving considerable support to the head of the talus by augmenting the strength and protecting the spring of the ligament. The fibers of the ligament run forward and medially. On account of its elasticity it is sometimes termed the **spring ligament.**

Calcaneonavicular part of the bifurcate ligament (figs. 386 and 391). The **bifurcate ligament** is attached posteriorly to the upper surface of the calcaneus, lateral to the anterior articular surface and splits into two limbs, one, the calcaneocuboid part extends to the dorsal surface of the cuboid bone. The calcaneonavicular part is a strong, well-marked band, extending from the rough upper surface of the calcaneus, to a slight groove on the lateral surface of the navicular near the posterior margin. It blends below with the plantar calcaneonavicular, and above with the dorsal talonavicular ligament. Its fibers run obliquely forward and medially. The deltoid ligament and middle fasciculus of the lateral ligament of the ankle-joint also add to the security of these two joints, and assist in limiting movements between the bones by passing over the talus to the calcaneus.

The **dorsal talonavicular ligament** [lig. talonaviculare dorsale] (fig. 391) is a broad, thin, but well-marked layer of fibers passing from the dorsal and lateral surfaces of the neck of the talus to the whole length of the dorsal surface of the navicular. Many of the fibers converge to their insertion on the navicular.

The **articular cavity** is common to both the anterior and middle talocalcaneal and the talonavicular joints.

The **arterial supply** of these joints is from branches of the medial plantar and dorsalis pedis arteries.

Nerves are given by the lateral terminal branch of the deep peroneal.

(c) The Calcaneocuboid Articulation

In the **calcaneocuboid articulation** [articulatio calcaneocuboidea] the calcaneus by its cartilage-covered saddle-shaped cuboidal articular surface joins with the reciprocally shaped posterior articular surface of the cuboid bone (see pp. 257, 260). An articular capsule unites the bones and the articular cavity is generally independent, but occasionally communicates with the cavity of the talocalcaneonavicular articulation.

The ligaments which are supplementary to the articular capsule and unite the bones are the calcaneocuboid part of the bifurcate, the dorsal calcaneocuboid, the long plantar, and the plantar calcaneocuboid.

The **calcaneocuboidal part of the bifurcate ligament** (fig. 393) is a strong band of fibers attached to the calcaneus along the medial part of the non-articular ridge above the articular facet for the cuboid, and also to the upper part of the medial surface close to the articular margin, and passes forward to be attached to the depression on the medial surface of the cuboid, and also to the rough angle between the medial and inferior surfaces.

The **dorsal calcaneocuboid** [lig. calcaneocuboideum dorsale] (fig. 391) is attached to the dorsal surfaces of the two bones, extending low down laterally to blend with the lateral part of the plantar calcaneocuboid ligament. Over the medial half, or more, the ligament stretches some distance beyond the margins of the articular surfaces; but toward the lateral side, the ligament is much shorter.

The **long plantar ligament** [lig. plantare longum] (fig. 394) is a strong, dense band of fibers which is attached posteriorly to the whole of the inferior surface of the calcaneus between the medial and lateral processes of the tuberosity and the rounded eminence (the anterior tubercle) at the anterior end of the bone. Most of its fibers pass directly forward, and are fixed to the lateral two-thirds or more of the oblique ridge on the plantar surface of the cuboid, while some pass further forward and medially, expanding into a broad layer, and are inserted into the base of the second, third, fourth, and medial half of the fifth metatarsal bones. This anterior expanded portion completes the canal for the peroneus longus tendon, and from its lower surface arise the oblique adductor hallucis and the flexor digiti quinti brevis muscles.

The **plantar calcaneocuboid** [lig. calcaneocuboideum plantare] (fig. 394) is attached to the rounded eminence (anterior tubercle) at the anterior end of the lower surface of the calcaneus, and to the bone in front of it, and then takes an oblique course forward and medially, and is attached to the whole of the depressed inferior surface of the cuboid behind the oblique ridge, except its lateral angle. It is strongest near its lateral edge, and is formed by dense strong fibers.

The **articular cavity** is distinct from that of any other tarsal joint.

The **arterial supply** is from the tarsal and metatarsal branches of the dorsalis pedis, and from the plantar arteries.

The **nerve-supply** is from the lateral division of the deep peroneal, and occasionally from the superficial peroneal or lateral plantar.

(*d*) The Transverse Tarsal (Chopart's) Articulation

The talonavicular and calcaneocuboid joints together form an area of union and movement across the middle of the tarsus in a frontal plane. Here the fore part of the foot moves on the hinder part almost as one piece although the two joints are usually quite separate from each other. The combined planes of the

Fig. 394.—Superficial Ligaments of the Sole of the Right Foot. (Fick.)

articular surfaces present an ∽ curve, having the anterior convexity at the medial end, the posterior convexity at the lateral end of the joint. The bifurcate ligament is the mainstay in the union of the two segments (fig. 391).

Relations.—On the *dorsal aspect* of the transverse tarsal joint lie the tendons of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius, the muscular part of the extensor digitorum brevis, the dorsalis pedis artery, and the deep peroneal (anterior tibial) nerve. On its *plantar aspect* are the tendons of the flexores digitorum longus and hallucis longus, quadratus plantæ (accessorius), and the medial and lateral plantar vessels and nerves. It is crossed laterally by the tendons of the peroneus longus and brevis and medially by the tendon of the tibialis posterior.

The **movements** of the foot are adapted to the contours of the surfaces ordinarily encountered in standing, walking and climbing. Hinge movements of flexion and extension are performed chiefly at the ankle, metatarsophalangeal and interphalangeal joints, to a small extent in the tarsal and tarsometatarsal articulations. The important movements of supination and pronation in which the medial and lateral margins of the foot are elevated respectively, and adduction and abduction which, together with flexion and extension to a small degree, are performed by the foot as a whole moving on the talus. In supination the foot is rotated so that the medial margin is elevated, the sole inclined medially, the foot is adducted and slightly extended. In pronation are present the opposite of these conditions.

The movements of the foot undergoing pronation and supination take place on a single axis (fig. 395). This axis passes obliquely from the dorsomedial side of the foot, downward, backward and laterally to emerge at the lateral side of the heel. In the natural position of the foot in standing, the heels near, the toes directed outward, the axis of supination and pronation does not lie in one of the chief planes of the foot, but, however, falls in a sagittal plane of the body as a whole. It is in a plane, therefore, which stands at an acute angle with the plane of the axis of the ankle joint. These two axes and the movements about them are to some extent like those at the elbow when the forearm moves on a hinge and turns in pronation and supination. The rotation axis in the foot by meeting the hinge axis at the ankle at an acute angle confers a greater degree of security in standing and walking than would be the case in a right angle relation of these two axes. Advantage in climbing is given by the sagittal position of the axis, whereby the soles in the supinated feet may be planted against the sides of a limb or the trunk of a tree.

The joint surfaces by which the rest of the foot moves upon the talus are limited to two bones, the calcaneus and the navicular. The talocalcaneal articular surfaces are not quite congruent and, especially at the posterior joint, are not in contact at all points at the same time. A certain amount of rocking follows. The posterior calcaneal surface of the talus is concave to meet the convex posterior articular surface of the calcaneus, whereas the anterior

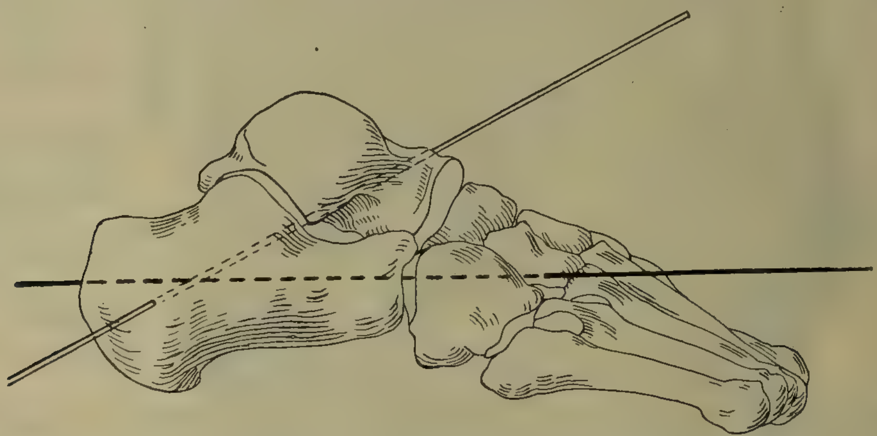


Fig. 395.—Axes of Movements of the Tarsus.
Double line, the axis for pronation and supination at the talocalcaneal and talonavicular joints; single line, the axis for pronation and supination at Chopart's joint. (Fick.)

capitular surface of the talus is rounded to fit the socket made by the posterior surface of the navicular and the anterior and middle facets of the calcaneus, and the plantar calcaneonavicular ligament. Between these two sets of joints, just the opposites in contour, the strong interosseous talocalcaneal ligament binds the bones together. The axis of supination and pronation passes through the neck of the talus, the interosseous ligament and the calcaneus.

The calcaneus, navicular and cuboid are bound together by exceedingly strong ligaments (in particular the plantar calcaneonavicular and the bifurcate ligaments) and move as one piece, carrying the rest of the foot with them in pronation and supination on the talus as a fixed bone. The range of pronation and supination is about 13° (that of supination being the greater), of abduction and adduction about 12.7°, of flexion and extension about 5.8°.

The range of supination and pronation can be increased by participation of Chopart's transverse joint in which the movement, generally restricted, takes place about an antero-posterior axis through the cuboid and calcaneus. Slight gliding between the cuneiform bones and talus, between the cuneiforms, at the tarsometatarsal and intermetatarsal joints may all contribute to increase the range of pronation and supination. These movements are to some extent the result at times of muscle action (tibialis anterior, tibialis posterior, peroneus longus), but come about usually by adjustment of the foot to the surface in standing, walking and climbing, through the superimposed weight of the body, in adjusting the balance of the body in locomotion.

In walking, the heel is first placed on the ground; the foot is slightly adducted; but as the body swings forward, first the lateral then the medial toes touch the ground, the talus presses against the navicular and sinks upon the plantar calcaneonavicular ligament; the foot then becomes slightly abducted. When the foot is firmly placed on the ground, the weight is transmitted to it obliquely downward and medially, so that if the ligaments between the calcaneus and talus did not check abduction, medial displacement of the talus from the tibiofibular arch would only be prevented by the tendons passing round the medial ankle (especially the tibialis posterior). If the ligaments be too weak to limit abduction, the weight of the body increases it, and forces the medial malleolus and talus downward and medially, giving rise to flat foot.

The advantages of the obliquity and peculiar arrangement of the posterior talocalcaneal articulation are seen in walking:—(1) for the posterior facet of the calcaneus receives the whole weight of the body when the heel is first placed on the ground; (2) by the upward pressure of this facet against the talus it transfers the weight to the ball of the toes as the heel is raised, the

posterior edge of the sustentaculum tali and the anterior and lateral part of the upper surface of the calcaneus preventing the talus from being displaced too far forward by the superincumbent weight; and (3) the calcaneus serves to support the talus when, with the heel raised by muscular action, the other foot is being swung forward.

(*e*) The Cuneonavicular Articulation

[Articulatio cuneonavicularis]

The navicular, by its anterior cartilage-covered surface, articulates with the three cuneiform bones (fig. 282) whose surfaces together with those of interosseous ligaments and dorsal and plantar ligaments comprise practically a continuous face, chiefly cartilage-covered (see pp. 258ff.).

The bones are united by a capsular ligament and by the following naviculocuneiform ligaments:—

Dorsal. Medial. Plantar.

The **articular capsule** is attached near the joint margins.

The **dorsal naviculocuneiform ligament** [lig. naviculocuneiforme dorsale] (fig. 386) is very strong, and stretches as a continuous structure, on the dorsal surface of the navicular, between the tubercle of the navicular on the medial side, and the dorsal cubonavicular ligament laterally, passing forward and a little laterally to the dorsal surfaces of the three cuneiform bones.

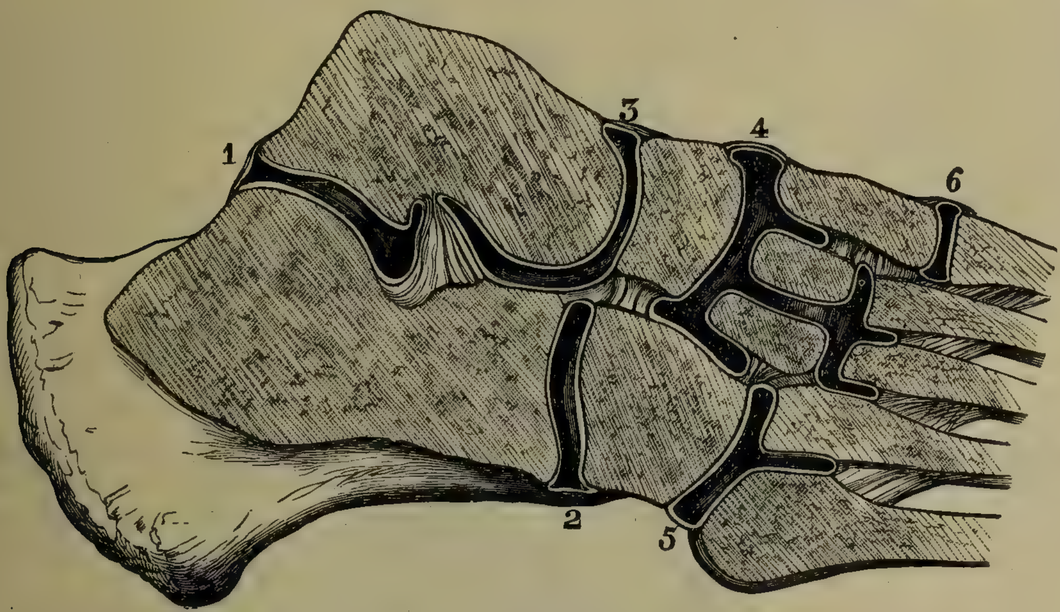


Fig. 396.—Section to show the Articular Cavities of the Foot.

1. **Posterior talocalcaneal.** **2.** **Calcaneocuboid.** **3.** **Anterior talocalcaneonavicular**
4. **Tarsal.** **5.** **Cuboideometatarsal.** **6.** **First metatarsocuneiform.**

The **medial naviculocuneiform ligament** [lig. naviculocuneiforme mediale] (fig. 390) is a very strong thick band which connects the tubercle of the navicular with the medial surface of the first cuneiform bone. It is continuous with the dorsal and plantar ligaments. Its lower border touches the tendon of the tibialis posterior.

The **plantar naviculocuneiform ligament** [lig. naviculocuneiforme plantare] (fig. 394) forms, like the dorsal, a continuous structure extending between the plantar surfaces of the bones. Its fibers pass forward and laterally. It is in relation below with the tendon of the tibialis posterior.

The **articular cavity** is continuous with that of the cuneocuboid joint and also with those of the intercuneiform joints (fig. 396).

It must be noticed that the expanded tendon of insertion of the tibialis posterior, and the ligaments uniting the navicular with the cuboid and cuneiform bones, pass forward and laterally, whereas the peroneus longus tendon and the ligaments uniting the first and second rows of bones, except the medial half of the dorsal talonavicular ligaments, pass forward and medially. This arrangement is admirably adapted to preserve the arches of the foot, and especially the transverse arch. Had these tendons and ligaments run directly forward, all the strain on the transverse arch would have fallen on the interosseous ligaments, but as it is, the arch is braced up by the above-mentioned structures.

(*f*) The Cuboideonavicular Articulation

[Articulatio cuboideonavicularis]

The articulating surfaces in this inconstant joint are the posterior medial angle of the cuboid and the lateral margin of the navicular (see pp. 258, 260).

The joint cavity is only occasionally present, forming an irregular diarthrosis. This joint is often included in the transverse tarsal. The **cuboideonavic-**

ular ligaments which unite the cuboid and navicular are the dorsal, the plantar, and the interosseous.

The **dorsal cuboideonavicular ligament** [lig. cuboideonaviculare dorsale] (fig. 391) runs forward and laterally from the lateral end of the dorsal surface of the navicular to the middle third of the medial border of the cuboid on its dorsal aspect, passing over the posterior lateral angle of the third cuneiform bone. It is wider laterally.

The **plantar cuboideonavicular ligament** [lig. cuboideonaviculare plantare] (fig. 394) is a well-marked strong band, which runs forward and laterally, from the plantar surface of the navicular to the depression on the medial surface of the cuboid, and slightly into the plantar surface just below it.

The **interosseous cuboideonavicular ligament** is a strong band which passes between the apposed surfaces of these bones from the dorsal to the plantar ligaments. Some of its posterior fibers reach the plantar surface of the foot behind the cuboideonavicular ligament, and radiate laterally and backward over the medial border of the cuboid to blend with the anterior extremity of the plantar calcaneocuboid ligament.

(*g*) The Intercuneiform and (*h*) The Cuneocuboid Articulations

The articular surfaces and cavities are indicated in fig. 396 (see pp. 258, 260 for the articular surfaces of the bones). The ligaments uniting these bones are divided into three sets: dorsal, plantar, and interosseous.

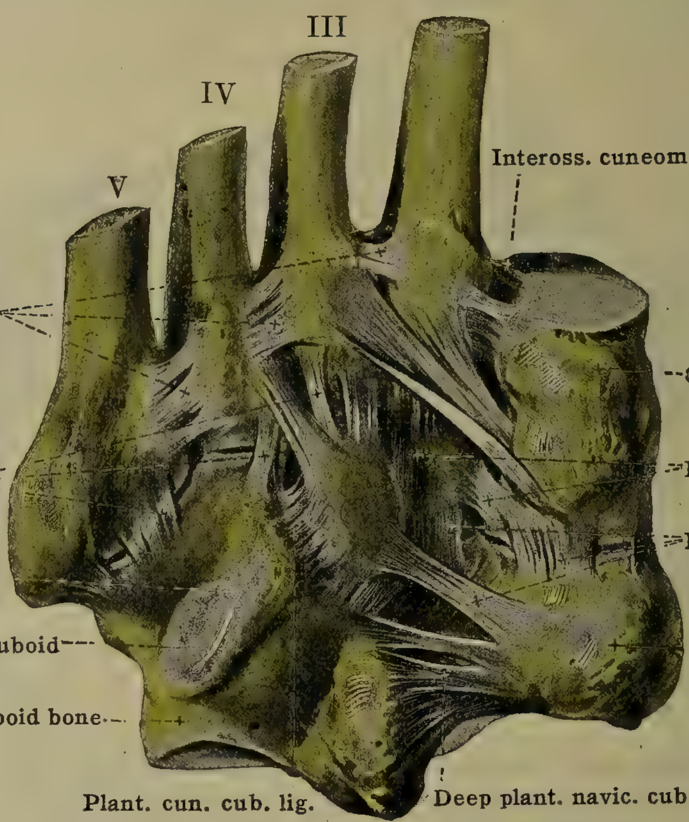


Fig. 397.—Ligaments of the Right Foot (Plantar view). (Fick.)

The **dorsal ligaments** are three in number, two, the **dorsal intercuneiform** [ligg. intercuneiformia dorsalia], connecting the three cuneiform bones, and a third, the **dorsal cuneocuboid** [lig. cuneocuboideum dorsale], uniting the third cuneiform with the cuboid. They pass between the contiguous margins of the bones and are blended behind with the dorsal ligaments of the cuboideonavicular and cuneonavicular joints (fig. 391).

The **plantar ligaments** are two in number: a very strong one, the **plantar intercuneiform** [lig. intercuneiforme plantare], passes laterally and forward from the lateral side of the base of the first cuneiform to the apex of the second cuneiform, winding somewhat to its lateral side. The second, the **plantar cuneocuboid** [lig. cuneocuboideum plantare], connects the apex of the third cuneiform with the anterior half of the medial surface of the cuboid along its plantar border, joining with the plantar cuboideonavicular ligament behind (fig. 397).

The **interosseous intercuneiform ligaments** [ligg. intercuneiformia interossea] are two in number. They are strong and deep masses of ligamentous tissue which connect the second cuneiform with the first and third cuneiform bones; and the **interosseous cuneocuboid ligament** [lig. cuneocuboideum interosseum] unites the third cuneiform with the cuboid. These ligaments occupy all the non-articular portions of the apposed surfaces of the bones. The interosseous ligaments extend the whole vertical depth between the second cuneiform and the third and the third cuneiform and the cuboid, and blend with the dorsal and plantar ligaments; they are situated in front of the articular facets, and completely shut off the synovial cavity behind from that in front. The ligament between the first and second cuneiform bones occupies the inferior and anterior two-thirds of the apposed surfaces, and does not generally extend high enough to separate the synovial cavity of the anterior tarsal joint from that of the second and third metatarsal and cuneiform bones. If it does extend to the dorsal surface, it divides the facets completely from one another, making a seventh synovial sac in the foot.

The **articular cavity** is shown in fig. 396. It is continuous posteriorly with that of the cuneonavicular, and anteriorly (between the second and third cuneiforms) it communicates with the second and third tarsometatarsal joints.

The **arterial supply** is from the metatarsal and plantar arteries.

The **nerves** are derived from the deep peroneal and medial and lateral plantar.

Muscles which act on the talocalcaneal, talocalcaneonavicular and calcaneocuboid joints (cf. p. 582).—*Supination and adduction* (inverters).—Tibialis anterior and posterior acting simultaneously; they are aided by the flexor digitorum longus and flexor hallucis longus. *Pronation and abduction* (everters).—The peronei longus, brevis, and tertius, acting simultaneously. They are aided by the extensor digitorum longus.

7. THE TARSOMETATARSAL ARTICULATIONS

There may be said to be three articulations [articulationes tarsometatarseæ] between the tarsus and metatarsus, as shown in figs. 396 and 397, viz.:—

(*a*) The medial, between the first cuneiform and first metatarsal bones.

(*b*) The intermediate, between the second and third cuneiform and second and third metatarsal bones.

(*c*) The lateral, or cuboideometatarsal, between the cuboid and fourth and fifth metatarsal bones.

(*a*) The Medial Tarsometatarsal Joint

The first metatarsal presents a slightly saddle-shaped surface (see p. 262). It is united with the first cuneiform by a complete **articular capsule,** the fibers of which are very thick on the inferior and medial aspects; those on the lateral side pass from behind forward in the interval between the interosseous ligaments which connect the two bones forming this joint with the second metatarsal. The ligament on the plantar aspect is by far the strongest, and blends at the cuneiform bone with the plantar naviculocuneiform ligament.

(*b*) The Intermediate Tarsometatarsal Joint

Into this union there enter the second and third cuneiforms, articulating by cartilage-covered surfaces with the cartilage-covered bases of the second and third metatarsal bones (see pp. 259, 263), which are bound together by the following ligaments (supplementary to the articular capsule): dorsal, plantar, interosseous. (See figs. 391 and 397.)

The dorsal tarsometatarsal ligaments [ligg. tarsometarsea dorsalia].—1. Some short fibers cross obliquely from the lateral edge of the first cuneiform bone to the medial border of the base of the second metatarsal bone; they take the place of a dorsal metatarsal ligament, which is wanting between the first and second metatarsal bones.

2. Between the second cuneiform and the base of the second metatarsal bone some fibers run directly forward.

3. The third cuneiform is connected with (1) the lateral corner of the second metatarsal bone by a narrow band passing obliquely medially; (2) with the third metatarsal by fibers passing directly forward; and (3) with the fourth metatarsal by a short band passing obliquely laterally to the medial edge of its base.

The plantar tarsometatarsal ligaments [ligg. tarsometarsea plantaria].—A strong ligament unites the first cuneiform and the bases of the second and third metatarsal bones. The tibialis posterior is inserted into these bones close beside it. Other slender ligaments connect the second cuneiform with the second, and the third cuneiform with the third metatarsal bones.

The interosseous cuneometatarsal ligaments [ligg. cuneometatarsea interossea].—(1) A strong broad interosseous ligament extends between the lateral surface of the first cuneiform and the medial surface of the base of the second metatarsal bone. It is attached to both bones below and in front of the articular facets, and separates the intermediate from the medial tarsometatarsal joint. (2) A second band is attached behind to a fossa on the anterior and lateral edge of the third cuneiform and to the interosseous ligament between it and the cuboid, and passes horizontally forward to be attached to the whole depth of the fourth metatarsal bone behind its medial facet, and to the apposed surfaces of the third and fourth below the articular facets upon their sides. It separates the middle tarsometatarsal, and intermetatarsal between the third and fourth bones, from the cuboideometatarsal joint. It is more firmly connected with the third bone than with the fourth. (3) A slender ligament composed of only a few fibers often passes from a small tubercle on the medial and anterior edge of the third cuneiform to a groove on the lateral edge of the second metatarsal bone between the two facets upon their sides.

The **articular cavity** (fig. 396) is prolonged forward from that of the cuneonavicular and intercuneiform articulations.

The **arteries for the tarsometatarsal joints** are derived:—(1) for the medial, from the dorsalis pedis and medial plantar; (2) for the rest, twigs from the arcuate and deep plantar arch.

The **nerve-supply** comes from the deep peroneal and plantar nerves.

(c) The Lateral or Cuboideometatarsal Joint

The bones comprising this joint are the cartilage-covered bases of the fourth and fifth metatarsal and the anterior cartilage-covered surface of the cuboid (see pp. 260, 264), firmly connected on all sides by the articular capsule, and strengthened by the dorsal and plantar tarsometatarsal ligaments (figs. 391, 397).

The **plantar tarsometatarsal ligament** is a broad, well-marked ligament, which extends from the cuboid behind to the bases of the fourth and fifth metatarsal bones in front. It is continuous along the groove at the base of the fifth metatarsal bone with the dorsal ligament, and as it passes round the lateral border of the foot it is somewhat thickened, and may be described as the **lateral tarsometatarsal ligament.** On its medial side it joins the interosseous ligaments, thus completing the capsule below. It is not a thick structure, and to see it, the long plantar ligament, the peroneus longus, and lateral slip of the tibialis posterior must be removed; the attachment of these structures to the fourth and fifth metatarsal bones assists considerably to unite them with the tarsus.

The **dorsal tarsometatarsal ligament** is composed of fibers which pass obliquely outward and forward from the cuboid to the bases of the fourth and fifth metatarsal bones. They complete the capsule above, and are continuous laterally with the lateral tarsometatarsal ligament.

The **articular cavity** is separate from the other articular cavities of the tarsus, and is continued between the fourth and fifth metatarsal bones (fig. 396).

Relations.—The line of the tarsometatarsal joints is crossed dorsally by the tendons of the long and short extensor muscles of the toes and the tendon of the peroneus tertius. On the plantar aspect it is in relation with the oblique adductor of the great toe, the short flexor of the great toe, the lateral plantar artery, and the tendon of the peroneus longus. Its medial end is subcutaneous except that it is crossed, near the plantar surface, by a slip of the tendon of the tibialis anterior, and its lateral end is crossed by the tendon of the peroneus brevis.

The **movements** permitted at these joints are slight and consist of flexion and extension of the metatarsus on the tarsus; and at the medial and lateral divisions, slight adduction and abduction. In the lateral, the side-to-side motion is freer than in the medial joint, and freest between the fifth metatarsal bone and the cuboid.

There is also a little gliding, which allows the transverse arch of the foot to increase or diminish in depth; the medial and lateral two bones sliding downward, and the two middle a little upward, when the arch is increased; and *vice versa* when the arch is flattened.

8. THE INTERMETATARSAL ARTICULATIONS

[Articulationes intermetatarseæ]

The bases of the metatarsal bones articulate with each other side by side, through small cartilage covered articular surfaces (see pp. 262–264) as shown in figs. 293 to 297. They are firmly held in position by dorsal, plantar, and interosseous basal ligaments, supplementing the articular capsules. The first only occasionally articulates by means of a distinct facet with the second metatarsal.

The **dorsal ligaments of the bases** [ligg. basium oss. metatars. dorsalia] (fig. 391) are membranous bands passing between the four lateral toes on their dorsal aspect; but in place of one between the first and second metatarsal bones, a ligament extends from the first cuneiform to the base of the second metatarsal bone.

The **plantar ligaments of the bases** [ligg. basium oss. metatars. plantaria] (fig. 394) are strong, well-marked ligaments which connect the bases of the bones on their plantar aspect.

The three **interosseous ligaments of the bases** [ligg. basium oss. metatars. interossea] between the four lateral metatarsals are very strong, and are situated at the points of union of the shaft with the bases of the bones, and fill up the sulci on their sides. They limit the articular cavities in front of the articular facets.

The common **articular cavity** (fig. 396) of the tarsus extends between the second and third, and third and fourth bones; that of the cuboideometatarsal joint extending between the fourth and fifth.

The **arterial** and **nerve-supply** is the same as for the tarsometatarsal joints.

The **movements** consist merely of gliding, the raising or widening of the transverse arch. Considerable flexibility and elasticity are thus given to the anterior part of the foot, enabling it to become moulded to the irregularities of the ground.

The Union of the Heads of the Metatarsal Bones

The **heads of the metatarsal bones** are connected on their plantar aspect by the **transverse ligament** [ligg. capitulorum transversa] (fig. 398), consisting of four bands passing transversely from bone to bone, blending with the fibrocartilaginous plates of the plantar accessory ligaments of the metatarsophalangeal joints, and the sheaths of the flexor tendons where they are connected with the fibrocartilages. The tendons of the interossei muscles pass dorsal and those of the lumbricales plantarwards of the ligament, together with the plantar digital

vessels and nerves. It differs from the corresponding ligament in the hand by having a band from the first to the second metatarsal bone.

9. THE METATARSOPHALANGEAL ARTICULATIONS

[Articulationes metatarsophalangeæ]

(a) The Metatarsophalangeal Joints of the Four Lateral Toes

These joints are formed by the oval concave articular surfaces of the proximal ends of the first phalanges articulating with the rounded heads of the metatarsal bones (see pp. 261, 264) and united by articular capsules strengthened by the collateral, dorsal and plantar accessory ligaments (fig. 398).

The joint capsule is loose, attached close to the articular cartilages dorsally and laterally, but removed ventrally. Delicate in its dorsal part, it is thickened in its plantar portion by the presence of a fibrocartilaginous plate.

Fig. 398.—Joints of the Toes.
Showing the joints partly opened, partly in connection with tendon sheaths; and the transverse ligament of the heads of the metatarsal bones. Right foot from plantar aspect. (Fick.)

The two **collateral ligaments** [ligg. collateralia] are strong bands passing from a ridge on each side of the head of the metatarsal bone to the sides of the proximal end of the first phalanx, and also to the sides of the plantar accessory ligament.

The **dorsal ligament** consists of loose fine fibers, extending between the collateral ligaments, thus completing a capsule. It is connected by fine fibers to the lower surface of the extensor tendons, which pass over and considerably strengthen this portion of the capsule.

The **plantar accessory ligament** [lig. accessorium plantare] helps to deepen the shallow facet of the phalanx for the head of the metatarsal bone, and corresponds to the accessory volar ligament of the fingers. It is firmly connected to the collateral ligaments and the transverse ligament, and is grooved inferiorly where the flexor tendons pass over it, here presenting the plantar fibrocartilaginous plate in which a sesamoid bone may be developed. It serves to prevent dorsal dislocation of the phalanx.

The second metatarsophalangeal joint is about 6 mm. in front of both the first and third metatarsophalangeal joints. The third metatarsophalangeal joint is about 6 mm. in front of the fourth, and the fourth about 9 mm. in front of the fifth. The head of the fifth metatarsal

is in line with the neck of the fourth. Thus the lateral side of the longitudinal arch of the foot is shorter than the medial; it is also distinctly shallower.

(b) The Metatarsophalangeal Joint of the Great Toe

The metatarsophalangeal joint of the great toe differs from the rest in the following particulars:—

(1) The bones are on a larger scale, and the articular surfaces are more extensive.
(2) There are two grooves on the plantar surface of the head of the metatarsal bone, one on each side of the middle line, for the sesamoid bones.
(3) The **sesamoid bones** replace the accessory plantar ligament (sesamoid plate). They are two small hemispherical bones developed in the tendons of the flexor hallucis brevis, convex below, which play in grooves on the head of the metatarsal bone; they are united by a strong transverse ligamentous band which is smooth below and forms part of the channel along which the long flexor tendon plays (fig. 398). They are firmly united to the base of the phalanx by strong short fibers, but to the metatarsal bone they are joined by somewhat looser fibers. At the sides they are connected with the collateral ligaments and the sheath of the flexor tendon. They provide shifting leverage for the flexor hallucis brevis as well as for the flexor hallucis longus.

The **arteries** come from the digital and metatarsal branches; and the **nerves** from the cutaneous digital, or from small twigs of the nerves to the interossei muscles.

The **movements** of the metatarsophalangeal joints (cf. p. 582) are: flexion extension, and slight abduction or adduction.

Flexion is more free than extension and is limited by the extensor tendons and dorsal ligaments; extension is limited by the flexor tendons, the plantar fibers of the collateral ligaments, and the sesamoid plates. The side-to-side motion is possible from the shape of the bony surfaces, but is very limited, being most marked in the great toe (although the joint is ginglymoid in form). The movement is limited by the collateral ligaments and sesamoid plates.

10. THE INTERPHALANGEAL JOINTS

The joints [articulationes digitorum pedis] (fig. 398) between the first and second and second and third phalanges of the toes are similar to those of the fingers, with this important difference, that the bones are smaller and the joints, especially between the second and third phalanges, are often ankylosed. The ligaments which unite them include, in addition to the articular capsule, the collateral, the dorsal and the accessory plantar.

The **two collateral ligaments** are well marked and pass on each side of the joints from a small rough depression on the head of the proximal, to a rough border on the side of the base of the distal phalanx of the joint.

The **dorsal ligament** is thin and membranous, and extends across the joint from one collateral ligament to the other beneath the extensor tendon, with the deep surface of which it is connected and by which it is strengthened.

The **accessory plantar ligament** covers in the joint on the plantar surface. It is a fibrocartilaginous plate, connected at the sides with the collateral ligaments, and with the bones by short ligamentous fibers; the plantar surface is smooth and grooved for the flexor tendons.

The **arteries** and **nerves** are derived from the corresponding digital branches.

The only **movements** permitted at these hinge joints are flexion and extension.

At the interphalangeal joint of the great toe there is very frequently a small **sesamoid bone** which plays on the plantar surface of the first phalanx, in the same way as the sesamoid bones of the metatarsophalangeal joint play upon the plantar surface of the head of the metatarsal bone.

Muscles acting on the metatarsophalangeal and interphalangeal joints of the foot.—For these the student may refer to the accounts given of the relations of the corresponding joints in the hand and of the actions of the muscles upon those joints. See also pp. 582, 583.

ARCHES OF THE FOOT

The bony construction of the longitudinal and transverse arches of the foot has been described above (Osteology, p. 265) and it remains now to point out the influence of the articulations and ligaments, together with that of muscular action, in perfecting the arch mechanism. It will be recalled that the talus forms the keystone of the longitudinal arch and transmits the weight of the body to the pillars formed by the calcaneus behind and the heads of the metatarsal bones in front. This arch may be compared to a double-armed lever, by which the body may be elevated on either the fulcrum of the short posterior pier (heel) or on the longer anterior pier (heads of the metatarsal bones).

The mosaic articulations of the bones of the foot are maintained by the passive effect of the numerous ligaments, which by analysis are shown to be adapted in function to permit sufficient movement of the individual bones so that the sole of the foot may fit or grasp the particular contour of the ground on which it rests. The long plantar ligament is specially functional in helping to sustain the longitudinal arch. Apparently there is a reserve of ligamentous function which comes into use in failure of muscles to do their part in supporting the arches. In this domain the short muscles are of great significance in opposing any tendency of the arches to spread; of the long extrinsic muscles, the flexor longus hallucis is the chief one in helping to maintain the longitudinal arch, the peroneus longus in compressing the transverse arch. The latter and the tibialis anterior, by their tendons, form a transverse sling, or stirrup, for the sole.

The toes are of much importance in perfecting the arch mechanism, for in their apposition to the ground they offer resistance to forward shoving of the arch, the bases of the first phalanges pressing against the heads of the metatarsals. One of the distinctive human characteristics is the position of the great toe in line with the medial margin of the foot, thus contributing greatly to the perfection of the longitudinal arch. It is, unlike the ape's great toe, and the human thumb, unopposable: the transverse capitular ligament binds its metatarsal to the second and the peroneus longus pulls it into apposition with the second metatarsal bone. Examination of foot prints (fig. 399) demonstrates that we still stand upon the outer margins of our feet and that the arches are manifested chiefly on the medial side.

a b c d

FIG. 399.—PRINTS OF THE LEFT FOOT. a, normal (high arch); b, normal (moderate arch); c low arch; d, flat foot.

Uses of the arches may be summarized as follows. (1) They give combined elasticity and strength to the tread. Thus they give firmness, free quickness, and dignity, both in standing and walking, instead of what we see in their absence, viz., the lameness of an artificial limb, and the shuffling or hobbling which goes with tight boots, deformed toes, flat-foot, bunions, corns, etc.; (2) they protect the plantar vessels, nerves, and muscles; (3) they add to man's height; (4) they make his gait a perfect combination of plantigrade and digitigrade, as is seen in man's walking, when he uses first the heel, then all the foot, and then the toes. (Humphry.)

References.—H. Morris, The Anatomy of the Joints of Man, Lond., 1879. Rudolf Fick, Handbuch der Anatomie und Mechanik der Gelenke. H. Strasser, Lehrbuch der Muskel-und Gelenkmechanik, Berlin. H. Braus, Anatomie des Menschen, I Bd., Berlin, 1921. Extensive bibliographies for the joints are given in the larger works on human anatomy by Quain, Poirier-Charpy and von Bardeleben. References to the most recent literature may be found in Schwalbe's Jahresbericht, the Index Medicus, Anatomischer Anzeiger and Anatomischer Bericht.

SECTION V
THE MUSCULATURE

By C. R. BARDEEN, A.B., M.D.

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF WISCONSIN

MUSCLES, the movements of which are under the control of the will, almost completely envelope the skeletal framework of the body; close in the oral, abdominal, and pelvic cavities; separate the thoracic from the abdominal cavity; surround the pharynx and the upper portion of the esophagus; and are found connected with the eye, ear, larynx, and other organs. They constitute about two-fifths to three-sevenths of the weight of the body.

In this section an account is given of the gross anatomy of the musculature attached to the skeleton and the skin, with the exception of certain of the muscles which are more conveniently treated in connection with the organs to which they are appended. Thus, the muscles of the eye, the ear, the pharynx, the larynx, and the intrinsic muscles of the tongue are described in the sections devoted to those structures.

Relations to the skin.—Beneath the skin is a sheet of connective tissue, the **tela subcutanea.** In this, in some regions of the body (the head, neck, and palm), thin, flat, **subcutaneous muscles** are embedded. Superficial muscles of this kind constitute a **panniculus carnosus,** much more extensive in the lower mammals than in man. The tela subcutanea is separated from the more deeply seated musculature by areolar tissue, which, in most places, is loose in texture over the muscles. In some regions, as over the upper part of the back, the tela subcutanea is firmly united to the underlying musculature and is less freely movable. In the tela subcutanea more or less fat is usually embedded. This constitutes the **panniculus adiposus,** which varies greatly in thickness in different parts of the body. As a rule, it is much more developed over muscles than over those regions where bone and joints lie beneath the skin. Fat is absent from the tela subcutanea of the eyelids, penis and scrotum. The deeper layer of the tela subcutanea is more or less free from fat, and in it run the main trunks of the cutaneous nerves and vessels. In some regions, as over the lower part of the abdomen, one or more fibrous membranes are differentiated in this deeper layer.

To the tela subcutanea the term **superficial fascia** has been commonly applied, but since this leads to a confusion with the superficial fasciæ which immediately invest the muscles, it seems better to restrict the term fascia to the membranes connected with the muscular system, and to use the term **tela subcutanea,** or subcutaneous tissue, for the layer of connective tissue which underlies the skin and is continuous over the whole surface of the body.

In several places where the skin overlies bony prominences well-marked **synovial bursæ,** or sacs (**bursæ mucosæ**), are developed in the tela subcutanea.

Since the skin and the subcutaneous tissue must be removed in order to study the muscles of various regions, the tela subcutanea and subcutaneous bursæ may be conveniently described in connection with the muscles, and brief references will, therefore, be made to them in connection with the musculature of various regions.

Muscle-fasciæ.—The musculature of the body, with the exception of some of the subcutaneous muscles, is ensheathed by fibrous tissue, which, in certain regions forms distinct membranes, while in other regions it is delicate and not clearly to be distinguished from the superficial connective tissue of the muscles, the perimysium externum. The membranes, or **muscle-fasciæ,** are united to various parts of the skeleton, either directly or by means of intermuscular septa, and, where strong, keep the underlying musculature in place. In some regions they are united to the muscles; in others they are separated from the underlying

musculature by loose areolar tissue, which allows free movement between the surface of the muscles and the overlying fascia. The best example of a strong fascia of this nature is that which envelopes the extensor muscles of the thigh. Where the fasciæ are well developed, the main bundles of constituent fibers take a course directly or obliquely transverse to the direction of the underlying muscles. They may be composed of several successive layers of fibrous tissue, the fibers of one layer taking a different direction from those of the next layer.

The **function** of the fasciæ is the mechanical one of restraining or modifying muscle action. The direction of the main component fiber-bundles indicates the direction of the greatest stress to which the fasciæ are subjected. Indirectly the fasciæ promote the circulation of the blood and lymph in places where the vessels lie between the contracting muscles and the overlying fascia.

Intermuscular septa.—Muscle-fasciæ enclose not only the external layer of the musculature of the body, but also the various groups of more deeply seated muscles. In addition, between the individual muscles, and between the different layers and groups of muscles, there intervenes a greater or less amount of connective tissue, sometimes loose in texture, sometimes dense in structure. In these intermuscular septa run the chief nerves and blood-vessels of the region in which the musculature lies.

Gross structure of the muscles.—The muscles are composed of bundles of reddish fibers surrounded by a greater or less extent of white and glistening connective tissue. They are attached by prolongations of this tissue in the form of **tendons** or **aponeuroses** usually to the bony skeleton, but also in places to cartilages, as in the thorax and larynx; to the skin, as in the face; to mucous membranes, as in the tongue and cheeks; to the tendons of other muscles, as in the case of the lumbrical muscles; to muscle fasciæ, as in the case of the oblique and transverse muscles of the abdomen; and to other structures, as, for instance, to the eyeball.

The fleshy portion of the muscle is called the **belly.** The belly is usually attached at one extremity to a portion of the skeleton or to some other structure which serves as a support for its action on the structures to which its other extremity is attached. The attachment to the more fixed part is called the **origin** of the muscle; the attachment to the structure chiefly acted on is called the **insertion.** Thus the origin of the biceps muscle, a flexor and supinator of the forearm is from the scapula; the insertion is into the radius and into the fascia of the forearm. The part of the muscle attached to the origin is called the **head** of the muscle. The part attached to the insertion is sometimes called the **tail,** but this term is much less frequently used than the former.

The muscles vary greatly in size and **form.** Thus the stapedius muscle of the middle ear is a slender little structure, only a few mm. long, while the gluteus maximus muscle of the hip is a large, rhomboid structure often several cm. thick and with a surface area of over 500 square cm. The length of a muscle from origin to insertion may be much less than the width of the muscle, as in the intercostal muscles; or much greater than the width, as in most of the long muscles of the limbs. The thickness of a muscle is usually less than the width—so much so in some instances that the muscle is described as flat, sheet-like, or ribbon-like; while in other instances the belly is cylindrical. In flat muscles the general outline is usually quadrilateral or triangular. In triangular muscles in most instances one angle of the triangle marks the insertion of the muscle, while the opposite side marks the origin. In cylindrical muscles the belly usually has a somewhat fusiform shape, and grows smaller both toward the origin and the insertion of the muscle.

Some muscles are divided by tendons transverse to the long axis of the muscle. When one such tendon exists, the muscle is called **digastric** (fig. 410); when several, **polygastric,** e. g., rectus abdominis (fig. 452).

Two muscle-masses with separate origins may have a common insertion. Such muscles are usually designated **bicipital** muscles (biceps muscles of the arm and thigh). Other muscles have three heads (the triceps muscle of the arm) or four (the quadriceps muscle of the thigh). In the latter case special names are given to the four parts or muscles which constitute the quadriceps as a whole. In addition to these comparatively simple compound muscles there are others in which the various component fasciculi and the tendons of origin and insertion are numerous and complexly interrelated. The intrinsic muscles of the back offer good illustrations of muscles of this nature.

In addition to muscles with distinct regions of origin and insertion, there are a few voluntary muscles which surround hollow viscera or their orifices and have a circular or tube-like form (sphincter muscles, voluntary muscles of the esophagus, etc.).

Number of muscles.—A logical constancy does not appear always to have been followed in the commonly accepted division of the musculature into muscles individually designated. Most of the muscles are symmetrically placed in pairs, one on each side of the body. Authors not only vary in the extent to which they carry the subdivisions of the musculature on each side of the body into individual muscles, but also in describing muscles placed near the median line either as single muscles with bilateral halves or as paired muscles. In addition some muscles are not constantly present, and there are differences of opinion as to which of these less constant muscles should be classed with the normal musculature. The BNA recognizes 347 paired and two unpaired skeletal muscles, and 47 paired and two unpaired muscles belonging to the visceral system and organs of special sense.

Of the skeletal muscles the head has 25 paired and one unpaired; the neck 16 paired; the back 112 paired; the thorax 52 paired, one unpaired; the abdomen and pelvis 8 paired; the upper extremity, 52 paired; the lower extremity, 62 paired (Eisler).

Finer structure of muscles.—While no attempt can be made here to describe in detail the finer microscopic features of muscle structure, some of the more general features of muscle architecture may be briefly mentioned.

The contractile cells of voluntary muscle are long, slender, multinucleated **'fibers'**, the protoplasm of which exhibits both cross and longitudinal striation. The longitudinal striation is due to the presence of fibrils situated in the sarcoplasma. The cross striation is due to alternate segments of singly and doubly refracting substance in these fibrils. The length of these fibers in the human body varies from a few millimeters to sixteen centimeters or more, and the thickness from ten to eighty microns. Each muscle-fiber is surrounded by an especially differentiated sheath, the **sarcolemma.** Outside of this is a layer of delicate connective tissue, the **perimysium internum or endomysium,** the fibers of which are in part inserted into the sarcolemma. This connective tissue, which is especially developed at the ends of the fibers, serves to attach them either directly to the structures on which the muscle acts or to the skeletal framework of the muscle.

In the simplest mammalian muscles the muscle-fibers take a parallel course from tendon to tendon, and are not definitely bound into secondary groups. An example may be seen in fig. 400, a, which represents two segments of the rectus abdominis muscle of a mouse. More often however, the individual fibers do not run the entire distance from tendon to tendon, but instead they interdigitate, and the interdigitating fibers are bound up into secondary and tertiary anastomosing fiber-bundles by connective tissue, in which there is usually a considerable amount of elastic tissue. Fig. 400,b, represents diagrammatically this interdigitation of fiber-bundles as seen in the abdominal musculature of one of the larger mammals.

In most of the flat muscles of the body the fiber-bundles either take a nearly parallel course from tendon to tendon or they converge from the tendon of origin toward the tendon of insertion (see fig. 400, c–e). The greater the distance from tendon to tendon, the more marked is the interdigitation of the constituent fiber bundles.

In elongated muscles the tendons of origin and insertion may either arise near the extremities of the muscle or may extend for a considerable distance on the surface or within the substance of the muscle. In the former case the belly of the muscle is composed of bundles of interdigitating fibers which take a course parallel with the long axis of the muscle. This is shown diagrammatically in fig. 400, f. An example may be seen in the sartorius muscle of the thigh (fig. 475). When the tendons extend far on the surface or within the substance of the muscle, the constituent fiber-bundles take a course oblique to the long axis of the muscle. When they take a course from a tendon of origin on one side toward a tendon of insertion on the other, the muscle is called **unipenniform** (see fig. 400, g, and the extensor digitorum longus, fig. 479). In other instances the fiber bundles converge from two sides toward a central tendon. Such a muscle is called **bipenniform** (see fig. 400, h, and the flexor hallucis longus, fig. 480). When there are several tendons in the muscle between which the fiber bundles run obliquely, the muscle is called **multipenniform.** In **fusiform** muscles the tendons usually either embrace the extremity of the muscle like a hollow cone, or they extend far on the surface or within the substance of the muscle. In such muscles the fiber-bundles take a curved course from one tendon to the other. The bundles which arise highest on one tendon are inserted highest on one other, and the fiber-bundles of lowest origin have the lowest insertion. This structure is diagrammatically shown in fig. 400, i. A good example may be found in the rectus femoris muscle (fig. 475).

Many other arrangements of the fiber-bundles are found, and the arrangements here shown may be variously combined. In most muscles the architecture is decidedly complex. In the more complex muscles dense connective-tissue septa, or intramuscular fasciæ, serve to separate different regions of the muscle from one another. In general there are groups of muscle fiber-bundles surrounded by a greater amount of connective tissue, or perimysium internum, than that surrounding the individual fiber-bundles, and the latter are surrounded by a denser connective tissue than that surrounding the component muscle-fibers. The muscles are surrounded externally by a more or less dense sheet of connective tissue called the perimysium externum, or epimysium, which is continuous with the connective tissue within the muscle, the perimysium internum. In the following pages 'muscle fiber-bundle' is used to denote small

groups of muscle-fibers, 'fasciculus' to denote large, more or less isolated, groups of fiber-bundles.

Embryonic development of muscles.—The voluntary muscles are of mesodermal origin. The muscles of the trunk arise chiefly from the myotomes (see p. 15), those of the head and limbs chiefly from the mesenchyme in these regions. New muscle-fibers are formed mainly before birth. After birth, growth of muscles depends on growth of individual muscle-fibers.

Tendons.—Muscles vary not only in general form and in the relations of the constituent fiber-bundles to the intrinsic skeletal framework, but also in the mode

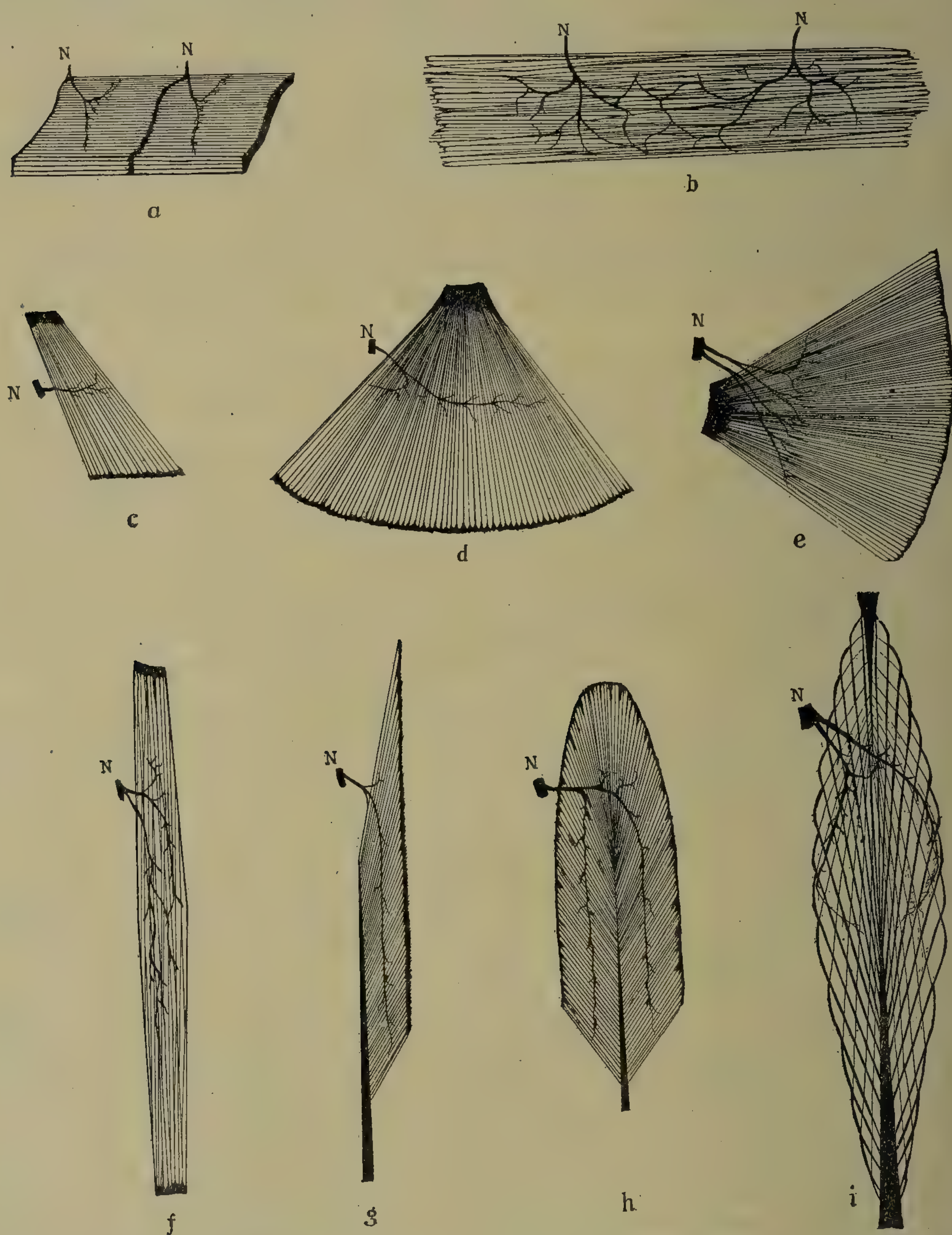


Fig. 400.—Diagrammatic Outlines to Illustrate Various Types of Muscle Architecture and the Relations of the Main Nerve Branches to the Fiber-bundles of the Muscle.

a. Two segments of the rectus abdominis muscle of a small mammal. b. Portion of sheet-like muscle with two nerve-branches and intramuscular nerve plexus. c. Typical quadrilateral muscle with nerve passing across the muscle about midway between the tendons. d and e. Two triangular muscles with different types of innervation. f. Long ribbon-like muscle with interdigitating fiber-bundles. g. Unipenniform muscle. h. Bipenniform muscle. i. Typical fusiform muscle. The main intramuscular nerve-branches are distributed to the fiber-bundles about midway between their origins and insertions. N. nerve.

of attachment to the parts on which they act. In many instances the fiber-bundles impinge, perpendicularly or obliquely, directly upon a bone or cartilage. The tendinous tissue arising from the fiber-bundles of the muscle here is attached to the periosteum or perichondrium or to the bone directly. A broad attachment is thus offered the muscle. Instances of this mode of attachment may be seen in

the attachment of the intercostal muscles and of many of the muscles attached to the shoulder and hip girdles.

In the case of most thin, flat muscles the muscle is continued at one or both extremities into thin, tendinous sheets called **aponeuroses**, composed of connective tissue. Well-marked instances may be seen in the transverse muscle of the abdomen (fig. 454), and the trapezius and latissimus dorsi muscles of the back (fig. 417). The extent of development of these aponeuroses is generally inversely proportional to the development of the muscle—the more extensively developed the muscle is in a given individual, the less extensive the aponeurotic sheet.

The terms fascia and aponeurosis are often loosely and interchangeably used. It seems best to make a distinction by restricting the term fascia to membranous sheets of investment, and aponeurosis to broad tendons. The latter may, however, be inserted into and form a part of the former.

Most muscles are continued at one or both extremities into dense, tendinous bands which may be comparatively short and thick, like the tendon of Achilles (fig. 477), or very long and narrow, like the tendon of the palmaris longus (fig. 433).

In this latter case the tendon represents in part the remnants of musculature more highly developed in the lower vertebrates. In most instances, however, the tendons are structures specifically differentiated for definite functions and are composed of bundles of parallel connectve-tissue fibrils held together by an interlacing fibrous-tissue framework. The tendons usually contain a relatively small amount of elastic tissue.

The tendons are attached to the skeleton early in embryonic development. As the bones enlarge the tendons become in part incorporated in the substance of the bone and ossified.

In some tendons **sesamoid bones** are developed in the neighborhood of joints over which the tendons pass. Examples of these are the patella at the knee-joint (fig. 476) and the sesamoid bones of the thumb and great toe.

Where muscles or tendons closely envelope a joint, there is usually formed a close union between the connective tissue of the capsule of the joint and that of the muscle or the tendon. Special bands may develop in the direction of the pull of the muscle (lig. popliteum obliquum).

Where tendons run for some distance across or beneath a fascia, they are usually either bound to the fascia by a special investment, as near the wrist and knee (figs. 428 and 478), or are fused with the fascia, as in the case of the iliotibial band.. Fibrous tracts in the fascia may indicate stress under muscle contraction (the lactertus fibrosus of the fascia of the forearm).

Often in broad aponeurotic attachments of muscles there is formed in the tendon near the attachment a fibrous archway [**arcus tendineus**] for the passage of blood-vessels, nerves, muscles, or tendons. The tendinous arch is either fastened at both ends to the bone, or at one end it is connected with a joint capsule or other membrane. The dorsal attachment of the diaphragm (fig. 455) and that of the adductor magnus to the femur (fig. 473) offer good examples of tendon arches. In digastric and polygastric muscles the transverse tendons which separate the bellies are often composed of narrow, incomplete bands of fibrous tissue. Such a transverse band is called an **inscriptio tendinea** (see RECTUS ABDOMINIS MUSCLE, fig. 452).

Tendon-sheaths.—The tendons are held in place by sheaths composed of dense connective tissue. These sheaths vary in different regions. In the most complete form they confine tendons in osseous grooves which they convert into osteofibrous canals on the flexor surface of the digits. The sheath is here called a **vagina fibrosa tendinis.** It is strengthened by tendinous bands (**vaginal ligaments**). In other regions special dense bands or ligaments, **retinacula tendinum,** confine a series of tendons in place, as at the ankle (fig. 481), or fasciæ may be modified for this purpose, as at the back of the wrist (fig. 428). A tendinous loop, **annulus fibrosus,** may hold a tendon in place, as, for instance, the trochlea of the tendon of the superior oblique muscle of the eye.

Synovial sheaths [vaginæ mucosæ tendinum].—Synovial sheaths are developed about tendons where the latter are confined in osteofibrous canals, as in the fingers. The wall of the canal and the enclosed tendon, or tendons, are each covered by a smooth membrane which at the extremities of the canal is reflected from the wall to the tendon. Between the membrane covering the tendon and

that lining the canal is a synovial cavity. An interesting feature of these tendon-sheaths is the presence of **mesotendons,** delicate bands of vascular connective tissue which run in places from the osseous groove to the tendon and carry blood-vessels and nerves. (See figs. 401, 437, 438.)

Trochleæ.—Where a tendon passes at an angle about a bone, the tissue in the groove in which the tendon runs frequently is composed of hyaline cartilage instead of bone. An example may be seen in the trochlear process of the calcaneus.

Synovial bursæ [bursæ mucosæ].—Where freedom of movement is essential between muscle tendons and the surrounding parts a loose connective tissue intervenes between these structures. In regions where considerable friction results from the play of the tendon on the underlying part a special structure, a synovial bursa, is developed. These bursæ are small closed sacs of connective tissue which are lined by a synovial membrane. They are similar in structure to the synovial tendon sheaths just described. The free movement is provided by the contact of the moist synovial surfaces. Most of these bursæ are developed from the intervening connective tissue at a period in embryonic life preceding muscular activity, but special bursæ may later be developed as the result of unusual pressure or muscular activity after birth. An instance of a bursa lying in a region of friction may be seen in the bursa intervening between the tendinous posterior surface of the iliopsoas muscle and the iliofemoral ligament. As an

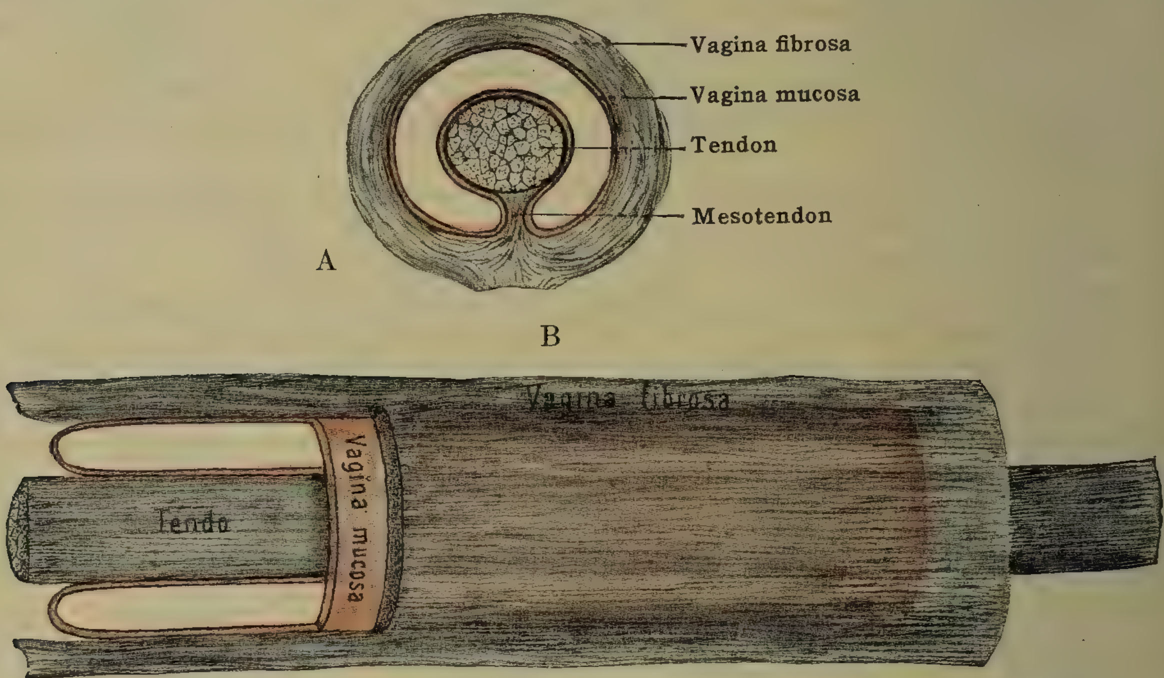


Fig. 401.—Schematic Drawing of a Tendon and Its Sheath. (Rauber-Kopsch.) Vagina mucosa tendinis is red. A, Cross section. B, Longitudinal section. At the left the sheath is opened.

instance of a bursæ lying in a region of intermittent pressure may be cited that between the tendon of Achilles and the calcaneus.

Most synovial bursæ intervene between a tendon and a bone, a tendon and a ligament, or between two tendons (**subtendinous bursæ mucosæ**). Others lie between two muscles, a muscle and some skeletal part, or between a muscle and a tendon (**submuscular bursæ mucosæ**); or below a fascia (**subfascial bursæ mucosæ**). Subcutaneous bursæ have been referred to in connection with the tela subcutanea (see p. 385). Most bursæ are developed near joints. The bursæ may so expand during active life that they come to communicate with other bursæ or with a neighboring joint cavity.

Nerves.—To each muscle of the body a nerve containing motor and sensory fibers is distributed. A few muscles receive two or more nerves. Sherrington has estimated that in the muscle-nerves of the cat two-fifths of the fibers are sensory and three-fifths motor. The muscles of the head and in part those of the neck are supplied by branches of the cranial nerves. The intrinsic muscles of the neck, back, thorax, and abdomen are supplied by branches which arise fairly directly from the spinal nerves. The muscles of the limbs are supplied by branches from nerve-trunks which arise from plexuses formed by the spinal nerves in the regions near which the limbs are attached.

The question of whether voluntary striated muscle receives an innervation from the sympathetic nervous system has recently been actively investigated. At the present time the negative evidence outweighs the positive findings. Reinvestigation of the problem has shown that the criterion formerlly used to establish a nerve fiber as sympathetic, namely, non-medullated with grape-like endings, is not specific for sympathetic fibers. (See Wilkenson, Jour. Comp. Neurol., vol. 51, p. 129.)

The main nerve-trunks lie beneath the superficial muscles. They usually run in the intermuscular septa which separate the deeper groups of muscles from one another and from the superficial muscles. The nerve-branches which enter a given muscle usually pass in where the larger intramuscular septa approach the surface of the muscle, and then ramify through the perimysium internum, the smaller branches being distributed in the finer layers of connective tissue which surround and separate the primary muscle fiber-bundles, to the constituent muscle-fibers of which terminal branches are given. Special sensory end organs are distributed chiefly in the large intramuscular septa, in the tendons and in the muscles near the tendons. Simple sensory endings are found on the muscle-fibers.

The size of a nerve supplying a muscle is not proportional to the size of the muscle, but rather to the complexity of movements in which the muscle plays a part.

Muscles receive their nerve supply early in development. During later development the muscle may wander a considerable distance from its place of origin and carry its nerve with it. The diaphragm, innervated by cervical nerves, is a good example.

The distribution of the motor nerves varies according to the architecture of the muscle, but in general it appears that the nerves are so distributed as to carry the main branches of distribution most directly to the middle of the constituent fiber-bundles. This is seen most clearly in muscles with comparatively short fiber-bundles, where the individual muscle-fibers run nearly or quite the entire distance from tendon to tendon (fig. 400 a, c, d, e, g h, and i). When the distance is long, a marked plexiform arrangement is found (fig. 400, b and f). To each muscle fiber there is distributed a terminal nerve-fiber which passes through the sarcolemma and ends in a motor end organ (muscle plate). Occasionally there are two such nerve-fibers to one muscle-fiber.

Vessels.—The muscles are richly supplied with blood. In many instances the larger blood-vessels accompany the larger nerve-trunks as they enter the muscle, and their primary branches are distributed in the larger intramuscular septa. Often, however, the main blood-vessels approach a muscle from a direction different from that taken by the nerves. Each muscle has, however, its own blood-supply. There is little anastomosis between the blood-vessels of a muscle and those of a neighboring structure, but the anastomosis between the vessels within the muscle is exceedingly rich. Veins, as a rule, accompany all but the smallest arteries within the muscle. The veins are richly supplied with valves, so that muscle contraction promotes the flow of blood through the muscle. Rich capillary plexuses surround the muscle-fibers. The capillaries are of unusually small diameter.

During contraction, the blood is forced from the muscles; during expansion it rushes in through dilated arteries which furnish five or six times as much blood to muscles during exercise as that supplied to them during rest.

The connective-tissue sheaths, the larger intramuscular septa, and the tendons of muscles are richly supplied with lymphatics. There are no lymphatics within the muscle-bundles or in small muscles.

Nomenclature.—The names of the various muscles and their classification are less satisfactory than is desirable. The muscular system was first carefully studied in the human body, and names based sometimes upon the shape, structure, size, or position, at other times upon the supposed function or other associated facts, were applied to the muscles found in various regions. Sometimes two or more names were applied to a muscle to indicate several of these factors. Thus *trapezius* and *triangularis* indicate the shape of the correponding muscles; *biceps* or *triceps* indicates the origin by two or three heads; *rectus*, *obliquus*, and *transversus* represent the direction taken by a muscle or its constituent fiber-bundles; *magnus* and *minimus* indicate size; *sublimis* (superficial) and *profundus* (deep) represent the relative positions occupied; *sterno-cleido-mastoid* indicates structures to which the muscle is attached; *flexor* and *extensor* indicate function; and *sartorius* indicates that the corresponding muscle was supposed to be of use to tailors.

Since careful study has been devoted to the comparative anatomy of the muscles in various vertebrates, it has become apparent that a simple and more consistent nomenclature applicable to corresponding muscles found in various animals would be of great value. A satisfactory nomenclature of this sort has not, however as yet been devised and adopted in comparative anatomy, and the established usage of the terms now familiarly applied to the muscles of the human body makes it seem improbable that even if such a system were devised for comparative anatomy it could be brought into extensive use in human anatomy. For many of the muscles in the human body various synonyms have been in use in different countries. The Anatomical Congress assembled at Basel in 1895, to simplify the nomenclature of human anat-

omy, adopted in large part the terms in familiar use in England and America. In the following pages the terms approved by the Congress will be employed, but where they differ materially from those previously in use, the synonym will be given in parentheses. Some of the more important changes recommended in the revision by the Nomenklatur-Kommission (NK) are also indicated.

Classification.—The muscles are usually treated strictly according to the region of the body in which they are found. This method of consideration is still of value in a dissector's guide and in text-books of topographical anatomy. But in studying the muscles scientifically it is of importance also to consider them in their more fundamental genetic relationships to one another and to the nervous system. Embryology and comparative anatomy have proved of the greatest value in revealing these relationships. Studies of this nature have revealed well-marked relationships in the adult human musculature which are of practical as well as scientific importance. The voluntary musculature may be broadly divided into that of the skeletal axis, the limbs, and the visceral orifices. The musculature of each of these divisions has a different and in general simpler form in the lower than in the higher vertebrates, and in the embryos of the higher vertebrates than in the adult. The musculature of the spinal region of the body-axis of fishes, the tailed amphibia, and all vertebrate embryos is metamerically segmented; that is, it is divided along the axis of the body into a series of components corresponding with the segmentation of the vertebral column. Although marked alterations take place in the subsequent ontogenetic differentiation in higher vertebrates, traces of this primitive segmentation are still to be found in the adult; in man, for instance, in the intercostal muscles and the segments of the rectus abdominis. In the region of the head conditions are complex, owing to the concurrent presence of muscles which primitively correspond in nature with the segmental spinal musculature and muscles non-segmental in character, which surround the visceral orifices. This also is true of the anus and external genitalia, where, however, the conditions are simpler. Embryology and comparative anatomy have done much to clear up puzzling features in both regions.

The muscles of the limbs are not metamerically arranged in any adult vertebrate. In some of the lower forms a series of axial muscle-segments, myotomes, furnishes material from which the musculature of the limbs is differentiated. In the mammals this appears not to be the case, and the muscles are differentiated from the non-segmental tissue of the limb-buds.

Where mammalian musculature is primitively segmental, each segment becomes associated with a corresponding spinal nerve or, in the head, with a nerve which corresponds in series with a spinal nerve. Even when subsequent differentiation brings about marked alterations in the axial musculature, the nerves maintain to a considerable degree a segmental distribution.

Into each of the limbs, where the intrinsic musculature is at no time segmental, there extends during embryonic development a series of segmental spinal nerves, so that in them, as in the region of the body axis, a certain segmentation in the nerve-supply can be made out in the adult. That part of the limb nearest the head in early embryonic development has its muscles supplied by the most cranial, that part nearest the caudal extremity of the body by the most caudal, of the nerves which supply the limb-musculature. There is here, however, considerable overlapping of the segmental areas.

Variation.—In man some variation in the arrangement of the muscles is met with in every individual, and often marked deviations from the normal conditions are found. The muscles vary in their mode of origin or insertion, and in the extent to which muscles of a given group are fused with one another or to which the chief parts of a complex muscle are isolated from one another. Some muscles, like the palmaris longus and the plantaris, are frequently entirely absent, and other muscles generally absent are sometimes present.

In addition to these frequent variations there are others so rare that many authors prefer to speak of them as anomalies rather than variations. Sometimes muscles may be found doubled by longitudinal division, or two or more muscles normally present may be fused into a single indivisible muscle. Occasionally there occur muscles constantly present in some of the lower animals, but normally not met with in the human body (anomalies of reversion or of convergence). In such instances the muscle may be normally represented by a tendon or fascia. At times the anomalies are supposed to be not a reversion to an ancestral condition, but a distinct step in advance. This, however, is difficult to prove. At other times no phylogenetic relation is apparent, and the anomaly is looked upon as a monstrous sport or as the result of some pathological condition.

The nerve-supply of the muscles is of value in the study of muscle-variations. There is, however, not infrequent variation in the nerves with relation to the supply of the muscles.

Physiology.—From the standpoint of morphology the muscles are grouped according to their intimate relations to one another and to the peripheral nerves; relations, as noted above, that are made more clear by a study of comparative anatomy and embryology. From the physiological aspect a different grouping of the muscles is required, because muscles belonging morphologically in one group may have different physiological functions in the animal body. The chief features of the mechanical action of muscles may be briefly considered here.

Most muscles act on the bones as levers. In physics three types of levers are recognized. In levers of the first type (fig. 402, I) the fulcrum (F) lies be-

tween the place where power (P) is exerted on the lever and the point of resistance or load (L). Levers of this kind are frequently met with in the body. A good example is seen in the attachment of the skull to the vertebral column. The fulcrum lies at the region of attachment; the weight of the skull tends to bend the head forward, while the force exerted by the dorsal muscles of the neck serves to keep the head upright or to bend it back.

In levers of the second class (fig. 402, II) the point on which power is exerted moves through a greater distance than the point of resistance. Speed of movement is thus sacrificed to power. Levers of this type are exceedingly rare in the animal body. An example in the human body is the foot when the body is raised on the toes, if the contact of foot with ground be considered the fulcrum.

In levers of the third class (fig. 402, III) the point on which force is exerted moves a less distance than the point of resistance. Power is thus sacrificed to speed. This is the common form of leverage found in the body. A good example is found in the action of the muscles which flex the forearm on the arm. The region in which the biceps and brachialis are attached is but a short distance from the elbow-joint or fulcrum, while the hand may be looked upon as the region of resistance to the force exerted. A movement of the point P through a short distance will cause L to move through a great distance.

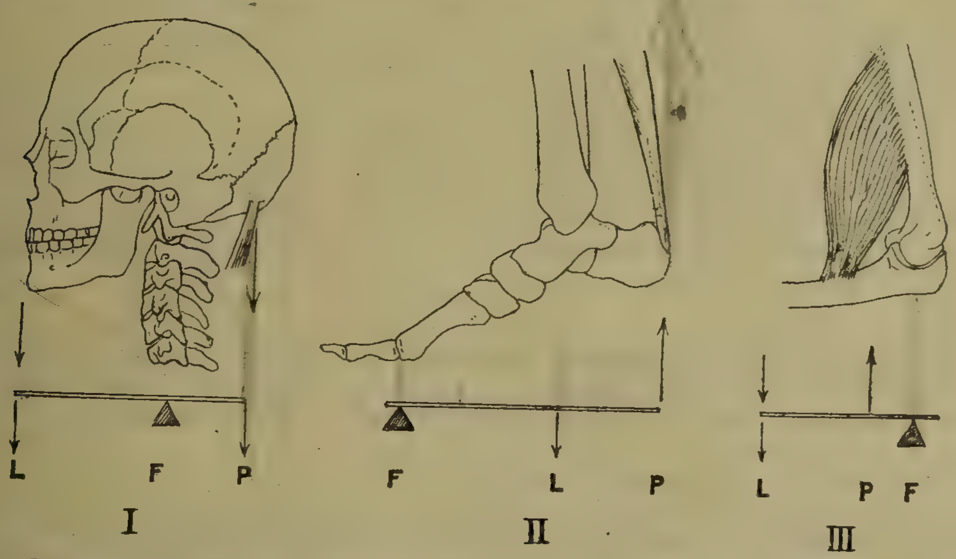


Fig. 402.—Three Diagrams (After Testut) to Illustrate Different Types of Levers in their Relations to the Mechanical Action of the Muscles.

The more the angle between a muscle or its tendon and the bone on which it acts approaches a right angle, the greater is the power of movement exerted by the muscle. The arm in fig. 402, III, is in the position of greatest advantage for the action of the brachialis on the forearm. All boys know that it is easier to 'chin' oneself after the arm is partly bent than when hanging straight from a bar. Many of the muscles run nearly parallel with the parts on which they act, but the tendons before their attachment are usually either carried over a bony prominence or some fascia or ligament acts as a pulley so that the tendon is inserted at an oblique angle. At other times a process for the attachment of the tendon projects from the bone and causes the force of the contracting muscle to be more advantageously exerted on the bone. It may, of course, readily be seen that the greater the distance of the attachment of a muscle from the joint on which it acts, the greater will be the power exerted by the muscle.

In considering the movements of the body, it is convenient to recognize two groups, simple and complex. To the former, which alone can be considered in a text-book of anatomy, belong such movements as flexion, extension, adduction, rotation, etc., while to the latter belong those associated movements which give rise to changes in the positions of the body as a whole or of extensive regions of the body.

In **flexion** the extremities of the trunk or limbs or special portions of these regions are bent near to one another; in **extension** the reverse movement is brought about. The parts are straightened or even bent beyond the straight position (over-extension).

In **abduction** transverse movements are made, a part being bent away from the median line of the body or limb; in **adduction** the reverse movement is brought about.

In **rotation** a part is turned on its longitudinal axis. The rotation of the femur at the hip-joint is called medial rotation when the toes are turned medialward, lateral rotation when the toes are turned lateralward. Rotation at the

shoulder-joint is called medial when the thumb is turned forward and medialward toward the body, lateral when the reverse movement takes place. These movements are also carried out in the forearm, but here medial rotation is called **pronation,** lateral rotation, **supination.** Fick prefers these terms also for the rotation at other joints as at the shoulder, hip and knee.

At the shoulder-joint the swinging of the arm toward the back is called extension; toward the front, flexion; and from the side, abduction. Moving the arm toward the mid-dorsal or mid-ventral line is called adduction.

Taking the body as a whole the musculature may be divided into two main divisions, an *expander division* and a *contractor division.* In general the extensors, abductors and lateral rotators expand, the flexors, adductors and medial rotators contract.

In the most expanded condition the head and spine are extended or even slightly hyperextended (flexed dorsally), and the limbs project laterally from the body with the backs of the hands and feet facing dorsalward, the palms and soles ventralward, and the digits spread out. In the fully formed human body it is not possible to put the lower extremity in the completely expanded position, although it is in this position early in embryonic development. As development proceeds the lower extremity is adducted and rotated medialward and the girdle is so fixed that full abduction becomes no longer possible. In many of the lower vertebrates full abduction is possible throughout life in the lower extremities just as it is throughout life in the upper extremities in man. Full extension of the spinal column in man is also hindered in the thoracic region by the thorax, and in the sacrococcygeal region by the osseous union of vertebræ with one another as well as by the attachment of the hip-girdles. The lumbar region in man is in a condition of permanent hyperextension.

In the fully contracted condition the head and spinal column are strongly flexed, and the digits are adducted the various segments of the limbs are flexed and the limbs are adducted, flexed and rotated medialward toward the middle of the trunk. The body approaches a ball in form. It is the position taken by a gymnast when turning a somerset in the air, and is in marked contrast to the fully expanded condition which would be assumed could man fly like a bat or glide like a flying squirrel.

In general the muscles which put the body or a part of the body into the expanded position form a distinct group as contrasted with those which put the body into the contracted position. The chief musculature which extends the head and trunk lies dorsolateral to the spinal column and is supplied by the dorsal divisions of the spinal nerves The chief musculature which flexes the head and trunk lies ventrolateral to the spinal column and is supplied by ventrolateral divisions of the spinal nerves. The chief muscles which abduct, extend and rotate the limbs lateralward arise during embryonic development on the dorsal sides of the limb buds and are innervated by branches from the dorsal sides of the brachial and lumbosacral nerve plexus. The chief muscles which flex adduct and rotate the limbs medialward arise on the ventral sides of the limb-buds and are supplied by nerves which arise from the ventral sides of the limb plexuses. To these general rules there are some exceptions, the most marked of which is at the hip-joint where rotation of the girdle has brought about a condition in which the primitive action of the flexor and extensor groups is partly reversed. The chief flexors (the iliopsoas and rectus femoris) belong to the dorsal division and some of the chief extensors (the hamstring muscles) belong to the ventral division. At the ankle-joint the exception is more apparent than real. What is usually called flexion at the ankle-joint is really hyperextension and the reverse movement is the nearest we can come to real flexion. In the extremely contracted positon of the body as a whole the feet are extended (flexed plantarward at the ankle joint).

Muscles which produce a movement in a common direction are called **synergists,** while those whose contraction produces opposite movements are called **antagonists;** e. g., the flexors and extensors are antagonists. In the actual working of the muscular system, however, when a set of muscles is contracting to produce a movement, the antagonists are simultaneously relaxed. A more extended treatment of this subject is given on p. 569.

The relation of the internal architecture of a muscle to the movements to which its contraction gives rise is a complex subject, the details of which cannot be entered into here. In general it may be said that when the fiber-bundles run directly from one attachment to the other, as in fig. 400, a and f, the force exerted by the contraction of the individual muscle-fibers is most efficiently utilised and the extent of the movement varies directly as the length of the fibers, while the force exerted varies directly with the number of the fibers. In muscles with tendons of insertion relatively small in cross-section compared with the belly of the muscle, the power of the muscle is concentrated on a small area. Long tendons frequently take a course which improves the leverage.

In muscles of the types indicated in fig. 400, g, h, i, a certain amount of the extent of movement and of the force exerted by the contraction of the individual fibers is not effectively exerted on the parts moved by the muscles, as may be seen by applying to this action the laws of the parallelogram of forces. In such muscles, however, the great number of short muscle-fibers composing them makes possible the exertion of great power with some loss of speed of contraction in the muscle as a whole.

The direction of the movements which result from muscular contraction is in large part determined by the shape of the articular surfaces, none of which are to be looked upon a simple

fulcra, but instead, during a given movement, the fulcrum shifts from one region to another of the joint.

In different muscles the extent of contraction of the constituent fiber-bundles during activity varies considerably. While usually the length of the contracted fiber-bundles is half that of those in the extended state, the amount of shortening in some muscles is only 25 to 35 per cent.

Functional activity is necessary for the full development or for the maintenance of development in muscles. Muscles atrophy if their nerve supply is injured or if they are passively prevented from contracting.

Order of treatment.—The muscles and fasciæ are here treated in the following order:—(1) those of the head and neck and shoulder-girdle (p. 395); (2) those of the upper extremity (p. 427); (3) those of the spine (p. 478); (4) those of the thorax and abdomen (p. 488); (5) those of the pelvic outlet (p. 505); (6) those of the lower extremity (p. 519). The reason for taking up the musculature in the order named is, that during embryonic development musculature belonging primitively to the head comes to overlap that of the neck; that of the neck spreads over the region of the back and thorax, and becomes attached to the shoulder-girdle; that of the arm extends over the region of the thorax, abdomen, and back; that of the back partially over the region of the thorax; while that of the abdomen enters into intimate relation with the pelvic girdle. So far as practicable the musculature of these various regions will be taken up according to fundamental morphological relationships.

Since a morphological grouping of the muscles does not accord perfectly with a physiological grouping, there is given at the end of this section a table showing what muscles are concerned in performing the simpler voluntary movements.

The topographical relations of the muscles in various regions of the body are illustrated in the series of cross-sections given for each region.

Tables illustrating the relations of the central nervous system and the peripheral nerves to the muscles are given in the section on the Nervous System (pp. 1000, 1042, 1071, 1094).

I. MUSCULATURE OF THE HEAD, NECK AND SHOULDER-GIRDLE

PHYSIOLOGICAL AND MORPHOLOGICAL ASPECTS

The head, situated at the anterior end of the trunk in bilaterally symmetrical animals, is primitively that part of the body first brought into contact with new surroundings as the animal moves forward. We therefore find developed here the most highly differentiated organs of special sense, those of vision, hearing, and smell, through which the animal is put in touch with an environment more or less removed from immediate contact with the body. In connection with these organs of special sense, the brain is developed. In most animals the head also is the chief organ for the prehension of food and for attack and defense. The neck is a part of the trunk differentiated to give freedom to the movements of the head. The forelimbs, relatively unimportant as the forefins in the fishes, become important organs of locomotion in the land animals. In the fishes there is no true neck, but the forefins are developed at the sides of the cervical part of the trunk. In the higher vertebrates the forelimbs are also first differentiated at the sides of the cervical region (see p. 20) but, as embryonic development goes on, they shift caudalward to the sides of the cranial (anterior) part of the thorax. The cervical region is thus left free for movement but the musculature and nerves of the upper extremity remain intimately related to it.

In man, with the assumption of the erect posture, the head no longer has to bear the brunt of the new surroundings as the body moves forward. There is, however, a distinct advantage in having those organs of special sense, which put the individual into touch with the more distant parts of the environment, situated high above the ground, and a motile neck is of great value in directing the organs of special sense toward various parts of the environment. The development of the superior extremities as organs for the prehension of food and as organs of attack and defense reduces the value of the head for these purposes, but still leaves it the important functions of the reception of food and air and the preparation of food for gastric and intestinal digestion. The head, furthermore, assumes a new and most important function as an organ for the expression of the emotions and of speech.

The expression of the emotions, such as anger, fear, affection and the like, is brought about largely through the action of flat, subcutaneous 'facialis' muscles which underlie most of the skin of the face and head and extend down under that of the neck (figs. 403 and 406). They also line the mucous membrane of the lips and cheeks. Most of them arise from the surface of the skull and are inserted into the skin, which they pull in various directions causing it to become smooth or wrinkled, according to the direction of the pull. The various muscles are grouped about the buccal, nasal and aural orifices and about the orbit of the eye. Some of the fiber-bundles are arranged so as to constrict the orifices, others radiate out so as to dilate them.

The chief groups of muscles of the head and neck, in addition to the facialis group just mentioned, are the muscles of the orbit and middle ear, the muscles used in mastication and swallowing (craniomandibular, supra- and infrahyoid groups, muscles of the tongue, soft palate and pharynx), the muscles of the larynx, and the ventral and dorsal groups of muscles which lie in the region of neck, extend over the thorax and move the head, neck and shoulder-girdle.

Of these various groups of muscles, some, for the sake of convenience, are treated in connection with the organs to which they belong. Thus the muscles of the eye and ear are taken up in Section IX, those of the palate, pharynx and larynx in Sections X and XI the deep dorsal musculature of the neck will be taken up in the section on the intrinsic muscles of the back, p. 479. The remaining groups of muscles will be taken up in the following order:—

The pectoral muscles and the latissimus dorsi, which extend from the skeleton of the limb to the front and side of the thorax and the lower part of the back, arise from the limb-bud during embryonic development, are innervated through the brachial plexus, and will, therefore, be taken up in considering the intrinsic musculature of the upper limb, p. 427.

THE FACIALIS MUSCULATURE

(Figs. 403, 406)

The muscles of this group are intimately connected with the scalp, with the skin of the face and neck, and with the mucous membrane lining the lips and the cheeks. Most of the muscles have an osseous origin and a cutaneous insertion, but there are exceptions. Both origin and insertion may be cutaneous, or the attachment may be to an aponeurosis instead of directly to the skin. The deeper musculature about the mouth is attached to the mucous membrane.

The muscles are composed of interdigitating muscle-fibers which are grouped in bundles that take a nearly parallel or slightly converging course and give rise to thin muscle-sheets. The extent of development of the various muscles of the group and their independence varies greatly in different individuals. The nerve supply is from the facial nerve.

The region from which the facial musculature originates in the embryo is, in the main at least, that of the hyoid arch immediately below the ear. From here the musculature spreads with the development of the facial nerve, dorsally to the occipital region behind the ear, caudalward over the neck, ventrally over the face, and upward toward the eye, forehead, and the side of the skull. The course of the development is indicated by the branches of the facial nerve. A somewhat similar phylogenetic development is indicated by conditions found in the inferior mammals and lower vertebrates According to Ruge and Gegenbaur, the facial musculature is to be looked upon as derived from two muscle-sheets, of which in man the deeper has disappeared in the region of the neck while it is differentiated into the deeper facial muscles in the region of the head. The deeper layer of transverse fibers in the neck, the *sphincter colli*, is found in several of the mammals. The complex development of the facial muscles in man is characteristic of the human species, and is associated with the use of these muscles as a means of expression of the emotions, a physiological function superadded to the primitive function of

opening and closing visceral orifices. (See Darwin: Expression of the Emotions in Man and Animals; also E. Huber, Evolution of Facial Musculature and Expression. The Johns Hopkins Press, 1931.

Fasciæ.—The skin of the head and neck is, in most regions, firmly fused with the **tela subcutanea.** This is composed of a dense fibrous tissue united by a looser areolar tissue to the underlying structures. But a slight amount of fat is embedded in the subcutaneous tissue of the scalp, forehead, and nose Considerable fat may be embedded in the region of the cheeks, the back of the neck, and the under surface of the chin (double chin). The constantly repeated action of various muscles of the facialis group usually results by middle life in the production of permanent wrinkles due to alterations in the structure of the tela subcutanea and the skin.

The subcutaneous muscles of the cranial vault and the neck are invested with fascial membranes. That covering the cranial musculature externally is firmly fused to the subcutaneous tissue of the scalp. That covering the subcutaneous muscle of the neck is less firmly fused with the subcutaneous tissue. In the facial region the more superficial muscles are so closely

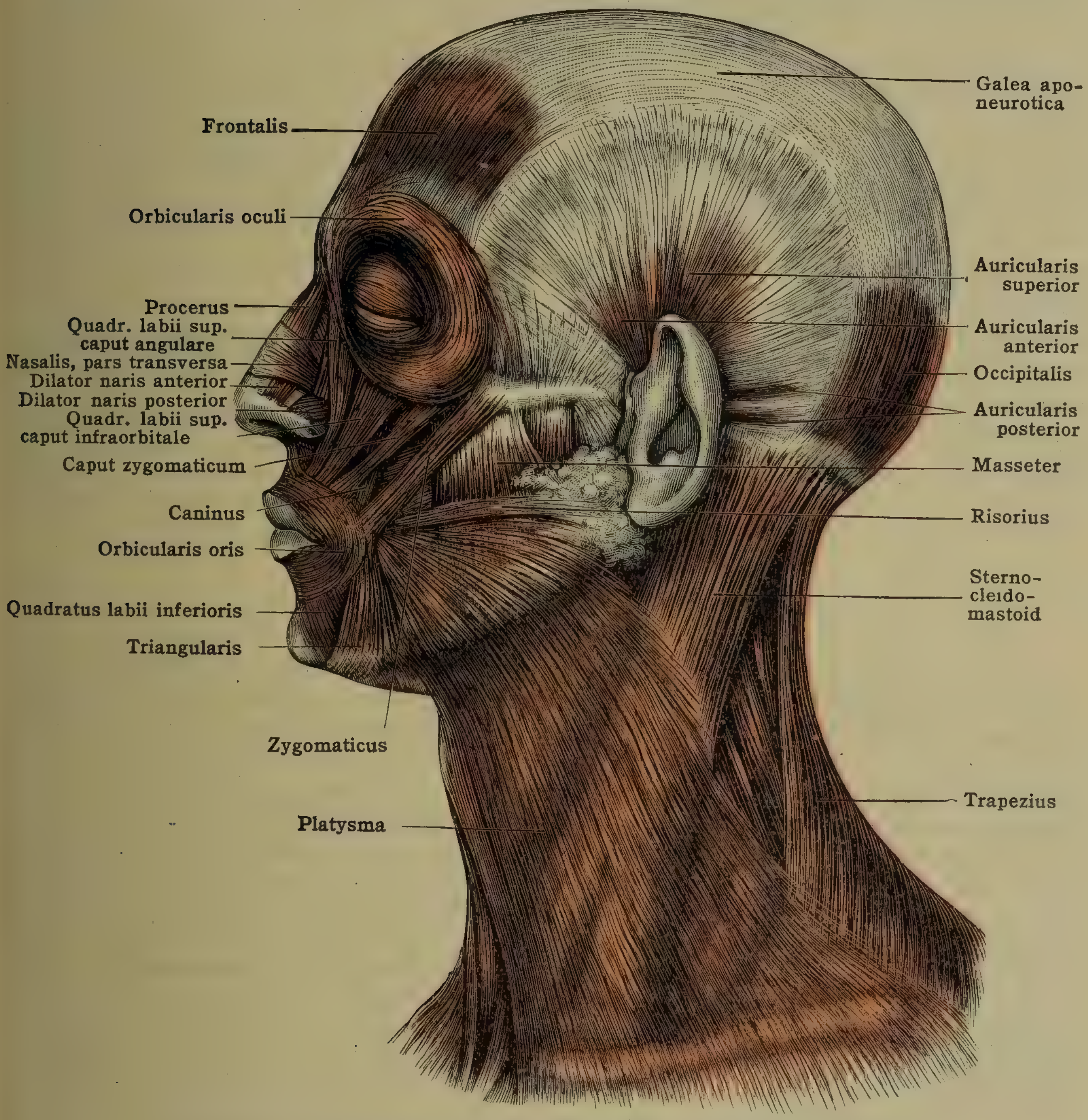


Fig. 403.—The Superficial Muscles of the Head and Neck.

embedded in the subcutaneous tissue that no distinct fasciæ intervening between the muscles and the skin can, as a rule, be distinguished. Of the deeper muscles of the facialis group, the buccinator alone possesses a distinct fascia. This muscle lies upon the mucous membrane of the lateral wall of the mouth, and is covered externally by a fascia continued into the fascia investing the superior constrictor of the pharynx.

Bursæ.—**Bursa subcutanea prementalis.** Between the periosteum at the tip of the chin and the overlying tissue. **Bursa subcutanea prominentiæ laryngeæ.** In front of the junction of the right and left laminæ of the thyroid cartilage.

MUSCLES

The muscles of the facialis group may be conveniently subdivided as follows:—

(*a*) **Cervical:** the platysma. (*b*) **Oral:** the orbicularis oris and the incisivus labii superioris and inferioris; the quadratus labii superioris and inferioris; the

caninus, zygomaticus, risorius, and triangularis; and the buccinator. (*c*) **Mental** (*d*) **Nasal**: the nasalis, depressor septi, and the dilatores naris. (*e*) **Periorbital**: the orbicularis oculi, corrugator, and procerus. (*f*) **Epicranial**: the frontalis and occipitalis, with the galea aponeurotica. (*g*) **Auricular**: anterior, superior, and posterior. With these the temporalis superficialis is also described.

(*a*) CERVICAL MUSCLE

The **platysma** is a large, thin, quadrangular muscle which extends obliquely from the chin, the corner of the mouth, and the lower part of the cheek across the mandible and the neck to the upper part of the thorax and shoulder. The muscles of each side interdigitate across the chin. A short distance below the chin, in the neck, the ventral margins diverge (fig. 403).

Origin.—From the tela subcutanea by somewhat scattered bundles—(1) along a line extending from the cartilage of the second rib to the acromion, and (2) along the dorsal margin of the muscle.

Insertion.—Into—(1) the mental protuberance of the mandible and the inferior margin of the mandible; and (2) into the skin of the lower part of the cheek and at the corner of the mouth, where it fuses more or less with the quadratus labii inferioris and the orbicularis oris.

Nerve-supply.—The cervical branch (ramus colli) of the seventh cranial nerve forms beneath the muscle a plexus to which the cutaneus colli nerve contributes sensory branches.

Relations.—The muscle is situated beneath the panniculus adiposus, to which in the neck it is not very firmly attached. For the most part it is separated from the external layer of the cervical fascia by loose areolar tissue. The main cutaneous rami of the cervical plexus and the external jugular vein lie beneath the muscle.

Action.—It wrinkles up the skin of the neck, depresses the corner of the mouth, and thus plays a part in expression of sadness, fright, and suffering. It aids the circulation by relieving pressure on the underlying veins.

Variations.—Either the facial or the thoracic development of the muscle may be more extensive than that described above. On the other hand, it may be less developed than usual, and rarely it is absent. Accessory slips have been seen going to the zygoma, the auricle, or the mastoid process, and to the clavicle and sternum. Rarely a deep transverse layer is found in man.

(*b*) ORAL MUSCLES

(Figs. 403–407)

The muscles of the mouth belonging to the facialis system include several *intralabial* muscles:—a sphincter, the **orbicularis oris**; a dorso-ventral, the **compressor labii**; and four deep submucous muscles which pass from the sides of the lips to the alveolar juga of the upper canine and lower lateral incisor teeth, the **incisivi labii superioris** and **inferioris.** From each corner of the mouth there radiate out several muscles; the **caninus** and **zygomaticus** upward to the maxilla and zygomatic bone; the **risorius** lateralward over the cheek; the **platysma** and the **triangularis** downward over the side of the jaw; and the **buccinator,** lateralward over the side of the oral cavity. From each of these, fiber-bundles are continued into the more peripheral and superficial portions of the orbicularis. In addition to these muscles there are two retractors or quadrate muscles, one of which, the **quadratus labii superioris,** extends to the bridge of the nose, the lower margin of the orbit, and the zygomatic bone from the upper lip medial to the angle; while the other, the **quadratus labii inferioris,** extends from a corresponding position in the lower lip to the side of the chin. The orbicularis oris, compressor labii, and incisive muscles close the lips; the other muscles open them and pull them in various directions. The buccinator, however, plays a part in the closing of the mouth by offering support for the orbicularis.

Intralabial Muscles

The **orbicularis oris** (figs. 403–405) is a complex muscle which surrounds the oral orifice and forms the chief intrinsic musculature of the lips. Immediately about the orifice and on the deep surface of the muscle, is a fairly well-defined sphincter, although at the corners of the mouth the fiber-bundles of one lip cross those of the other and are inserted into the mucosa, and to a less extent into the skin. In the midline the fiber-bundles end partly in the perimysium, partly in the skin. About this sphincter area and between its outer margin and the skin is a complex musculature comprised partly of fiber-bundles prolonged from the muscles which radiate from the corners of the mouth. The more superficial portion of the muscle in the upper lip is composed of fiber-bundles from the triangularis (depressor anguli oris), the more superficial portion of that in the lower lip by fiber-bundles from the caninus (levator anguli oris), These fiber-bundles form commissures at the angles of the mouth and extend toward the median line, where many of them interdigitate with those of the opposite side, and are attached to the

skin of the lips. The deeper portions are partly formed by fiber-bundles prolonged from the buccinator, the mandibular fiber-bundles of the latter muscle going mainly to the upper lip, the maxillary fiber-bundles mainly to the lower lip. These fiber-bundles are attached chiefly to the mucosa, near the corners of the mouth.

The **compressor labii**, or muscle of Klein, is composed of bundles of fibers which take a course transverse to those of the orbicularis, and pass obliquely from the skin surrounding the oral orifice toward the mucosa which bounds its inner margin. It is said to be best marked in infants.

The **incisivus labii superioris** (insertio maxillaris of orbicularis oris NK) is a small muscle-bundle which passes from the alveolar jugum of the upper canine tooth to the back of the orbicularis near the corner of the mouth.

The **incisivus labii inferioris** (insertio mandibularis NK) passes similarly from the alveolar jugum of the lower lateral incisor tooth to the back of the orbicularis in the lower lip.

Nerve-supply.—These muscles are supplied by the buccal branches of the facial nerve which enter the orbicularis on the lateral border.

Relations.—The main mass of intrinsic musculature of the lips is placed slightly nearer the mucosa than the skin. On its deep surface lie the labial arteries.

Action.—The orbicularis draws the upper lip downward, the lower lip upward. The incisive muscles draw the corners of the lips medialward, and the compressor flattens the lips. Together they serve to close the mouth. Acting separately they may draw different parts of it in the directions indicated by their structure. The circumferential portion of the orbicularis acting with the incisive muscles makes the lips protrude. The central portion of the orbicularis draws the lips together, and when the buccinator also acts, draws them against the teeth. It is this portion of the muscle that has chiefly to do with nutritive functions. The more peripheral parts of the muscle are chiefly utilised in the expression of the emotions.

Retractors of the Lips or Quadrate Muscle.

(Fig. 403)

The **quadratus labii superioris** is a thin, quadrangular muscle with three heads, all of which are inserted into the skin and musculature of the upper lip. It includes the following:

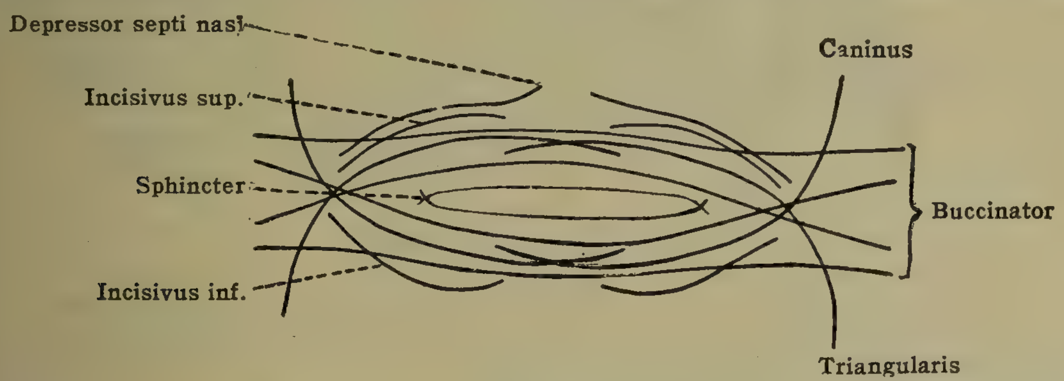


Fig. 404.—Diagram to Illustrate the Architecture of the Orbicularis Oris. (After T. D. Thane.)

(1) The **caput zygomaticum** (zygomaticus minor NK) is long and slender and arises from the lower part of the external surface of the zygomatic bone beneath the lower border of the palpebral portion of the orbicularis oculi. It passes obliquely forward over the caninus and orbicularis oris muscles, and extends to a cutaneous and muscular insertion in the upper lip medial to the corner of the mouth. It lies medial to the zygomaticus.

(2) The **caput infraorbitale** (m. levator nasi et labii lateralis NK) (levator labii superioris), a broad, flat muscle, arises from the infraorbital margin of the maxilla, where it is concealed by the orbicularis oculi. It extends obliquely forward over the caninus and beneath the caput angulare to the skin and musculature of the lateral half of the upper lip.

(3) The **caput angulare** (m. levator nasi et labii medialis NK) (levator labii superioris alæque nasi) arises from the root of the nose, where it is fused with the frontalis. As it descends it divides into two fasciculi, one of which is attached to the skin and the alar cartilage of the nose; the other passes obliquely downward over the caput infraorbitale to the skin and musculature of the lateral half of the upper lip.

Nerve-supply.—The zygomatic ramus of the facial nerve sends branches to enter the deep surface of each of the divisions of the muscle.

Actions.—It raises the lateral half of the upper lip and the wing of the nose. It is of value in inspiration, serves to express the emotion of discontent, and comes into play in violent weeping.

Variations.—The caput zygomaticum is often absent. It may be fused with the zygomaticus (major). It may be doubled. Its origin may extend to neighboring structures. The other heads, though more stable, vary considerably, especially in the extent of their fusion with neighboring muscles.

The **quadratus labii inferioris** (depressor labii inferioris) is a thin, rhomboid muscle which arises below the canine and bicuspid teeth from the base of the mandible, between the mental protuberance and the mental foramen, and extends obliquely upward in a medial direction to the orbicularis oris, through which its fiber-bundles pass. Its more medial fibers cross at their insertion with those of the muscle of the other side. It is attached to the skin and mucosa of the lower lip. It is essentially a part of the platysma, and is superficially united to the skin except where covered by the triangularis (depressor anguli oris). It crosses the mental vessels and nerves and a part of the mentalis (levator menti).

Nerve-supply.—The mandibular branch of the facial sends twigs into its deep surface near the lateral border.

Action.—It draws down and everts the lower lip. It is an antagonist of the mentalis (levator menti). It plays a part in the expression of terror, irony, great anger, and similar emotions.

Muscles of the Angle of the Mouth

(Figs. 403–407)

The **caninus** (levator anguli oris) is a flat, quadrilateral muscle which arises from the canine fossa of the maxilla and runs beneath the quadratus (levator) labii superioris to the corner of the mouth, where it becomes attached to the skin and sends some fasciculi into the orbicularis of the lower lip. Between the caninus and the quadratus labii superioris there is a certain amount of fatty areolar tissue through which the infraorbital vessels and nerves run. Its deep surface extends over the canine fossa, the buccinator muscle, and the mucosa of the lip. The external maxillary (facial) artery passes over its inferior extremity.

The **zygomaticus** (z. major) is a long, ribbon-shaped muscle which arises by short tendinous processes from the zygomatic bone near the temporal suture under cover of the orbicularis oculi. It passes obliquely to the corner of the mouth, where it is attached to the skin and mucosa. The body of the muscle is subcutaneous and is usually surrounded by fat. It crosses the masseter and buccinator muscles and the anterior facial vein.

The **risorius** is a thin, triangular, subcutaneous muscle which extends across the middle of the cheek and lies in a more superficial plane than the platysma, with which it is often fused. It arises from the tela subcutanea above the parotid fascia. Its fibers converge across the masseter muscle toward the angle of the mouth and are attached to the skin and mucosa in this vicinity. It lies above the anterior facial vein and external maxillary artery.

The **platysma** has been described above.

The **triangularis** (depressor anguli oris) is a broad, flat, well-developed, subcutaneous muscle which arises from the base and external surface of the body of the mandible below the canine, bicuspid and first molar teeth. From here its fibers converge toward the corner of the mouth, where they are in part inserted into the skin and in part are continued into the orbicularis or of the upper lip. It overlies the buccinator and the quadratus (depressor) labii inferioris muscles. Not infrequently (58 out of 92 bodies—LeDouble) some fasciculi are continued into the neck as the **transversus menti,** a fibromuscular band formed by the interdigitation of the slips prolonged from each side below the chin and superficial to the platysma. Santorini described the transversus menti as an independent though inconstant muscle. According to Eisler the true transversus menti muscle is to be distinguished from aberrant slips of the triangularis or of the platysma in this region. In one instance Eisler found a slender nerve emerging through the platysma and passing to this muscle.

Nerve-supply.—The zygomatic branch of the facial nerve supplies the canine (levator anguli oris) and zygomatic (major) muscles. Branches enter the middle of the deep surface of the latter muscle and the superficial surface of the former near its lateral border. The risorius is supplied by branches from the buccal rami of the facial nerve, which enter its deep surface. The triangularis (depressor anguli oris) is supplied by the buccal branch through branches which enter its deep surface near the posterior margin.

Action.—The caninus (levator anguli oris) and zygomatic (z. major) muscles raise the corner of the mouth, the former at the same time drawing it medially, the latter, laterally. The caninus gives rise to expression of bitterness or menace. The zygomaticus is active in smiling or laughing. When contracted greatly it elevates the cheek and the lower eyelid and produces crow's-foot wrinkles at the corner of the eye. The risorius draws the angle of the mouth laterally. In spite of its name it is not used to express pleasure, but instead gives rise to an expression of pain. The triangularis (depressor anguli oris) depresses the corner of the mouth and draws it laterally, giving rise to the expression of grief.

Variations.—The risorius is very inconstant in its development, and in its relations to neighboring muscles, and is not infrequently quite small. The zygomaticus is rarely absent. Its origin may extend to the temporal or masseteric fasciæ. It may be doubled throughout its length or at one extremity. Frequently the triangularis is divided into three fasciculi.

The **buccinator** (figs. 404, 405) arises from—(1) the molar portion of the alveolar process of the maxilla; (2) the buccinator crest of the mandible, and (3) the pterygomandibular raphe of the buccopharyngeal fascia. This narrow fibrous band, which separates the buccinator from the superior constrictor of the pharynx, extends from the pterygoid hamulus to the buccinator crest of the mandible. The fiber-bundles of the muscle are divisible into four sets. The most cranial extend directly into the orbicularis of the upper lip. The next pass through the commissure at the corner of the lips into the orbicularis of the lower lip; the third through the commissure into the orbicularis of the upper lip, and the fourth directly into the orbicularis of the lower lip. The muscle is attached chiefly to the mucosa of the lips near the angle of the mouth. Some fiber-bundles extend to the more medial portion of the mucosa and some through the orbicularis to the skin.

Nerve-supply.—By the buccal branch of the facial nerve through filaments which enter the posterior half of its outer surface.

Relations.—The muscle is covered externally by the thin buccopharyngeal fascia; internally by the mucosa of the mouth. Above its outer surface lie the zygomatic (z. major), risorius, and masseter muscles. Between the last and the buccinator lies a large pad of fat (the buccal fat pad). The parotid duct passes forward over the muscle, and slightly in front of its center pierces it and passes into the mouth. It is crossed by the external maxillary (facial) artery and anterior facial vein and by the buccal artery and nerve.

Actions.—It draws the corner of the mouth laterally pulls the lips against the teeth, and flattens the cheek. It is of use in mastication, swallowing, whistling, and blowing wind-instruments.

Variations.—Occasionally it consists of two laminæ, a condition found in many mammals. It may be continuous in part with the superior constrictor of the pharynx, as in the cat.

(*c*) MENTAL MUSCLE

The **mentalis** (levator menti) (fig. 405) is a short, thick muscle which arises from the alveolar jugum of the lower lateral incisor tooth and the neighboring region of the mandible under cover of the quadratus (depressor) labii inferioris and beneath the oral mucosa, where this is reflected from the lips to the gums. It extends to the chin, where it is fused with the muscle of the opposite side and is inserted into the skin of the chin.

Nerve-supply.—The mandibular branch of the facial nerve sends terminal twigs into this muscle.

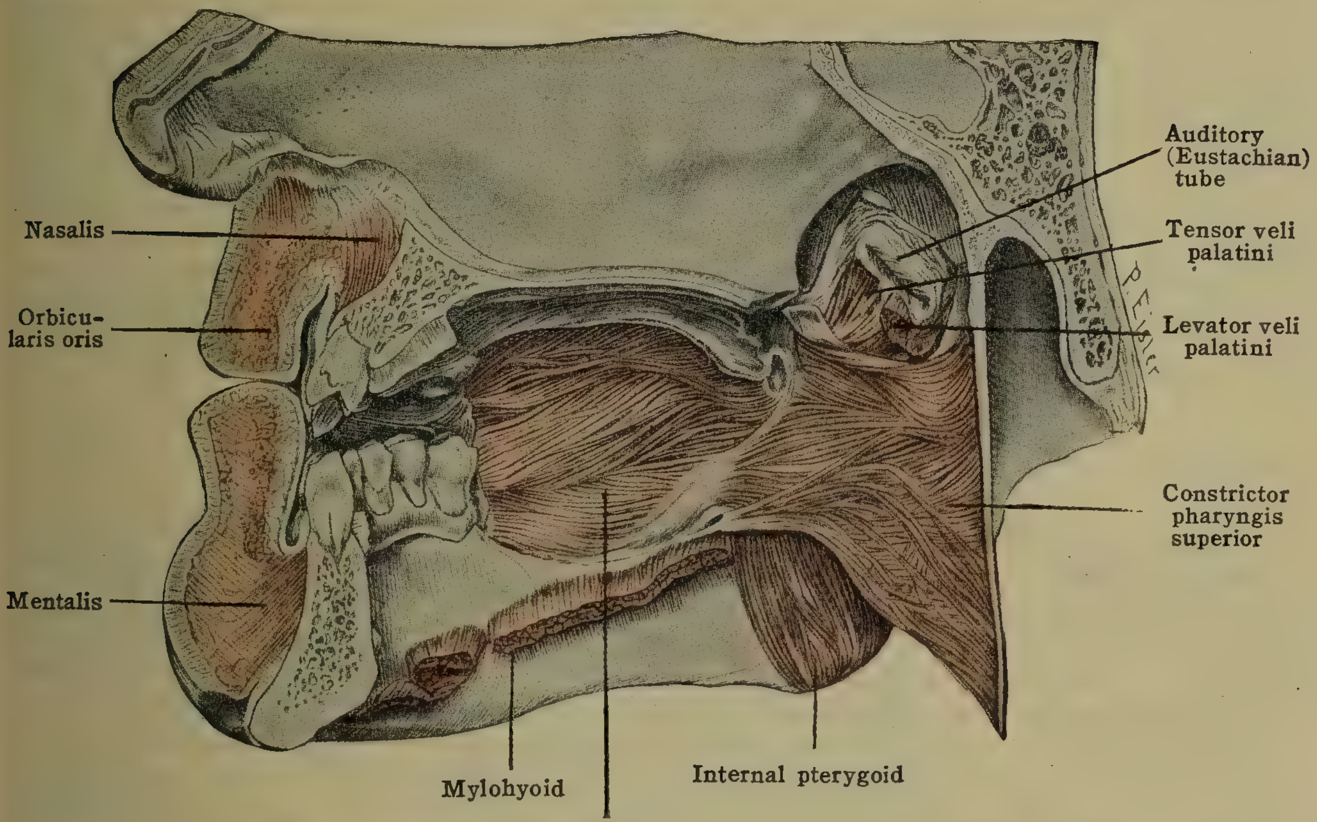


Fig. 405.—Buccinator Muscle and Pterygomandibular Raphé, as seen from the Buccal Side. (After Eisler.)

The alveolar processes of both jaws have been removed in the region of the molar teeth. The soft palate and its muscles have been removed.

Actions.—It draws up the skin of the chin and thus indirectly causes the lower lip to protrude. It is of use in articulation, in forcing bits of food from between the gums, and in the expression of various emotions (muscle of pride).

Variations.—It varies greatly in size and generally is fused with the platysma.

(*d*) NASAL MUSCLES

(Figs. 403 and 406)

Toward the nasal apertures several muscles converge. Those extending from above elevate and dilate, those from below depress and contract, the nostrils. To the former belongs the **pars transversa** of the **nasalis** (compressor naris), a triangular muscle extending from the bridge of the nose to the nasolabial sulcus; the **caput angulare** of the **quadratus labii superioris** (levator labii superioris alæque nasi), which arises from the root of the nose and sends a fasciculus to the wing of the nose; and the **dilatores naris,** described below; to the latter, the **pars alaris** of the **nasalis** (depressor alæ nasi), which extends from the alveolar juga of the upper lateral incisor and canine teeth to the dorsal margin of the nostril; and the small **depressor septi nasi.**

The **nasalis** consists of two parts, the pars transversa and the pars alaris. The pars transversa (compressor naris) is triangular. It lies on the side of the nose above the wing. Its fiber-bundles arise from an aponeurosis which overlies the bridge of the nose, is adherent to the skin, and is not closely attached to the underlying cartilage. From this aponeurosis the fiber-bundles converge toward the back of the wing where they are attached to the skin along the line which separates the wing from the cheek (nasolabial sulcus). Its insertion is covered by the nasal process of the caput angulare (levator labii superioris alæque nasi) of the quadratus labii superioris (p. 399), with which its fibers interdigitate. An attachment (origin) is also described by many as taking place in the lower part of the canine fossa of the maxilla.

The **pars alaris** (depressor alæ nasi) (figs. 405, 406), is a small quadrangular muscle situated below the aperture of the nose between this and the alveolar portion of the maxilla. It is cov-

ered by the mucosa of the gum, by the orbicularis oris and the quadratus (levator) labii superioris, and laterally is fused with the pars transversa (compressor naris) It arises from the alveolar juga of the lateral incisor and the canine teeth. Its fiber-bundles extend vertically to the skin of the dorsal margin of the nostril, from the dorsal part of the cartilage of the wing to the septum.

The dilator naris posterior is a thin, triangular muscle which lies on the side of the wing of the nose. It arises from the skin of the nasolabial groove and is attached to the inferior border of the wing of the nose.

The dilator naris anterior is a very small, thin muscle which runs from the lower margin of the cartilage at the front of the wing of the nose to the skin. It is not usually clearly marked.

Nerve-supply.—The muscles of this group are supplied by the infraorbital and buccal branches of the facial nerve.

Actions.—The transverse portion of the nasalis (compressor naris) acts with the angular head (levator labii superioris alæque nasi) of the quadratus labii superioris in drawing the lateral margin of the wings of the nose laterally and upward, and gives rise to the expression of sensuality. (Poirier.) This accords with the electrical experiments of Duchenne. However, acting in conjunction with the alar portion, the transverse portion of the nasalis may constrict the nostrils. The alar portion (depressor alæ nasi) of the nasalis and the depressor septi nasi draw down the nostril. The former tends to contract it from side to side, the latter from front to back and at the same time to depress the tip of the nose. They play a part in the expression of anger and of pain. The functions of the other muscles are indicated by their names.

Variations.—The muscles of the nose vary considerably in extent of development, and one or more may be absent. Authors differ considerably in their description of several of the muscles. The **anomalus** is a longitudinal muscle strip occasionally found running from the frontal process to the body of the maxilla near the lateral margin of the nasal aperture.

(*e*) PERIORBITAL MUSCLES

(Figs. 403 and 406)

The muscles which encircle the orbit constrict the entrance of the orbit so as to shut out light and protect the eye against foreign bodies. To these belong the orbicularis oculi, the corrugator, and the procerus. The **orbicularis oculi** is a large, flat, elliptical mucle which lies in the eyelids and over the bone surrounding the orbit. **Three parts** are recognized: a **palpebral**, an **orbital** and a **lacrimal**. The quadrangular **corrugator** extends from the nasal portion of the frontal bone to the skin of the middle half of the eyebrow; the narrow **procerus** (pyramidalis nasi) from the bridge of the nose to the skin at the root. The muscles which have an antagonistic action are the levator palpebræ superioris and the epicranius. The levator palpebræ is described in the chapter on the Eye (see Section IX), the epicranius in the following subsection.

The **orbicularis oculi.**—The **palpebral portion** arises from the anterior surface and margins of the lateral portion of the medial palpebral ligament (tendo oculi), and from the covering of the lacrimal sac. The fiber-bundles spread out as they pass into the eyelids and again are concentrated toward their insertion into the outer surface of the lateral palpebral ligament. Many of the fiber-bundles interdigitate here without being inserted into the ligament. The muscle in each eyelid lies between the tarsal plate and the skin, separated from both by loose tissue. The superficial muscle-fibers nearest the margin of the lids constitute the ciliary muscle, or muscle of Riolan. They are very small fibers and probably act on the eyelashes and Meibomian lands.

The **orbital portion** arises by a superior origin from the medial palpebral ligament (tendo oculi), the nasal portion of the frontal bone, and the anterior lacrimal crest of the maxilla and by an inferior origin from the medial palpebral ligament and the medial portion of the inferior rim of the orbit. The fiber-bundles form a flat ring which surrounds the orbit for a considerable distance, especially inferiorly. The muscle is adherent to the overlying skin. It lies over the bones surrounding the margin of the orbit and over the attachments of several of the facial muscles attached to these bones. With these muscles some of the fiber-bundles are usually continuous.

The **lacrimal portion** (tensor tarsi or Horner's muscle) arises from the posterior lacrimal crest of the lacrimal bone and passes down on the dorsal surface of the lacrimal sac and the medial palpebral ligament (tendo oculi). It bifurcates and furnishes a fasc culus attached to each tarsal plate. Some of the fiber-bundles surround the lacrimal canaliculi and some surround the ducts of the tarsal glands and the roots of the eyelashes.

The **corrugator** arises from the frontal bone near the frontonasal suture. It extends obliquely upward and lateralward to be inserted into the skin of the medial half of the eyebrow. The fiber-bundles of insertion interdigitate with those of the frontalis. The muscle lies relatively deep. It is covered by the procerus (pyramidalis nasi), the frontalis and the orbicularis. Under it lie the supraorbital vessels and nerves.

The **procerus** (pyramidalis nasi) overlies the nasal bone. It arises from the lateral cartilage of the nose through a fibrous membrane and also directly from the nasal bone, and is attached to the skin over the root of the nose, where its fibers interdigitate with those of the frontalis.

Nerve-supply.—The muscles of this group are supplied by temporal and infraorbital branches of the facial nerve which enter the deep surfaces near the lateral margins.

Action.—The palpebral portion of the orbicularis closes the eyelids, of which the upper moves more freely than the lower. It also serves to dilate the lacrimal sac and allow the tears to flow away readily. The tensor tarsi probably contracts the sac and forces the tears

into the nose. The upper half of the orbital portion of the orbicularis contracts and depresses the tissue overhanging the orbit, and stretches the skin of the forehead. The corrugator draws the skin of the brow downward and medially, thus aiding the preceding muscle. It causes the perpendicular furrows characteristic of frowning. The procerus (pyramidalis nasi) draws down the skin of the forehead and wrinkles the skin across the root of the nose. The lower half of the orbital portion of the orbicularis raises the skin of the cheek, causing the wrinkles seen to radiate from the corner of the eye. The whole set of muscles comes into play in the forcible closure of the eyes. In case of violent expiratory efforts, as in shouting, sneezing, coughing, etc., the eye is thus usually forcibly closed. The pressure thus exerted on the eyeball prevents a too violent flow of blood to the vessels of the eye. Pressure is thought at the same time to

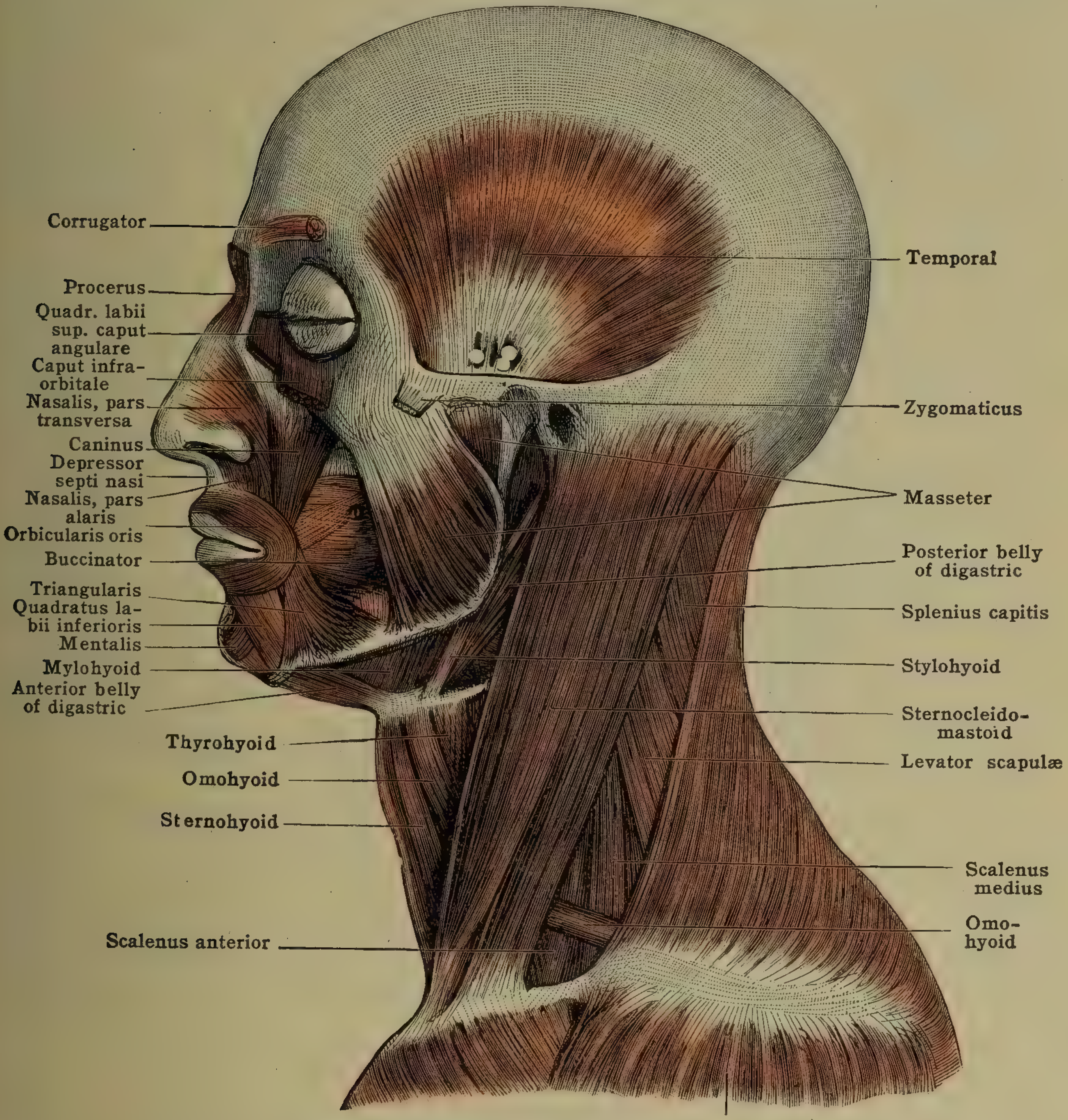


Fig. 406.—The Deeper Muscles of the Face and Neck.

be exerted on the lacrimal gland so as to cause the excessive flow of tears often experienced at such times.

Variations.—The muscles of this group vary in extent and differentiation and may be more or less fused with one another or with neighboring muscles. The orbital portion of the orbicularis, the corrugator, and the procerus have been found absent.

(*f*) THE EPICRANIAL MUSCULATURE

(Fig. 403)

The **epicranius** (occipitofrontalis) is formed of the two **frontal** muscles, which lie on each side of the forehead, the two **occipital** muscles, which occupy corresponding positions on the occipital bone, and of the epicranial aponeurosis, the **galea aponeurotica,** which extends between these. The occipital muscles arise from the supreme nuchal line and are inserted into the galea aponeurotica. The frontal muscles arise from the latter and are inserted into the skin near the eyebrows. The chief function of these muscles is to elevate the brows. The muscles and the intervening aponeurosis lie between two layers of fascia, the ex-

ternal of which is fused to the skin, while the internal moves freely over the periosteum, to which it is loosely attached. Hemorrhages and abscesses spread freely between the deep layer of fascia and the periosteum.

The **frontalis** is a large, thin muscle with convex upper and concave lower border. It arises from the epicranial aponeurosis midway between the coronal suture and the orbital arch, and is inserted into the skin of the eyebrow and of the root of the nose. The medial fiber-bundles take a sagittal direction; the lateral converge obliquely toward the brow. The medial margins of the muscles of each side are approximated near the attachment. The more medial fiber-bundles are continuous with those of the procerus (pyramidalis nasi) and the angular portion (levator labii superioris alæque nasi) of the quadratus labii superioris; the more lateral interlace with those of the corrugator and orbicularis muscles. The branches of the vessels and nerves of the frontal region pierce the muscle and are distributed between it and the skin.

The **occipitalis**, flat and quadrangular, lies on the occipital bone above the supreme nucha line. It rises by tendinous fibers from the lateral two- thirds of this line and from the posterior part of the mastoid process of the temporal bone, and is inserted into the epicranial aponeurosis. The medial fiber-bundles run sagittally, while the lateral run obliquely forward. The occipital artery and nerve lie between the muscle and the skin. The lateral border of the muscle comes in contact with the posterior auricular muscle. The muscles of each side are usually separated by a strip of aponeurosis.

The **galea aponeurotica** (epicranial aponeurosis) is a fibrous membrane which extends between the occipital muscles and from them anteriorly to the frontal muscles. In the area between these two sets of muscles it is composed largely of sagittally running fibers into which coronal fibers radiate from the region of the muscles of the ear. Between the two occipital muscles the aponeurosis is attached to the supreme nuchal line and external occipital protuberance. Laterally the fascia covering it is continued as a special investment of the auricular muscles, beyond which it is attached to the mastoid process, the zygoma, and to the external cervical and the nasseteric fasciæ.

Nerve-supply.—The frontalis is supplied by the temporal branches of the facial nerve, the occipitalis by the posterior auricular branch. The branches enter the deep surface of each of these muscles near its lateral border.

Action.—The occipitalis serves to draw back and to fix and make tense the epicranial aponeurosis. The frontalis, with its aponeurotic extremity fixed, elevates the brows and throws the skin of the forehead inso transverse wrinkles as in the expression of attention, surprise, or horror. When both muscles contract forcibly there is, in addition, a tendency to make the hair stand on end because the hair-bulbs of the occipital region slant forward, those of the frontal region backward. The frontalis when fixed below pulls the scalp forward.

Variations.—The occipitalis is occasionally absent, a condition normal in ruminants. The muscles of the two sides may be fused in the median line (normal in dogs). It may be fused with the posterior auricular. The frontalis is rarely missing. The frontalis may send slips to the medial or lateral angles or the orbital arch of the frontal bone, to the nasal process of the maxilla or to the nasal bone. The fiber-bundles of the frontalis may interdigitate across the median line.

The **transversus nuchæ**, or occipitalis minor, is a small muscle, frequently present (27 per cent., Le Double), which runs from the occipital protuberance toward the posterior auricular muscle, with which it may be fused. It may lie over or under the trapezius.

Scalp.—The skin and the underlying tissues over the bony cranium are collectively referred to as the scalp. Over the major portion of the cranium the scalp is composed of five layers: (1) The thick skin with its many hair follicles; (2) a dense layer of fibrous subcutaneous tissue; (3) the epicranius musculature and galea aponeurotica above described; (4) the subaponeurotic layer of loose connective tissues; and (5) the pericranium (external periosteum). Over the temporal regions the temporalis muscle and its fascia form two additional layers. For clinical considerations, see p. 68 and fig. 78.

(*g*) AURICULAR MUSCLES

(Fig. 403)

The intrinsic muscles of the auricle are described in Section IX. There are three 'extrinsic' auricular muscles which converge from regions anterior, superior, and posterior to the auricle and are inserted into it.

The **auricularis anterior** (attrahens aurem) is a small, flat, triangular muscle which arises between the two layers of the fascia of the galea aponeurotica, extends over the zygomatic arch, and is inserted into the front part of the helix. The fiber-bundles converge from the origin toward a tendon of insertion. The area of origin of this muscle is often marked by a fibrous band tangential to its component fibers. From this band muscle fiber-bundles radiate out toward the frontal region of the skull. To the muscle formed of these radiating fibers the names epicraniotemporalis (Henle), temporalis superficialis (Sappey) and auriculofrontalis (Gegenbaur) have been given.

The **auricularis superior** (attollens aurem) is a large, thin, triangular muscle which, from its tendinous insertion on the eminence of the triangular fossa of the ear, radiates upward into the fascia of the galea aponeurotica, between the layers of which it takes origin near the temporal ridge. It lies over the temporal fascia and the periosteum of the parietal bone.

The **auricularis posterior** (retrahens aurem) is a thin, band-like muscle which extends over the insertion of the sternocleidomastoid from the base of the mastoid process and the aponeurosis of the sternocleidomastoid muscle to the convexity of the concha, where it has a ten-

dinous insertion. It is usually composed of two fasciculi, and is contained between two layers of fascia derived from the galea aponeurotica.

Nerve-supply.—The auricularis anterior and superior are supplied by the temporal branch of the facial, the auricularis superior and posterior by the posterior auricular branch. The twigs of supply run to the deep surface of the muscles.

Relations.—The superficial ascending branch of the auriculotemporal nerve usually runs superficial to the anterior and superior auricular muscles. The superficial temporal vessels run at first beneath these muscles and the lateral expansion of the galea aponeurotica, then between the two fascial layers which enclose the muscles. Their branches of distribution finally come to lie between the muscles and aponeurosis and the skin. The posterior auricular artery and nerve usually run under cover of the auricularis posterior.

Action.—The anterior muscle is a protractor, the superior an elevator, and the posterior a retractor of the ear, but usually in man they are inactive.

Variations.—These muscles vary much in development. The most constant of them is the superior. The posterior frequently is increased in size and may be fused with the occipitalis, which originally was probably an ear muscle From the anterior muscle a special deep fasciculus is occasionally isolated. Each of the muscles is occasionally, though rarely, absent, the anterior most frequently. An inferior auricular muscle is very rarely found in man, though present in many of the lower mammals. A slip of the posterior auricular may run beneath the ear to the parotid fascia.

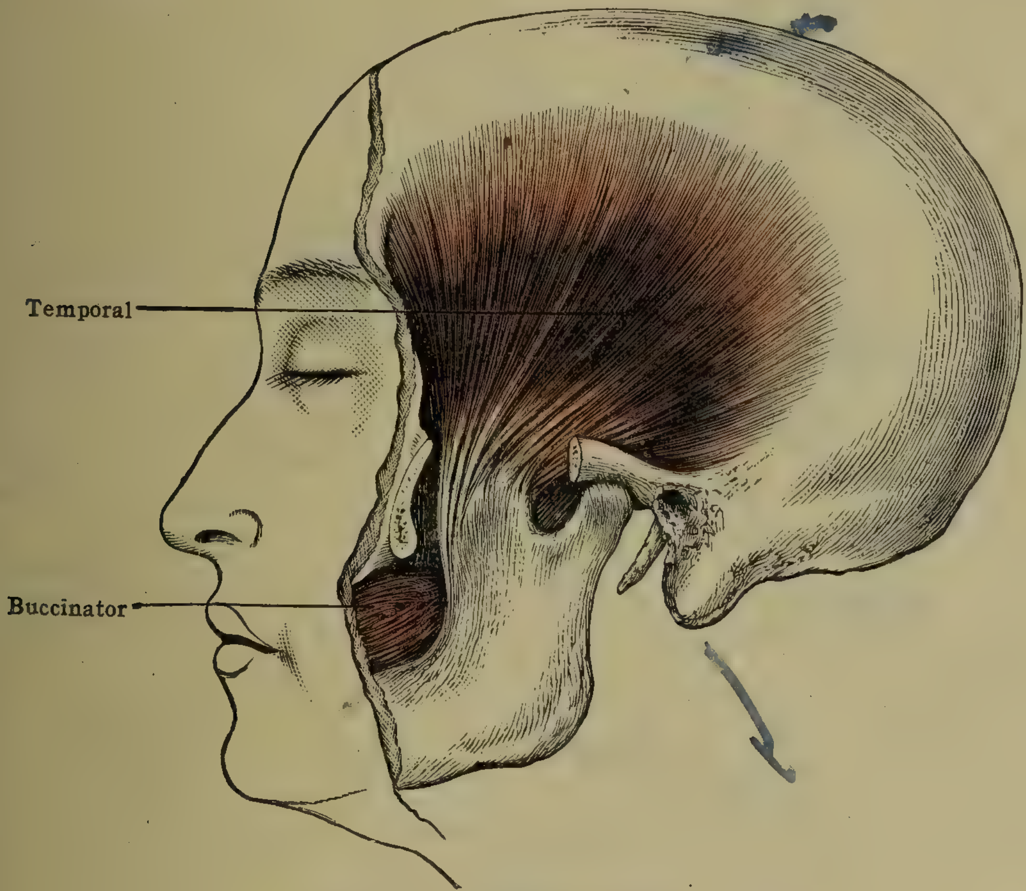


FIG. 407.—THE TEMPORAL MUSCLE.

2. CRANIOMANDIBULAR MUSCULATURE

(Figs. 406–409C)

The craniomandibular muscles, or muscles of mastication, pass from the base of the skull to the lower jaw. They are represented in the selachians by a single muscle mass, the adductor mandibulæ (Gegenbaur), but in the higher vertebrates this muscle mass becomes variously subdivided during embryonic development. The muscles are innervated by the masticator nerve (motor root of the trigeminal cranial nerve, the nerve of the mandibular arch). In man four muscles are recognized, the temporal, masseter, and internal and external pterygoids.

The **temporal** and **masseter** muscles are situated on the lateral surface of the skull, partly under cover of muscles of the facialis group. The **temporal** muscle (fig. 407), which resembles the quadrant of a circle, arises from the temporal fossa and is inserted into the coronoid process of the mandible; the thick, quadrilateral **masseter** (fig. 406) muscle arises from the zygomatic arch and is inserted into the lateral surface of the ramus and angle of the mandible. The **pterygoids** (fig. 408) are more deeply seated. The cone-shaped **external pterygoid** arises from the lateral side of the pterygoid process and lower surface of the great wing of the sphenoid and is inserted into the condyloid process of the mandible and the capsule of the joint. The thick, quadrilateral **internal pterygoid** parallels

the masseter. It arises from the pterygoid fossa of the sphenoid and is inserted into the inner side of the angle of the mandible. It will be noted that the temporal, masseter, and internal pterygoid muscles have an approximately vertical pull and adduct the lower jaw, while the external pterygoid has an approximately horizontal pull and draws the jaw forward and, when acting on one side, toward the opposite side.

The first three muscles act in the main on the joint between the condyle and the disk, about an axis passing transversely through the condyle. The external pterygoid, on the other hand, acts chiefly on the joint between the disk and the temporal bone. When both of the latter muscles act, the axis of movement passes transversely from the base of the articular tubercle on one side to that of the other. When only one muscle contracts, the approximate axis is vertical, through the condyle of the opposite side of the mandible (fig. 491).

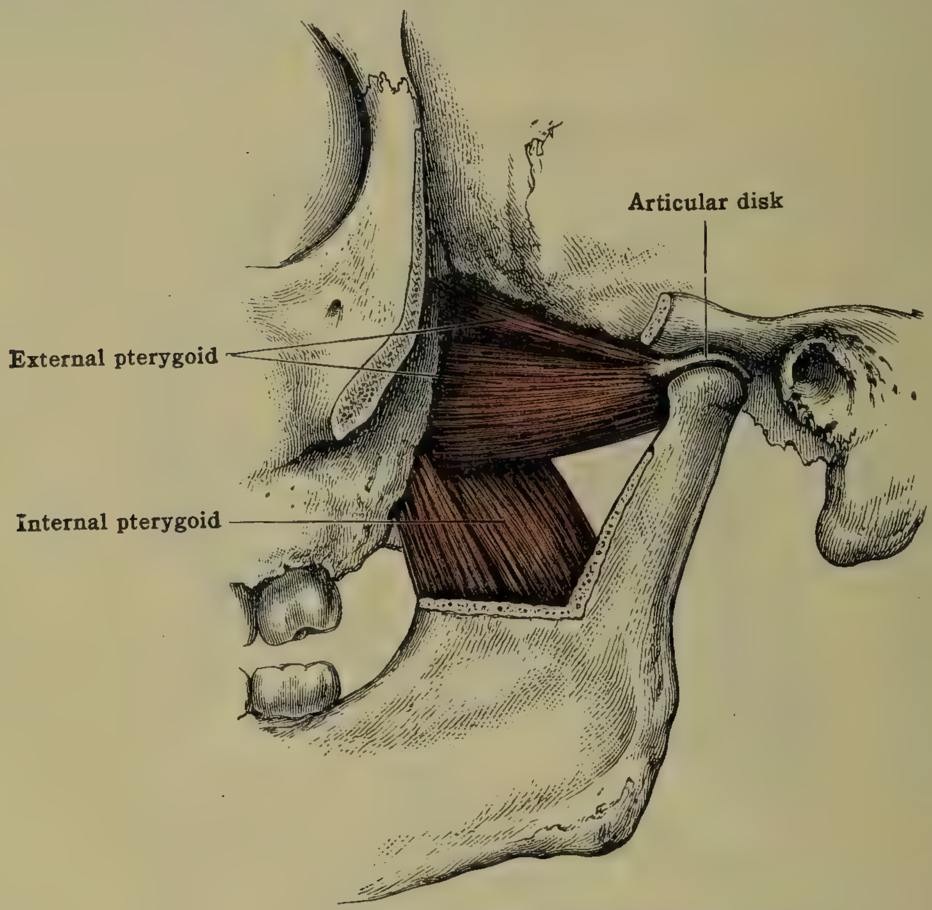


Fig. 408.—The Pterygoid Muscles.

FASCIÆ

The **temporal fascia** arises from the temporal line of the frontal bone and from the superior temporal line of the parietal and the periosteum immediately below this. It extends to the zygomatic arch. In its inferior quarter the fascia divides into two lamellæ, one of which passes to the outer, the other to the inner, surface of the arch, but at the superior margin of the arch these two lamellæ are united by dense fibrous tissue. Between the two lamellæ above the arch lies a fatty areolar tissue in which the middle temporal artery often runs. The outer surface of the fascia is covered by the superficial temporal and anterior and superior auricular muscles, and by a thin layer of fascia from the galea aponeurotica, with which, toward the zygomatic arch, it becomes merged The superficial temporal artery and auriculotemporal nerve cross it.

The **masseteric fascia** represents essentially a continuation of the temporal fascia from the inferior margin of the zygomatic arch over the masseter muscle which it covers. It is less thick than the temporal fascia, but is firm and strong. It is attached posteriorly to the posterior margin of the mandible, inferiorly to the inferior margin, and anteriorly to the body and to the anterior margin of the ramus and the coronoid process of the mandible. In part it extends over the fat pad of the cheek to the buccinator fascia. The parotid gland, covered by the parotid extension of the external cervical fascia, extends over the posterior portion of this fascia. The **parotid fascia** becomes fused to its external surface at the anterior margin of the gland. Over it lie the parotid duct, the transverse facial artery, branches of the facial nerve, the zygomaticus (major), risorius, and platysma muscles.

The pterygoid muscles are each surrounded by a delicate membrane. In addition an interpterygoid fascia separates the two muscles. This arises from the sphenoidal spine and follows the internal surface of the external pterygoid to the mandible. Medially it is attached to the lateral lamella of the pterygoid process; posteriorly and laterally it presents a free margin which forms with the neck of the mandibular condyle, an orifice for the passage of the internal maxillary artery, the auriculotemporal nerve, and several veins. Its posterior margin is

strengthened into the sphenomandibular ligament, which runs from the spine of the sphenoid to the lingula of the mandible.

The pharyngeal region is separated from the pterygoid by a dense membrane, the **lateral pharyngeal fascia.** This extends from the depth of the pterygoid fossa to the prevertebral fascia, and separates the tensor veli palatini from the internal pterygoid muscle. It is attached above along a line extending from the external margin of the carotid canal to the internal margin of the oval foramen.

The **sigmoidal septum** is a thin membrane which occupies the incisura mandibulæ and separates the masseter from the external pterygoid muscle.

MUSCLES

The temporalis (figs. 407 and 409C).—**Origin.**—(1) From the whole of the temporal fossa with the exception of that part formed by the body and temporal process of the zygomatic (malar) bone; and (2) from the fascia covering the fossa. **Insertion** is into the tip posterior and anterior borders, and the whole internal surface of the coronoid process of the mandible and the anterior portion of the medial surface of the ramus.

In *structure*, the muscle is thin near its superior margin, but becomes thick as its insertion is approached. The fiber-bundles arising from the medial surface of the fossa and from the fascia converge upon the medial and lateral surfaces and the margins of a thick, broad tendon which begins very high in the muscle, becomes visible laterally some distance above the zygomatic arch, and is inserted into the tip, edges, and internal surface of the coronoid process. On the anterior and posterior margins of the tendon the insertion of fiber-bundles continues to the coronoid process, while medially the insertion of the fiber-bundles is continued on the medial surface of the coronoid process and often on the ramus as far as the body of the bone.

Nerve-supply.—Usually three branches from the anterior branch of the mandibular division of the trigeminal nerve curve upward over the temporal surface of the great wing of the sphenoid and enter the deep surface of the muscle. The posterior and middle nerves pass above the external ptergyoid; the anterior, which springs from the buccinator nerve, passes between the two heads of the external pterygoid before curving upward.

Relations.—The muscle is covered by the temporal fascia and the zygomatic arch. Below the temporal fossa the pterygoid muscles and the buccinator lie medial to it. The temporal fossa in front of the muscle is filled with a fatty areolar tissue and this also extends between the muscle and the temporal fascia. Fatty tissue likewise lies between the muscle and the buccinator. Medial to the muscle run the deep temporal vessels and nerves, the buccinator nerve and the sphenomandibular ligament. The masseteric nerve passes lateralward behind and below the tendon.

The masseter (figs. 406 and 409C) is composed of two layers. The **superficial layer** arises by an aponeurosis from the anterior two-thirds of the lower border of the zygomatic (malar) bone. The fiber-bundles arise from the deep surface of this aponeurosis and its tendinous prolongations pass obliquely downward and backward, and are inserted into the lower half of the external surface of the ramus, into the angle, and into the neighboring portion of the body of the mandible—the more anterior directly, the posterior by means of an aponeurosis. The **deep-layer** arises from the lower border and internal surface of the zygomatic arch. The fiber-bundles pass nearly vertically downward, and are inserted upon the upper half of the external surface of the ramus. The origin and insertion are by tendinous bands, to which the fiber-bundles are attached in a multipenniform manner. The two layers are fused near the origin and insertion and in front. From the temporal surface of the zygomatic bone and the neighboring part of the deep layer of the temporal fascia there arises a fasciculus which is separated by a pad of fat from the main body of the temporal muscle, and is inserted into the lateral surface of the lower extremity of the tendon of the temporal muscle and into the anterolateral surface of the tip of the coronoid process. This fasciculus, sometimes described as a part of the temporal muscle, is innervated by the masseteric nerve.

Nerve-supply.—The branch arises in common with the posterior nerve to the temporal muscle from the motor root of the trigeminal (the masticator nerve). It passes above the external pterygoid through the mandibular (sigmoid) notch, and enters the deep surface of the muscle near the dorsal margin.

Relations.—It is covered by the masseteric fascia (see above). It lies upon the ramus of the jaw and ventrally is separated by a pad of fat from the buccinator muscle. At the mandibular (sigmoid) notch the sigmoid septum separates it from the external pterygoid muscle. The parotid gland partly overlaps its posterior border.

The pterygoideus externus (lateralis NK) (figs. 408 and 409C) consists of two fasciculi. Each is thick and triangular. The superior is flattened in a horizontal, the inferior in a vertical, plane. At their origin they are separated by a narrow cleft. Near the insertion they become more or less fused. The **superior fasciculus** arises by short tendinous processes from the infratemporal (pterygoid) crest and from the neighboring portion of the under surface of the great wing of the sphenoid. Its fiber-bundles converge toward the insertion, which takes place by short tendinous processes into—(1) the capsular ligament in front of the articular disk and (2) the upper third of the front of the neck of the condyle. The **inferior fasciculus** is the larger. It arises by short tendinous processes from the lateral surface of the lateral lamina of the pterygoid process, from the pyramidal process of the palate bone, and from the adjacent portions of the maxillary tuberosity. The fiber-bundles converge toward their insertion into a depression on the front of the neck of the condyle.

Nerve-supply.—A branch from the masticator nerve (motor root of the trigeminus) approaches the muscle near the upper border of the medial surface of the superior fasciculus and gives branches to both portions.

Relations.—It is partly covered by the maxillary fasciculus of the internal pterygoid and by the temporal and masseter muscles. Medial to it lies the chief fasciculus of the internal pterygoid muscle. The masseteric and the posterior and middle temporal nerves usually pass above

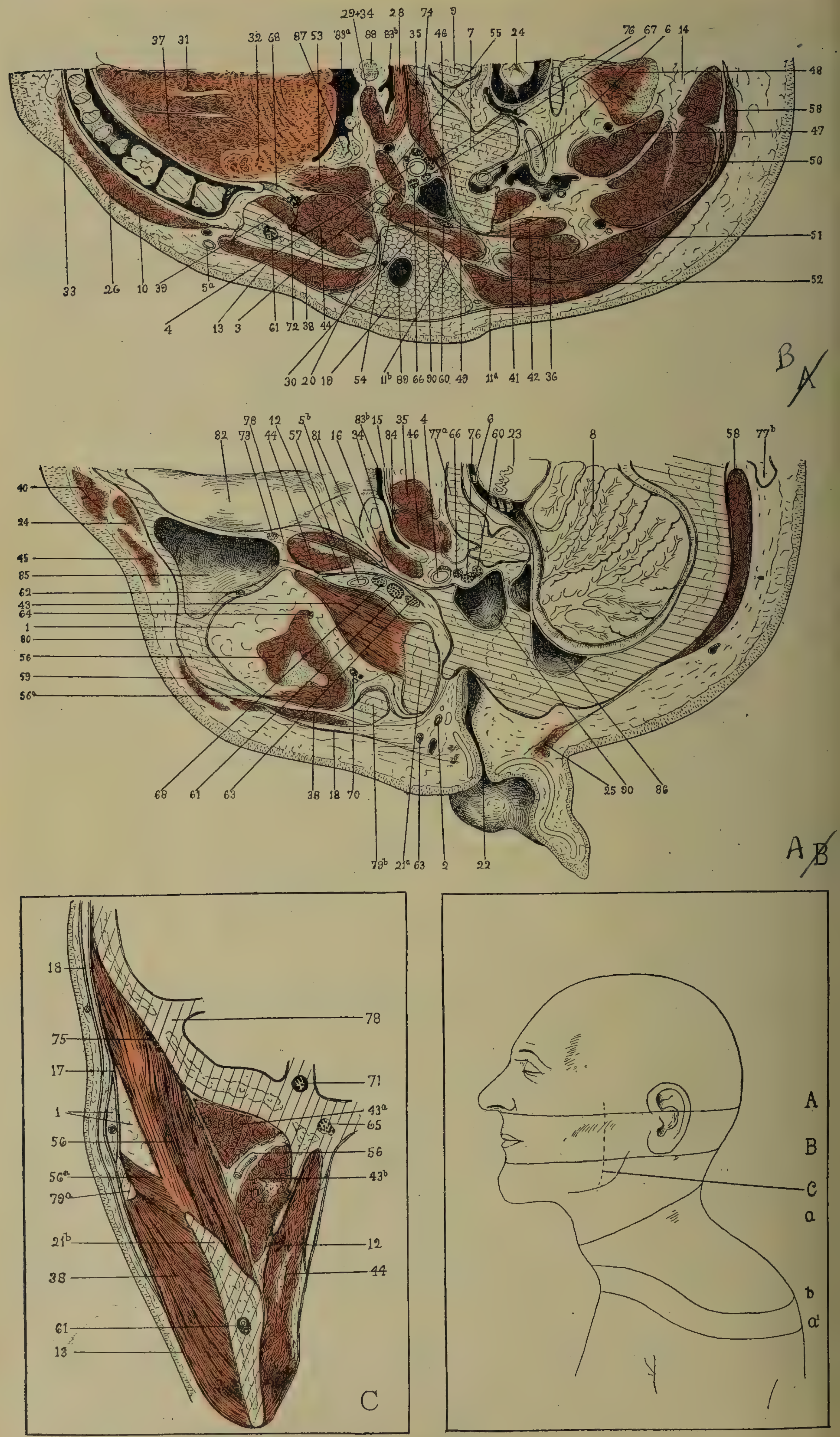


FIG. 409.

the muscle, the anterior temporal and the buccinator nerves and frequently the internal maxillary artery between the two fasciculi. The internal maxillary vessels usually pass below the lower border of the muscle and across its external surface; and the auriculotemporal, lingual, and inferior alveolar (dental) nerves cross the deep surface of the muscle.

The **pterygoideus internus** (medialis NK).—*Origin.*—From (1) the pterygoid fossa, and (2) from the maxillary tuberosity and the pyramidal process of the palatine, where these adjoin.

Structure and Insertion.—From the medial and lateral laminæ of the pterygoid process there arise aponeuroses and from the palatine bone at the lower margin of the fossa, and from the maxillary tuberosity and palatine bone in front of the external pterygoid, there arise short tendons. From these aponeuroses and tendons and directly from the fossa the fiber-bundles take a nearly parallel course downward, backward, and outward, and are inserted in part in a multipenniform manner into the lower half of the internal surface of the ramus of the mandible. The insertion extends to the mylohyoid ridge. The muscle is divided at its origin into two fasciculi by the margin of the external pterygoid.

Nerve-supply.—The internal pterygoid nerve arises from the back of the mandibular nerve near the foramen ovale. It passes near or through the otic ganglion, and thence to the medial surface of the muscle near the dorsal edge. Both the buccinator and lingual nerves are also described as sending sensory filaments to this muscle.

Relations.—Laterally the muscle is covered by the interpterygoid fascia and the spheno-mandibular ligament, the external pterygoid, temporal, and masseter muscles, and the ramus of the mandible. The inferior alveolar (dental) and lingual nerves and the corresponding vessels run across this surface. Medial to the muscle lie the lateral pharyngeal fascia, the tensor veli palatini muscle, and the superior constrictor of the pharynx.

Action.—The muscles of this group adduct the lower jaw and carry it forward and backward and rotate it. The elevation is produced by the masseter, temporal, and internal pterygoid muscles. The suprahyoid muscles and the external pterygoid are the feeble antagonists. The forward movement of the jaw is produced by the simultaneous action of the two external pterygoids (slightly by the superficial layer of the masseter, and the anterior fibers of the temporal) while the inferior posterior portions of the temporal muscles carry the jaw at the temporodiscoidal joint somewhat backward. Oblique lateral rotatory movements are produced chiefly by the action of one of the external pterygoids. The alternate action of these two muscles associated with the elevating action of the other muscles of the group, gives rise to the grinding movement of the molar teeth. Purely lateral movements of the jaw may be produced by the internal pterygoids, acting alternately.

Variations.—The temporal muscle may have a more extensive cranial origin than usual. It may be formed of two superimposed layers. It may be more or less fused with the external pterygoid, or send a fasciculus to the coronoid process. The masseter may be completely

---

FIG. 409.*—A AND B ARE TRANSVERSE SECTIONS AND C (AFTER TESTUT), A FRONTAL SECTION THROUGH THE LEFT SIDE OF THE HEAD, IN THE REGIONS INDICATED IN THE DIAGRAM. *a* and *b* in the diagram indicate the regions through which pass sections A and B, fig. 413; and a^1, section A, fig. 419.

1. Adipose tissue. 2. Arteria temporalis superficialis. 3. A. carotis externa. 4. A. carotis interna. 5*a*. A. maxillaris externa (facial). 5*b*. A. maxillaris interna. 6. A. vertebralis. 7. Atlas. 8. Cerebellum. 9. Epistropheus (axis). 10. Fascia buccopharyngea. 11. F. cervicalis, *a* (superficial layer), *b*, deep parotid process. 12. F. interpterygoidea. 13. F. masseterica. 14. F. nuchæ. 15. F. pharyngobasilaris. 16. F. pharyngis lateralis. 17. F. temporalis. 18. Galea aponeurotica. 19. Glandula parotica. 20. Ligamentum stylomandibularis. 21*a*. Mandible, capitulum; *b*, coronoid process. 22. Meatus acusticus ext. 23. Medulla oblongata. 24. Medulla spinalis (spinal cord). 25. Musculus auricularis posterior (retractor auris). 26. M. buccinator. 27. M. caninus (levator anguli oris). 28. M. constrictor pharyngis medius. 29. M. constrictor pharyngis superior. 30. M. digastricus. 31. M. genioglossus. 32. M. hyoglossus. 33. M. incisivus labii inferioris. 34. M. levator veli palatini. 35. M. longus capitis (rectus capitis anticus major). 36. M. longissimus capitis (trachelomastoid). 37. M. longitudinalis inferior. 38. M. masseter. 39. M. mylohyoideus. 40. M. nasalis (alar portion). 41. M. obliquus capitis inferior. 42. M. obliquus capitis superior. 43. M. pterygoideus externus —*a*, superior fasciculus; *b*, inferior fasciculus. 44. M. pterygoideus internus. 45. M. quadratus (levator) labii superioris. 46. M. rectus capitis anterior (minor). 47. M. rectus capitis posterior major. 48. M. rectus capitis posterior minor. 49. M. rectus capitis lateralis. 50. M. semispinalis capitis (complexus). 51. M. splenius capitis. 52. M. sternocleidomastoideus. 53. M. styloglossus. 54. M. stylohyoideus. 55. M. stylopharyngeus. 56. M. temporalis (*a*, fasciculus from zygoma). 57. M. tensor veli palatini. 58. M. trapezius. 59. M. zygomaticus (major). 60. Nervus accessorius (spinal accessory). 61. N. alveolaris inferior (dental). 62. N. alveolaris posterior superior (dental). 63. N. auriculotemporalis. 64. N. buccinatorius. 65. N. canalis pterygoidei (Vidian nerve). 66. N. glossopharyngeus. 67. N. hypoglossus. 68. N. lingualis. 69. N. mandibularis. 70. N. massetericus. 71. N. maxillaris. 72. N. mylohyoideus. 73. N. palatinus. 74. Sympathetic trunk. 75. N. temporalis profundus. 76. N. vagus. 77. Os occipitale—*a*, basilar portion; *b*, external protuberance. 78. Os sphenoidale. 79. Os temporale—*a*, processus zygomaticus; *b*, tubercle. 80. Os zygomaticum (malar). 81. Pharyngeal orifice of tuba auditiva (Eustachian tube). 82. Palatum durum (hard palate). 83. Pharynx—*a*, oral portion; *b*, nasal portion. 84. Pharyngeal recess. 85. Sinus maxillaris (antrum of Highmore). 86. Sinus transversus (lateral). 87. Tonsilla palatina. 88. Uvula. 89. Vena facialis posterior (temporomaxillary). 90. V. jugularis interna.

* This and the following series of cross-sections are taken from a thin, not very muscular, adult male. The fasciæ are represented in most instances disproportionately thick.

divided into two fasciculi, a condition normal in many mammals. A special fasciculus may arise from the temporomandibular articulation or from the zygomatic (malar) bone. Its deepest fibers may be fused with the temporal muscle. The two fasciculi of the external pterygoid may be distinct, as in the horse. It has been seen fused with the temporal and with the digastric muscle. The internal pterygoid may send a fasciculus to the masseter. It may give origin to the styloglossus. Inconstant fasciculi (*accessory pterygoids*) extending from the body of the sphenoid to the pterygoid process represent perhaps remnants of the muscles which act on the movable pterygoids possessed by many inferior vertebrates.

3. SUPRAHYOID MUSCULATURE

(Fig. 410)

From the hyoid bone there extend to the base of the skull on each side four muscles which form a fairly well-defined group. They are situated external to

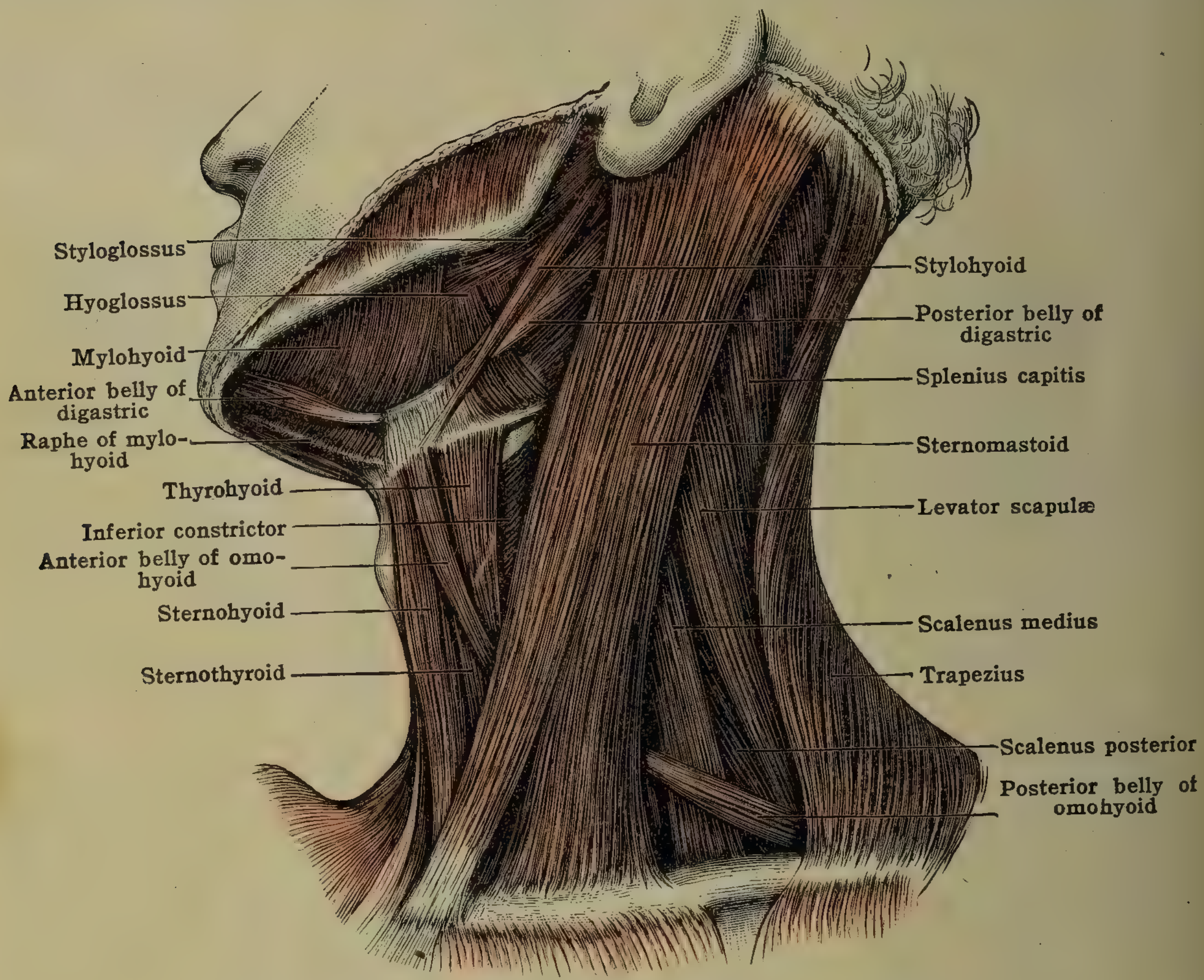


Fig. 410.—Anterior and Lateral Cervical Muscles.

the musculature of the tongue and pharynx. They elevate the hyoid bone and larynx and depress the mandible. The anterior part of this musculature pulls the hyoid bone and larynx forward and opens up the pharynx, and therefore is of use in swallowing. The most superficial of the group is the slender, fusiform **stylohyoid,** which arises from the styloid process of the temporal bone and is inserted into the body of the hyoid. Immediately behind this is the flattened posterior belly of the **digastric,** which extends from its origin in the mastoid notch to a tendon that runs between two divisions of the tendon of the stylohyoid and is inserted into the hyoid bone by an aponeurotic process. From the digastric tendon the flat, triangular anterior belly is continued to the back of the anterior portion of the inferior margin of the mandible. Beneath this anterior belly the thin, quadrangular **mylohyoid** arises from the inner surface of the body of the mandible and is inserted into a median raphe extending from the mandible to the hyoid. Still deeper the triangular **geniohyoid** extends from the hyoid to the mental spine of the mandible. The last two muscles form the muscular floor of the mouth. The motor innervation of the posterior belly of the digastric and of the stylohyoid is from the facial nerve, the sensory innervation probably from the glossopharyngeal. The mylohyoid and the anterior belly of the digastric are supplied by the masticator (fifth) cranial nerve; the geniohyoid

from the hypoglossal by a branch, the fibers of which are possibly derived through anastomosis from the first cervical nerve.

From the morphological standpoint, therefore, the stylohyoid, and the posterior belly of the digastric belong to the facialis group; the anterior belly of the digastric and the mylohyoid to the group of mandibular muscles, and the geniohyoid to the muscles of the tongue innervated by the hypoglossal; or, if we consider the nerve-fibers of the nerve to the genio-hyoid as derived from the first cervical nerve, to the same group as the infrahyoid muscles. It is convenient, however, to follow the usual custom of considering these muscles as a suprahyoid group.

FASCIÆ

The muscles of this group lie internal to that portion of the external cervical fascia which extends above the hyoid bone. This fascia, which is described on p. 414, comes into contact merely with the tendon, the anterior belly, and to a slight extent with the posterior belly of the digastric muscle. Above the tendon it sends inward a process which curves down internal to the tendon, and is inserted into the external surface of the hyoid bone. The individual muscles of the group are covered by delicate adherent membranes. An aponeurotic membrane usually extends between the anterior bellies of the digastric muscle of each side.

MUSCLES

(Fig. 410)

The **stylohyoideus** (stylohyalis NK).—*Origin.*—From the lateral and dorsal part of the base of the styloid process by a rounded tendon which soon becomes a hollow cone to the internal surface of which the fiber-bundles of the muscle are attached. *Structure and Insertion.*—The fiber-bundles are inserted on both sides of a slender tendon which divides to let the tendon of the digastric pass through and then is attached to the ventral surface of the body of the hyoid bone near its junction with the great cornu.

Nerve-supply.—From the facial nerve as it emerges from the stylomastoid foramen a small twig is given off which enters the proximal third of the deep surface of the muscle. The glossopharyngeal nerve also gives to it a small twig, probably sensory.

Relations.—It descends immediately in front of the posterior belly of the digastric. Externally lie the parotid and submaxillary glands. Medially it crosses the internal and external carotid artery, the hypoglossal nerve, the stylopharyngeus muscle, the superior constrictor of the pharynx, and the hyoglossus muscle. The posterior auricular artery passes between it and the posterior belly of the digastric and the external maxillary artery crosses over it.

The **digastricus** (biventer mandibulae NK).—The **posterior** (mastoid) **belly** arises by tendinous processes from the mastoid (digastric) notch of the temporal bone. The fiber-bundles form a ribbon-like belly which converges on the intermediate tendon. This begins as a semiconical laminar process on the outer surface of the muscle a short distance above the hyoid bone. The **anterior** (mandibular) **belly** arises by short tendinous processes from the digastric fossa of the mandible. This attachment is often described as an insertion. The fibers converge on both surfaces of the flattened anterior end of the intermediate tendon. The **intermediate tendon** lies a variable distance above the hyoid bone, usually less than a centimeter. It curves upward toward each belly of the muscle. It is united to the outer surface of the body and to the base of the great cornu of the hyoid bone by an aponeurotic expansion from its inferior margin. Other expansions are usually continued into the interdigastric aponeurotic membrane. Occasionally the intermediate tendon of the digastric is bound to the hyoid bone by a fibrous loop which allows the tendon free play.

Nerve-supply.—The facial nerve near the stylomastoid foramen gives off a branch which enters the proximal third of the anterior margin of the muscle. From this a ramus may be continued through the muscle to the glossopharyngeal nerve. The anterior belly is supplied by a branch of the nerve to the mylohyoid muscle. This enters the middle of the lateral part of the deep surface. Very rarely the vagus may supply the anterior belly, the hypoglossal, the posterior belly.

Relations.—The posterior belly of the digastric lies internal to the mastoid process and the longissimus capitis (trachelomastoid), splenius, and sternocleidomastoid muscles Posteriorly near its origin are the rectus capitis lateralis and obliquus cap. sup. muscles, the occipital artery and the spinal accessory nerve. It helps to form the deep wall of the cavity in which the parotid gland is placed. Internally it crosses the origin of the styloid muscles, the carotid arteries, the internal jugular vein, and the hypoglossal nerve. The intermediate tendon of insertion lies below the inferior margin of the submaxillary gland, and crosses the hypoglossus and mylohyoid muscles. The relations to the stylohyoid muscle have been described above The anterior belly lies on the mylohyoid and is covered by the external cervical fascia and the platysma.

The **mylohyoideus** (mylohyalis NK).—*Origin.*—From the mylohyoid ridge of the mandible. *Structure and insertion.*—Its fiber-bundles take an oblique course and are inserted into—(1) a median raphe extending from the middle of the ventral surface of the hyoid bone nearly or quite to the posterior aspect of the inferior margin of the mandible, and (2) into the ventral surface of the hyoid bone. Some of the fiber-bundles may cross the median line. The muscles of the two sides form a sheet with a downward convexity which lies between the inner surface of the body of the mandible and the hyoid bone. On the diaphragm thus formed rests the tongue.

Nerve-supply.—From the mylohyoid branch of the inferior alveolar (dental) nerve several filaments enter the under surface of the muscle.

Relations.—The mylohyoid muscle is covered externally by the external cervical fascia. It is crossed by the submental

artery. With the geniohyoid and the genioglossus muscles it helps to bound a compartment in which are lodged the sublingual gland, the duct of Wharton, and the deep portion of the submaxillary gland. Its deep surface also faces the styloglossus and hyoglossus muscles, the lingual and hypoglossal nerves, and to a slight extent the buccal mucosa.

The **geniohyoideus** (geniohyalis NK) (fig. 411).—*Origin.*—By short tendinous fibers from the mental spine of the mandible. *Structure and Insertion.*—The fiber-bundles diverge and are inserted into the ventral surface of the body of the hyoid bone. Usually a special fasciculus goes to the great cornu of the hyoid bone.

Nerve-supply.—The hypoglossal nerve sends a filament to the middle third of the deep surface of the muscle. The nerve-fibers are thought to be derived chiefly from the first cervical nerve.

Relations.—It lies between the genioglossus and mylohyoid muscles. It adjoins its fellow of the opposite side and is often fused with it. Lateral to it lie the sublingual and submaxillary glands and the hypoglossal nerve.

Action.—The muscles of this group all elevate the hyoid bone and, through this, the larynx and inferior part of the pharynx, and thus play a part in the act of swallowing. The stylohyoid and posterior belly of the digastric serve also to draw the hyoid bone in a dorsal direction; the ventral belly of the digastric and the geniohyoid, in a ventral direction. The digastric geniohyoid, and mylohyoid depress the mandible, when the hyoid bone is fixed. The digastric acting on one side rotates the jaw toward that side. The two digastrics may retract the jaw. The posterior belly of the digastric has a slight power to bend the head backward.

Variations.—The stylohyoid tendon frequently passes entirely in front of and less frequently entirely behind the digastric muscle. Its insertion may be of greater extent than usual. A special fasciculus to the lesser cornu is not very infrequent; more rarely one extends to the angle of the jaw or to other regions. The muscle may arise from the petrous portion of the temporal or from the occipital bone, as in some lower vertebrates. It may be doubled or absent, or fused with the posterior belly of the digastric. The anterior belly of the digastric may be missing; the posterior belly may be inserted into the angle of the jaw. The intermediate tendons of the digastric of each side may be connected by a fibrous arch. The anterior bellies of the muscles of each side may be united by a fasciculus or fused. The anterior belly is frequently doubled. The posterior belly may be divided by a tendinous inscription. Fasciculi may pass from either belly to neighboring structures. The mylohyoid may not extend quite to the hyoid bone. It may be more or less fused with neighboring muscles. Rarely it is absent. The geniohyoid is frequently more or less fused with the muscles of the tongue or with the geniohyoid of the opposite side. A considerable number of infrequently found muscles have been described superficial to the stylohyoid and digastric muscles. Most of them are innervated by the glossopharyngeal nerve or by the facial nerve.

4. MUSCLES OF THE TONGUE

(Fig. 411)

The tongue is a flexible organ, composed chiefly of various muscles, some of which lie entirely within its substance, while others extend to be attached to neighboring parts of the skeleton. To the former the term **intrinsic,** to the latter the term **extrinsic,** is frequently applied. In this section the extrinsic muscles will alone be taken up. The intrinsic muscles are described in the section on the Digestive System. Certain pharyngeal and palatal muscles which are continued into the tongue are described in connection with the pharynx. The extrinsic musculature of the tongue is concealed below by the suprahyoid musculature and the sublingual gland. It is covered on the free surface of the tongue by the mucosa.

The musculature of the tongue is supplied by the hypoglossal nerve, which is in series with the motor roots of the spinal nerves. It is, primitively at least, derived from the ventral portion of myotomes in series with the spinal myotomes.

Four extrinsic muscles are recognized on each side. The **styloglossus** is a slender muscle, which arises from the styloid process and is inserted into the side of the tongue. It is cylindrical near its origin, flat and triangular near its insertion. The thin, quadrilateral **hyoglossus** arises from the body and great cornu of the hyoid bone and is inserted into the dorsum of the tongue. The **chondroglossus** arises from the lesser cornu of the hyoid bone and joins the superior and inferior longitudinal muscles of the tongue. The **genioglossus** (geniohyoglossus), which forms the main part of the body of the tongue, arises from the mental spine of the mandible, from which the fiber-bundles radiate out toward the whole length of the dorsum of the tongue and to the hyoid bone.

Under the mucous membrane of the tongue is a dense layer of fibrous tissue, the **lingual fascia.** In the body of the tongue there is a sagittal **septum linguæ,** which separates the two genioglossus muscles. A transverse fibrous lamella, the **hyoglossal membrane,** helps to unite the tongue to the hyoid bone. Delicate membranes invest the free portions of the extrinsic muscles of the tongue.

MUSCLES

The **styloglossus.**—This *arises* from the front of the lower end of the styloid process of the temporal bone and from the upper part of the stylomandibular ligament. *Insertion.*—It runs obliquely downward, forward, and medially, with slightly diverging fiber-bundles, to the lateral margin of the tongue, where it gives rise near the anterior (glossopalatine) arch to two fasciculi. The larger, lateral, longitudinal fasciculus runs superficially along the lateral margin of the tongue to the tip. The fiber-bundles are attached to the overlying mucosa and underlying musculature. The smaller, inferior, transverse fasciculus gives rise to diverging fiber-bundles which pass medially through the hyoglossus into the base of the tongue. The most posterior of these diverging bundles may extend to the hyoid bone.

The **hyoglossus.**—This *arises* from—(1) the lateral part of the ventral surface of the body of the hyoid bone and (2) from the upper border of the great cornu. The fiber-bundles take a nearly parallel course upward, diverging, however, slightly. Near the upper margin of the back part of the tongue they curve medianward and interlace with the intrinsic musculature of this region. The dorsal fiber-bundles pass transversely, the middle obliquely, the ventral longitudinally. They are inserted into the fibrous tissue which forms the skeletal framework of the tongue.

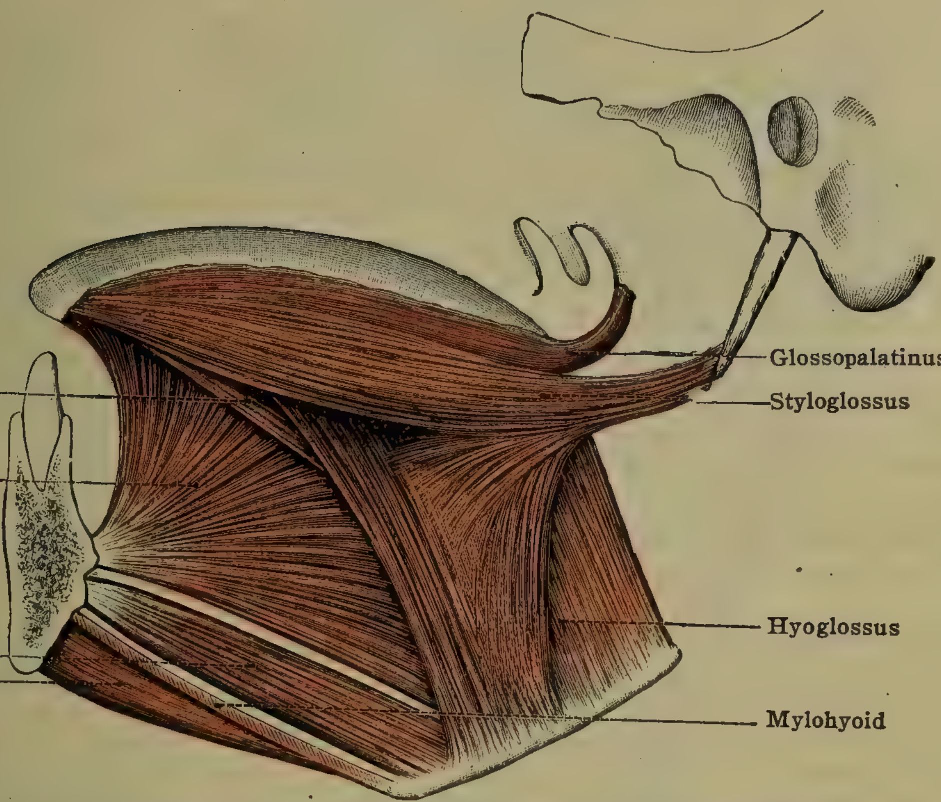


FIG. 411.—SIDE VIEW OF THE MUSCLES OF THE TONGUE.

The **chondroglossus** is a small muscle which arises from the lesser cornu of the hyoid bone and gives rise to fasciculi which join the longitudinalis inferior and the longitudinalis superior of the tongue described in Section X.

The **genioglossus.**—This *arises* from the mental (genial) spine of the mandible partly directly, partly by means of a short, triangular tendon. The more superior fiber-bundles radiate toward the tip of the tongue; the intermediate extend directly toward the dorsum of the tongue, where they are *inserted* into the lingual fascia and skeletal framework. The inferior curve back to be inserted on the median part of the superior border of the hyoid bone.

Nerve-supply.—Twigs from the hypoglossal nerve enter the lateral surfaces of the muscles of this group.

Action.—The chief of the muscles, the genioglossus, performs various services according to the part which contracts. The anterior portion serves to withdraw the tongue into the mouth and depress the tip; the middle portion to draw the base of the tongue forward, depress the median portion of the tongue, and make the tongue protrude from the mouth; the inferior fibers to elevate the hyoid bone and carry it forward. The styloglossus retracts the tongue, elevates its margin, and raises the hyoid bone and base of the tongue. The hyoglossus draws down the sides of the tongue and is also a retractor. The chondroglossus aids in both these movements.

Relations.—The main portion of the tongue is composed of the two genioglossus muscles which are separated in the median line by the lingual septum. The genioglossus is covered inferiorly by the geniohyoid and the mylohyoid muscles; along the lateral margin of the tongue by the glossopalatinus, the styloglossus, the longitudinalis inferior, and the glossopharyngeus muscles; and posteriorly by the hyoglossus, and the chondroglossus. Below it forms a part of the medial wall of the space in which the sublingual gland is lodged. Over the dorsum and tip of the tongue it is covered by the mucosa. This likewise covers laterally, in the region of the base of the tongue, the styloglossus, hyoglossus, and the longitudinalis inferior. The lingual artery runs between the hyoglossus and the genioglossus, and along the boundary between the longitudinalis inferior and the genioglossus to the tip of the tongue. The lingual vein, which lies lateral to the hyoglossus muscle, takes a similar although much more irregular course. The glossopharyngeal nerve passes down medial to the styloglossus muscle to the root of the tongue. The lingual nerve passes along the lateral margin of the tongue external to the stylo-

glossus, hyoglossus, and inferior longitudinal muscles. The hypoglossal nerve lies lateral to the inferior portion of the hyoglossus muscle and then sinks into the genioglossus.

The hyoglossus muscle is covered laterally below the free portion of the tongue by the mylohyoid, digastric, and stylohyoid muscles and by the deep part of the submaxillary gland. Medially it covers in part the middle constrictor of the pharynx.

The styloglossus muscle above the tongue lies medial to the stylohyoid and the internal pterygoid muscles and the parotid gland, and between the internal and external carotid arteries. It lies lateral to the superior constrictor of the pharynx.

Variations.—The genioglossus often sends a slip to the epiglottis (**levator epiglottidis**). It may send some bundles into the superior constrictor of the pharynx (**geniopharyngeus**) or to the stylohyoid ligament. Various parts of the muscle may be more or less isolated. Of these, a fasciculus from the mental (genial) spine to the tip of the tongue is the most frequent (**longitudinalis linguæ inferior medius**). The hyoglossus exhibits considerable variation in structure. Some authors consider the chondroglossus but a portion of this muscle, while Poirier considers it merely the origin of the longitudinalis inferior. The styloglossus may be absent on one side or on both. Its origin varies considerably and may be from the angle of the jaw. The muscle may be doubled.

5. SUPERFICIAL MUSCULATURE OF THE SHOULDER GIRDLE AND THE EXTERNAL CERVICAL FASCIA

(Figs. 410, 417)

The **sternocleidomastoid** is a strong, band-shaped muscle, bifurcated below, which arises from the medial third of the clavicle and the front of the manubrium and is inserted into the mastoid process of the temporal bone and the neighboring part of the occipital. The large, flat, triangular **trapezius** arises from the occipital bone and the spines of the cervical and thoracic vertebræ and is inserted into the lateral third of the clavicle and into the acromion and spine of the scapula. The two muscles lie in a well defined layer of fascia which ensheaths the neck beneath the platysma, the *external cervical fascia.* Both muscles bend the head and neck toward the shoulder, and rotate and extend the head. The sternocleidomastoid also elevates the thorax and flexes the neck. The trapezius draws the scapula medially and rotates the glenoid fossa upwards. The upper part of the muscle elevates, the lower part depresses, the scapula. The nerve supply of these muscles is from the spinal accessory and second to fourth cervical nerves.

These two superficially placed muscles represent differentiated portions of a musculature found in elasmobranchs and in the amphibia and all higher vertebrates. In sharks this musculature is associated with the musculature of the branchial arches, and, like them, is innervated by the vagus nerve. In the higher vertebrates it is innervated by the vagus or by the spinal accessory nerve, developed in connection with the vagus. To this innervation by a cranial nerve, innervation by cervical nerves is added in those higher vertebrates in which the musculature is more extensively developed. In the human embryo the muscles migrate from their origin in the upper lateral cervical region to the positions found in the adult.

FASCIÆ

The **fasciæ** of the neck and the relations of the muscles are shown in cross-section in figs. 409, 412, and 413.

The **tela subcutanea** of the head and neck in the upper dorsal region is thick, fibrous, and closely adherent to the underlying muscle fascia. Ventrally in the cervical region it contains the platysma. Suppuration between the external cervical fascia and the skin is prone to spread through the loose alveolar tissue but usually points superficially.

The **external cervical fascia** (fig. 415) lies beneath the subcutaneous tissue and the platysma, completely invests the neck and extends cranialward over the parotid gland to the zygoma and the masseteric fascia. The trapezius lies between two closely adherent laminæ of the fascia. From the ventral margin of the trapezius it is continued as a thin but strong membrane across the posterior triangle of the neck, between this muscle and the sternocleidomastoid, and is attached below to the clavicle. It invests the sternocleidomastoid with two adherent laminæ and extends from the ventral margin of this muscle across the anterior triangle to the mid-line where it is continued into that of the opposite side. In this triangle the fascia is bound to the hyoid bone, and is thus divided into a submaxillary and an infrahyoid portion. The **infrahyoid** portion is simple above, but it splits below into two layers attached to the front and back of the manubrium. In **Burns' space** between these two layers are some lymph nodes, the lower portion of the anterior jugular veins with their communication across the midline, and the sternal heads of the sternomastoid muscles. The **submaxillary portion** of the fascia is attached to the inferior margin of the mandible. It covers the submaxillary gland and along the inferior margin gives rise to a strong, membranous process which passes inward below the gland and, after extending around the tendon of the digastric muscle, becomes united to the superior margin of the hyoid bone. This process ventrally becomes fused with the perimysium of the ventral belly of the digastric. Dorsally it extends over the posterior end of the submaxillary gland and becomes attached to the angle of the jaw. Here it is strengthened by fibrous tissue which extends in from the ventral margin of the sternocleidomastoid and serves to separate the parotid from the submaxillary gland. This 'mandibular process' is continued into the stylomandibular ligament.

The *parotid gland* is enclosed between two laminæ of the external cervical fascia. These are continued over the gland from the fascial investment of the sternocleidomastoid, and unite anteriorly to become fused to the masseteric fascia along the anterior margin of the gland. They unite below the inferior margin of the gland, and are continued into the mandibular process mentioned above. The external layer, which is the thicker and stronger, is attached above to the cartilage of the auditory canal and to the zygoma. The inner lamina is attached above to the base of the temporal bone. It is incomplete and is more or less fused to the posterior

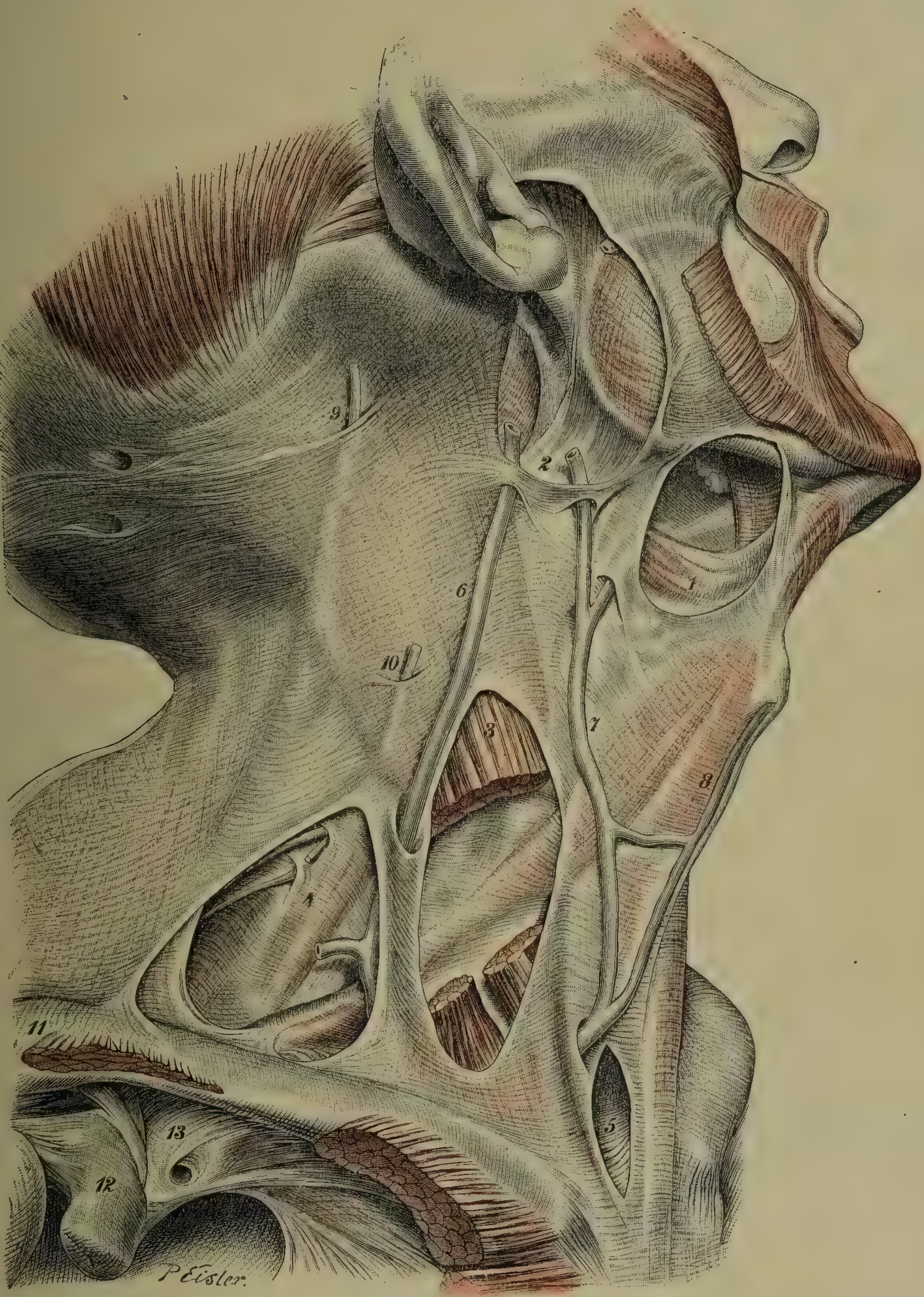


Fig. 412.—Fasciæ of the Neck. (After Eisler.) The superficial fascia has been removed in places in order to show the deeper fasciæ; the sternocleidomastoid has been partly removed; the submaxillary gland, almost wholly; the parotid gland, as far as the duct.

1. Submaxillary space. 2. Parotid space. 3. Sternocleidomastoid. 4. Supraclavicular fossa. 5. Suprasternal space. 6. External jugular vein. 7. Anterior jugular vein. 8. Median colli vein. 9. N. occipitalis minor. 10. N. auricularis magnus. 11. Deltoid. 12. Proc. coracoideus. 13. Fascia coracoclavicularis.

belly of the digastric muscle, the styloid process, and the muscles arising from this process. Beween the styloid process and the angle of the jaw this lamina is strengthened to form the stylomandibular ligament.

In the back beyond the spine of the scapula, the fascia arising from the investing adherent fascial sheath of the trapezius muscle is continued laterally across the fascia investing the infraspinatus muscle, and becomes fused with the most superficial layer of this fascia and more distally with that of the latissimus dorsi muscle. Near this lateral line of fusion it is usually closely adherent to the tela subcutanea.

MUSCLES

The **sternocleidomastoideus** (fig. 410)—*Origin.*—By a medial (sternal) head from the front of the manubrium and by a lateral (clavicular) head from the upper border of the medial third of the clavicle. Of the two heads, the sternal is the thicker and more prominent, the clavicular the wider. Between the two origins there intervenes a triangular area covered by the external cervical fascia. Its *insertion* is—(1) on the anterior border and outer surface of the mastoid process, and (2) on the lateral half of the superior nuchal line of the occipital bone.

Structure.—The tendons are comparatively short, the longest being that on the anterior surface of the sternal attachment. The fiber-bundles of the muscle take a nearly parallel course from origin to insertion. Five fasciculi may be more or less clearly recognized. In a superficial layer—(1) a superficial sternomastoid; (2) a sterno-occipital; and (3) a cleido-occipital. In a deep layer—(4) a deep sternomastoid and (5) a cleidomastoid.

Nerve-supply.—(1) From the spinal accessory nerve, which gives it branches during its course through the deep portion of the muscle, and (2) by branches from the anterior primary divisions of the second and sometimes the third cervical nerves. These branches enter the deep surface of the upper half of the muscle.

Action.—To bend the head and neck toward the shoulder and rotate the head toward the opposite side. When both muscles act, the neck is flexed toward the thorax and the chin is raised; or, with fixed head, the sternum is raised, as in forced respiration. When the head is bent back, the two muscles may further increase the hyperextension.

Relations.—The muscle and its sheath are covered externally by the tela subcutanea, which here contains the platysma and the external jugular vein, as well as the superficial branches of the cervical plexus. Beneath the muscle lie the sternohyoid, sternothyroid, omohyoid, levator scapulæ, scaleni, splenius, and digastric muscles, the cervical plexus, the common carotid artery, internal jugular vein and the vagus nerve. The spinal accessory nerve usually runs through its deep cleidomastoid portion.

Clinical relations.—The sternocleidomastoid muscle is the landmark for several important operations. Its medial border, the thicker and better marked of the two, overlaps the carotids: the common carotid corresponding, as far as the upper border of the thyroid cartilage, with a line drawn from the sternoclavicular joint to midway between the mastoid process and the angle of the jaw. The artery can be best compressed above the level of the cricoid, as here it is less deeply covered. The student should recall the deep relations of the sternomastoid muscle to the vessels, nerves, muscles, glands, and bones. A stab through the interval which lies between the two heads might wound the bifurcation of the innominate on the right side, and the common carotid on the left, the internal jugular vein, vagus, and phrenic nerves, according to the direction of the wound. Injury of the sternomastoid during child-birth, followed by scar-tissue formation, may give rise to wry-neck.

Variations.—There is considerable variation in the extent of independence of the main fasciculi of the muscle. In many of the lower animals the cleidomastoid portion of the muscle is quite distinct from the sternomastoid portion, and this condition is frequently found in man. The cleido-occipital portion of the muscle is that most frequently absent (Wood found it present in 37 out of 102 instances). The clavicular portion of the muscle varies greatly in width. The sternal head has been seen to extend as far as the attachment of the fifth rib. Slips from the muscle may pass to various neighboring structures. The main fasciculi of the muscle may be doubled. Sometimes one or more tendinous inscriptions cross a part or the whole of the superficial layer of the muscle.

The **trapezius** (fig. 417).—*Origin.*—By a flat aponeurosis from the superior nuchal line and external protuberance of the occipital bone, the ligamentum nuchæ, and the vertebral spines and supraspinous ligament from the seventh cervical to the twelfth thoracic vertebra. The aponeuroses of the right and left muscles are continuous across the middle line. Between the middle of the ligamentum nuchæ and the second thoracic vertebra, the aponeuroses give rise to an extensive quadrilateral tendinous area. At the distal extremity of the muscle they are also well developed.

Structure and insertion.—The superior fiber-bundles pass obliquely downward, lateralward and forward to the posterosuperior aspect of the lateral third of the clavicle; the middle-fiber bundles, transversely to the medial edge of the acromion and the upper border of the spine of the scapula; the lower fiber-bundles, obliquely upward and laterally to terminate through a flat triangular tendon on a tubercle at the medial end of the spine of the scapula.

Nerve-supply.—The external branch of the spinal accessory nerve descends for a distance near the superior border of the trapezius muscle and then along the ventral surface. Soon it gives rise to ascending branches for the superior portion of the muscle and descending branches for the middle and inferior portions. The main branches of distribution run about midway between the origin and insertion of the fiber-bundles. The branches from the (second) third and fourth cervical nerves anastomose with the trunk of the spinal accessory, sometimes as it passes along the margin of the muscle, at other times within the substance of the upper portion of the muscle.

Action.—When the whole muscle contracts, it draws the scapula toward the spine and turns it so that the inferior angle points laterally, the lateral angle upward. In addition the upper portion draws the point of the shoulder upward, and with the scapula fixed extends the head, bends the neck toward the same side, and turns the face to the opposite side. The lower portion of the muscle tends to draw the scapula downward and inward and at the same time to rotate the inferior angle of the scapula lateralward.

Relations.—It is covered merely by skin and fascia. It lies external to the semispinalis, splenii, rhomboidei, latissimus dorsi, levator scapulæ, supraspinatus, and a small portion of the infraspinatus muscles.

Variations.—The lower limit of attachment of the muscle may be as high as the fourth thoracic vertebra. The right and left muscles are seldom symmetrical. The upper attachment may not extend to the skull. The clavicular attachment may be much more extensive than normal or may be missing. The attachments to the scapula show considerable variations. Occasionally the cervical and thoracic portions are separate, a condition normal in many mammals. Ventrally the trapezius may become continuous with the sternocleidomastoid in the neck, or send a fasciculus to it or to the sternum. Aberrant fasciculi are not infrequent. Rarely a transverse tendinous inscription is found in the cervical or in the thoracic portion of the muscle. Sometimes a fasciculus is sent into the deltoid. The innervation of either the sternocleidomastoid or the trapezius may be by cervical nerves only. The *omocervicalis* (*levator claviculæ*) is a fasciculus frequent in the lower mammals, but rarely found in man. It usually extends from the acromial end of the clavicle to the atlas and axis, but may extend to more distal cervical vertebræ. It is innervated by a ramus from the cervical branches to the trapezius. The *supraclavicularis proprius* is a muscle rarely found. It extends on the cranial surface of the clavicle from the sternal to the acromial end and is innervated by the third cervical nerve. It is said to make tense the superficial layer of the cervical fascia.

A **bursa** is often found between the base of the spine of the scapula and the tendon of insertion of the thoracic portion of the trapezius. Another bursa is also frequently found between the insertion of the transverse portion and the supraspinous fascia.

6. INFRAHYOID MUSCULATURE

(Figs. 410 and 413)

The four infrahyoid muscles constitute a well-defined group of muscles which depress the hyoid bone, the larynx, and the associated structures. They lie beneath the sternocleidomastoid muscle and the external cervical fascia. Two strata may be recognized. In the superficial stratum are comprised the **omohyoid,** a narrow, ribbon-like digastric muscle which arises from the superior margin of the scapula and is inserted into the hyoid bone; and the thin, quadrangular **sternohyoid,** which arises from the superior margin of the sternum and the medial end of the clavicle and is inserted into the hyoid bone. Between these two muscles is an aponeurotic membrane which constitutes the main part of the middle layer of the cervical fascia, and represents possibly a retrograde portion of a single muscle, of which the two above named are but the ventral and dorsal margins. Beneath this superficial musculature the thin, quadrangular **thyrohyoid** descends from the hyoid bone to the thyroid cartilage, and the ribbon-like **sternothyroid** arises from the dorsal surface of the manubrium and is inserted into the thyroid cartilage.

All these muscles are supplied by branches from the ansa hypoglossi. The nerve-fibers arise from the first three cervical nerves.

The muscles of this group are derived from the ventral portions of the ventrolateral divisions of the first three cervical myotomes, and correspond with the rectus abdominis muscle, which is derived from the ventral portions of the eighth to the twelfth thoracic myotomes. This musculature is characterised by metameric segmentation, which may be more or less obscured, and by a general longitudinal direction taken by the component fiber-bundles. The course of the fibers in the omohyoid may be looked upon as a secondary condition due to the shifting laterally of the distal attachment of the muscle. Musculature of this nature is not derived from the lower cervical and upper thoracic myotomes in man, but in some of the lower vertebrates it forms a continuous ventral band. Even in man occasional traces of this ventral musculature may, however, be seen as muscular and aponeurotic slips on the upper part of the thoracic wall, above the ribs and the aponeurosis of the external intercostal muscles.

FASCIA

(Figs. 413 and 419)

The **middle cervical fascia** is composed of two laminæ. Of these, the superficial, which ensheaths the sternohyoid and omohyoid muscles and fills in the intervening area, is much the stronger and better differentiated. The more delicate deep lamina ensheaths the thyrohyoid and sternothyroid muscles, and laterally extends out to become fused with the superficial lamina. It is also more or less closely bound to the sheath which covers the internal jugular vein, carotid artery, and vagus nerve.

The middle cervical fascia is attached above to the hyoid bone. Beyond the lateral edge of the omohyoid it becomes fused with the deep lamina of the external layer of the cervical fascia, beneath the sternocleidomastoid. Posterior to this muscle it usually terminates along the cranial margin of the omohyoid in the areolar tissue of the neck. Its distal attachment takes place into the dorsal surface of the upper margin of the sternum, and from here a process is sent over the left innominate vein to the pericardium. Lateral to the sternum the fascia is attached for some distance to the inner margin of the clavicle, and gives rise to processes, one of which extends to the fascia of the subclavius muscle, while the others pass on each side of the subclavian vein to the first rib. Still more laterally the fascia is fused along the lower margin of the scapular belly of the omohyoid to the underlying dense, fatty areolar tissue.

Suppuration between the external and middle cervical fascia is common but most often it points to the surface.

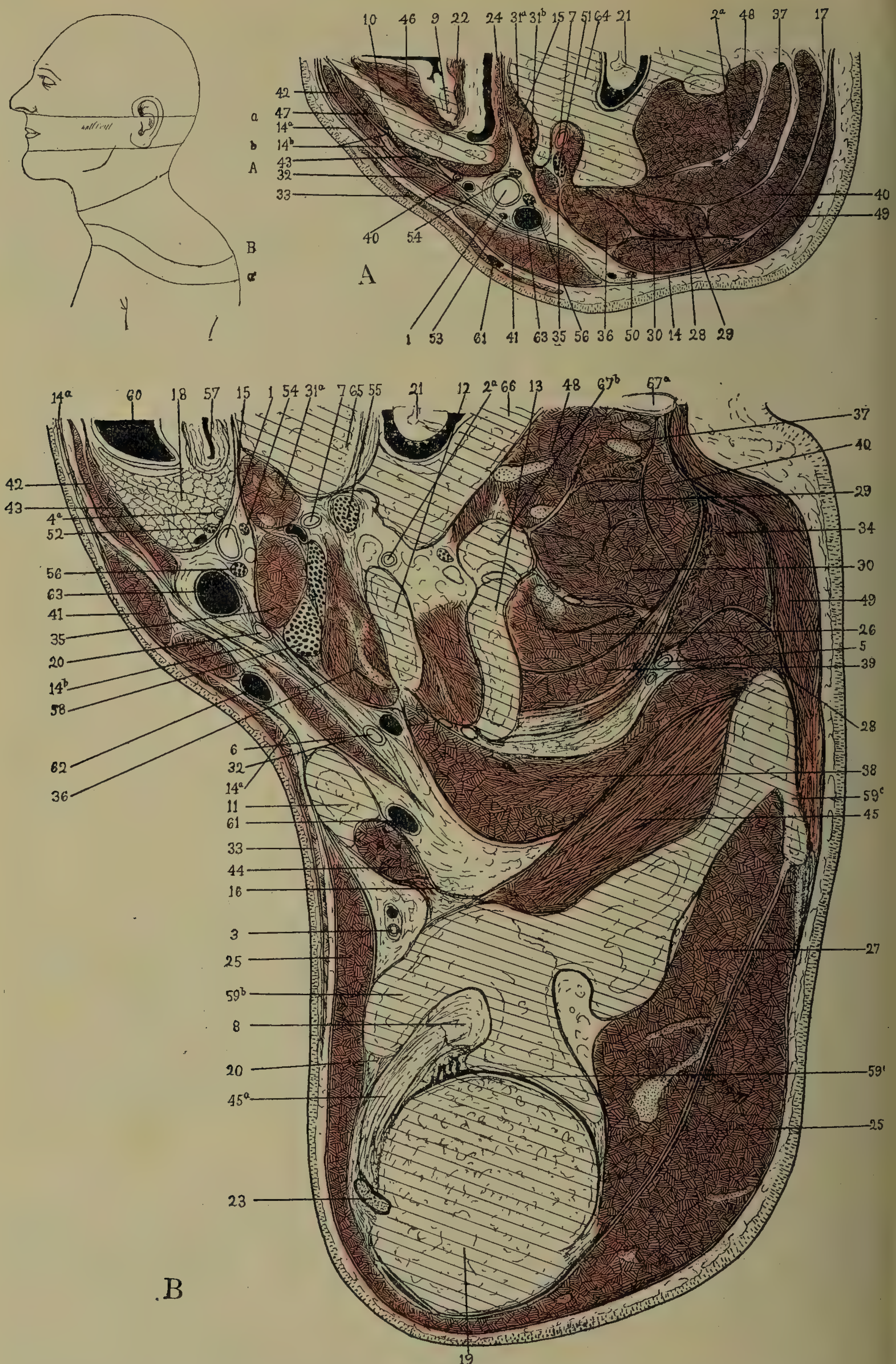


Fig. 413, A and B.—Transverse Sections Through the Left Side of the Neck and Shoulder in the Regions indicated in the Diagram.

a and b in the diagram indicate sections A and B of fig. 409. a' that of section A, fig. 419.
1. Arteria carotis communis. 2a. A. cervicalis profunda. 2b. A. cervicalis superficialis 3. A. thoracoacromialis (acromial branch). 4a. A. thyreoidea inferior. 4b. A. thyreoidea superior. 5. A. transversa colli. 6. A. transversa scapulæ. 7. A. vertebralis. 8. Bursa m. subscapularis. 9. Cartilago arytenoidea. 10. Cartilago thyreoidea. 11. Clavicle 12. Costa I. 13. Costa II. 14. Fascia cervicalis—a, superficial layer; b, middle layer.

INFRAHYOID MUSCLES

(Figs. 410 and 413)

The **sternohyoideus** (sternohyalis NK).—*Origin.*—From (1) the deep surface of the media extremity of the clavicle; (2) the costoclavicular (rhomboid) ligament; and (3) the neighboring part of the sternum. The origin may extend to the cartilage of the first rib. *Structure and insertion*—The fiber-bundles take a nearly parallel course upward. The muscle belly, however, contracts slightly in width and increases slightly in thickness and slants somewhat toward the median line. The insertion takes place directly upon the inferior margin of the body of the hyoid lateral to the midline. Not infrequently a tendinous inscription near the junction of the middle and inferior thirds more or less completely divides the muscle into two portions. A second inscription is sometimes found at the level of the oblique line of the thyroid cartilage. *Nerve-supply.*—One or more branches from the ansa hypoglossi enter the lateral margin of the muscle. Frequently one goes to the upper third, another to the lower third, of the muscle.

The **omohyoideus** (omohyalis NK).—*Origin.*—From the superior margin of the scapula near, and occasionally also from, the superior transverse ligament of the scapula. *Insertion.*—The lower border of the hyoid bone lateral to the sternohyoid muscle. *Structure.*—The inferior belly of the muscle near its origin is thick and fleshy. It contracts as it passes ventrally across the posterior triangle of the neck. Beneath the sternocleidomastoid it is attached to a short tendon from which, as it bends upward toward the hyoid bone, the superior belly takes origin and thence expands toward the insertion. The tendon of attachment is short. The fiber-bundles of both bellies take a nearly parallel course. The central tendon of the muscle is held in place by a strong process in the middle layer of the cervical fascia. This process is attached to the dorsal surface of the clavicle and to the first rib. *Nerve-supply.*—The superior belly is supplied by a branch which enters its deep surface near the medial margin somewhat below the center; the inferior by a branch which enters the proximal third of its deep surface. These branches arise from the ansa hypoglossi.

The **sternothyroideus.**—*Origin.*—Partly directly, partly by tendinous fibers, from—(1) the dorsal surface of the manubrium from the middle line to the notch for the first rib; (2) the dorsal surface of the cartilage of the first rib. Occasionally also from the back of the cartilage of the second rib or from the clavicle. *Structure and insertion.*—The fiber-bundles take a nearly parallel course upward and slightly lateralward. The muscle is inserted by short tendinous fibers into the oblique line on the lamina of the thyroid cartilage. A transverse tendinous inscription near the upper border of the interclavicular ligament not infrequently divides the belly of the muscle more or less completely into two parts. Sometimes a second transverse inscription is found at the level of the lower margin of the thyroid cartilage. *Nerve-supply.*—By one or two branches from the ansa hypoglossi, which enter the ventral surface of the muscle near the lateral margin. One branch usually goes to the upper, another to the lower, third of the muscle.

The **thyrohyoideus** (thyreohyalis NK).—*Origin.*—From the oblique line on the lamina of the thyroid cartilage. *Structure and insertion.*—The fiber-bundles take a parallel course and are inserted on the inferior margin of the lateral third of the body of the hyoid bone and the external surface of the great cornu. Many fiber-bundles are continuous with those of the sternothyroid.

Nerve-supply.—By a branch of the hypoglossal which enters the muscle near the middle of its lateral border. The fibers are said to be derived from the first cervical nerve.

Action.—The sternohyoid and omohyoid depress the hyoid bone; the sternothyroid depresses the thyroid cartilage; and the thyrohyoid approximates the bone to the cartilage. The omohyoid tends to draw the hyoid bone somewhat laterally. In this is aided by the posterior belly of the digastric and the stylohyoid and is opposed by the sternothyroid and thyrohyoid muscles, and the anterior belly of the digastric.

Relations.—The muscles of this group lie beneath the external cervical fascia. The sternocleidomastoid muscle crosses the omohyoid, the sternohyoid, and sternothyroid muscles. The latter two muscles extend for a distance behind the manubrium of the sternum. The omohyoid is partly covered by the trapezius, crosses the scalene muscles, the brachial plexus, the internal jugular vein, carotid artery, and the sternothyroid and thyrohyoid muscles. The sternohyoid extends over the sternothyroid muscle, the thyroid gland, cricothyroid muscle, and the thyroid cartilage. The sternothyroid lies over the innominate vein, the trachea, and

---

15. Deep or prevertebral layer. 16. Fascia coracoclavicularis. 17. Fascia nuchæ. 18. Glandula thyreoidea. 19. Humerus. 20. Ligamentum coracohumerale. 21. Medulla spinalis (spinal cord). 22. Musculus arytenoideus transversus. 23. M. biceps brachii, tendon long head. 24. M. constrictor pharyngis inferior. 25. M. deltoideus. 26. M. Iliocostalis. 27. M. infraspinatus. 28. M. levator scapulæ. 29. M. longissimus capitis (trachelo-mastoid). 30. M. longissimus cervicis. 31*a*. M. longus colli. 31*b*. M. longus capitis (rectus capitis anticus major). 32. M. omohyoideus. 33. M. platysma. 34. M. rhomboideus minor. 35. M. scalenus anterior. 36. M. scalenus medius. 37. M. semispinalis capitis (complexus). 38. M. serratus anterior. 39. M. serratus posterior superior. 40. M. splenius. 41. M. sternocleidomastoideus. 42. M. sternohyoideus. 43. M. sternothyreoideus. 44. M. subclavius. 45 M. subscapularis; *a*, tendon. 46. M. thyreoarytenoideus (and vocalis). 47. M. thyreohyoideus. 48. M. transversospinales. 49. M. trapezius. 50. Nervus accessorius. 51. N. cervicalis IV. 52. N. laryngeus inferior. 53. N. descendens hypoglossi. 54. Sympathetic trunk. 55. N. thoracalis I. 56. N. vagus. 57. Esophagus. 58. Plexus brachialis. 59. Scapula—*a*, glenoid cavity; *b*, coracoid process; *c* spine. 60. Trachea. 61. Vena transversa colli. 62. V. jugularis externa. 63. V. jugularis interna. 64. Vertebra cervicalis V. 65. Vertebra cervicalis VII. 66. Vertebra thoracalis I, arch. 67. Vertebra thoracalis II—*a*, spine; b, transverse process.

thyroid bland. It is partly covered by the sternohyoid and omohyoid muscles. The thyrohyoid is largely covered by the omohyoid and sternohyoid muscles, and lies upon the hyothyroid membrane and the upper part of the thyroid cartilage.

Variations.—The muscles vary in extent of development and may be more or less fused with one another. The sternal attachment of the sternohyoid is more frequently absent than the clavicular attachment. The region between the omohyoid and sternohyoid may be composed of muscle instead of fascia. Each of the muscles may be longitudinally divided into two distinct fasciculi, may send fasciculi to one another or to the middle layer of the cervical fascia, or may have an abnormal origin or insertion. The omohyoid is the one of the group most frequently absent. One of the bellies is much more frequently absent than both. The intermediate tendon of the omohyoid may be reduced to a tendinous inscription for even disappear entirely. The inferior attachment may take place on the scapular spine, the acromion, the coracoid process, or even the first rib or clavicle. An extra fasciculus from the clavicle is found in 3 per cent. of instances. (Le Double.) Not very infrequently a muscle innervated by a branch of the *descendens hypoglossi* is found extending from the sternum to the clavicle behind the origin of the sternocleidomastoid. It may also extend from the sternum or clavicle in various directions upward toward the head.

BURSÆ

The **bursa m. sternohyoidei** is inconstantly found between the lower margin of the hyoid bone and median hyothyroid ligament and the sternohyoid muscle and external cervical fascia. It is better developed in men than in women and is found either on each side of the median line or fused in the median line.

The **bursa m. thyrohyoidei** is frequently found between the greater cornu of the hyoid bone and hyothyroid membrane and the thyrohyoid muscle.

THE CERVICAL TRIANGLES

Various cervical muscles together with the mandible and the clavicle form the boundaries of triangular regions in the neck on each side known as the cervical triangles (fig. 410). The sternocleidomastoid laterally, the mandible above and the mid-line medially bound the **anterior cervical triangle.** This is subdivided into three smaller triangles by the digastric muscle above and the anterior belly of the omohyoid below. These three smaller triangles are called the submaxillary, the superior carotid and the inferior carotid triangles. The *submental triangle* is an additional small unpaired area bounded on either side by the anterior belly of the digastric, and posteriorly by the body of the hyoid.

The *submaxillary* or *digastric triangle* is bounded above by the mandible and a line drawn back to the mastoid process, behind by the stylohyoid and posterior belly of the digastric and in front by the anterior belly of the digastric. The submaxillary gland, external maxillary (facial) artery and anterior facial vein are among the structures found in the submaxillary triangle.

The *superior carotid triangle* is bounded above by the posterior belly of the digastric below by the omohyoid and behind by the sternocleidomastoid. Many important structures lie within the boundaries of this space such as the carotid arteries, internal jugular vein, the vagus nerve, and cervical sympathetic trunk.

The *inferior carotid* (muscular or tracheal) *triangle* is bounded above by the omohyoid, behind by the sternocleidomastoid and in front by the midline of the neck. It contains the inferior thyroid vessels, recurrent laryngeal nerve, trachea, thyroid gland and esophagus.

The **posterior cervical triangle** is bounded anteriorly by the sternocleidomastoid, posteriorly by the trapezius and inferiorly by the clavicle. The posterior belly of the omohyoid passes obliquely across it dividing it into two *smaller* triangles, the larger occipital above and the smaller subclavian below. The *occipital triangle* contains the accessory nerve and parts of the cervical and brachial plexuses, and some of the deep cervical lymph nodes.

The *subclavian triangle* corresponds to a surface depression, the supraclavicular fossa. Here the brachial plexus may be felt, and by pressure downward the subclavian artery can be compressed upon the first rib.

7. SCALENE MUSCULATURE

(Figs. 410 and 414)

The three muscles which form this group constitute a triangular mass which extends in front of the levator scapulæ and intrinsic dorsal musculature and behind the prevertebral musculature from the first two ribs to the transverse processes of the cervical vertebræ. They cover laterally the apex of the pleural cavity. They bend the neck ventrolaterally and rotate it toward the opposite side, and fix the first two ribs or raise the thorax. In front lies the **scalenus anterior,** which extends from the first rib to the fourth to sixth vertebræ. Behind this the **scalenus medius** extends from the first rib to the lower six vertebræ. The most dorsal of the group, the **scalenus posterior,** extends from the second rib to the fifth and sixth vertebræ. These muscles are supplied by direct branches of the cervical nerves.

These muscles are probably derived from the lateral portions of the cervical myotomes. According to Gegenbaur, the two more ventral are homologous with intercostal muscles, the dorsal with the levatores costarum. It is to be noted, however, that the anterior muscle lies

in front of the brachial plexus, *i.e.*, in a position simlar to that of the subcostal musculature. The scalene musculature is morphologically closely related to the deep shoulder-girdle musculature, p. 424.

FASCIA

(Figs. 413, 419)

The *prevertebral fascia* is continued from the front of the bodies of the cervical vertebræ laterally over the longus colli and the scalene muscles, and extends dorsally into the fascia covering the levator scapulæ. Between the muscles fascial processes are sent in to become attached to the cervical vertebræ. Inferiorly the fascia extends to the outer aspect of the thorax.

The space between the middle and prevertebral fascia is called the visceral compartment, enclosing such important structures as the larynx, trachea, esophagus, thyroid gland, brachial plexus and subclavian artery.

Suppuration or new growths in this compartment are more serious than in the more superficial spaces because they produce pressure on the above structures. Abscesses in this region may arise from infections of the nasopharynx or the upper deep cervical lymph nodes. Pus (especially in the loose prevertebral space) not infrequently moves downward behind the sternum to invade mediastinal tissues. The space between the prevertebral fascia in front and the prevertebral muscles and cervical vertebra behind is also a site of retropharyngeal abscess. Such an abscess may arise from infections of the cervical vertebrae, and will probably spread laterally, behind the carotid sheath (Stiles, Chiene). In making incisions along the posterior border of the sternomastoid muscle, the surgeon should keep close to the transverse processes of the vertebrae, to avoid opening and infecting the visceral compartment.

SCALENE MUSCLES

(Fig. 414)

The **scalenus anterior.**—This *arises* from the ventral part of the inferior border of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, usually also from the third, rarely from the seventh, by means of long, slender tendinous processes. From each tendon arises a fasciculus composed of nearly parallel fiber-bundles. The fasciculi soon fuse to form a muscle-belly which contracts somewhat toward the insertion. This takes place by means of a tendon which sends a fibrous lamina a short distance upward on the outer surface of the muscle. The tendon is *inserted* into the scalene tubercle on the upper surface of the body of the first rib.

The **scalenus medius.**—This *arises* usually from the third to the seventh, sometimes from all seven or from merely the last four or five cervical vertebræ. The origin take place from the posterior part of the lateral border of the transverse processes by means of a slender tendon from each of the upper and directly by a muscular fasciculus from each of the lower vertebræ. The fasciculi become combined into a compact muscle-belly which is *inserted* in a manner similar to the scalenus anterior into the upper surface of the first rib behind the subclavian groove. The insertion usually extend to the second rib.

The **scalenus posterior** *arises* by short tendons from the posterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ. The origin may extend as high as the fourth vertebra, or as low as the seventh. It is *inserted* by a short tendon into the lateral surface of the second rib. Occasionally it extends to the third rib.

Nerve-supply.—The scalenus anterior is innervated by branches from the fifth, sixth, and seventh cervical nerves; the middle by the fourth, fifth, sixth, seventh, and eighth cervical nerves; the posterior by the seventh or eighth nerves.

Action.—With the thorax fixed the scalene muscles bend the neck to the side and slightly forward and turn it slightly toward the opposite side. With the neck fixed they serve to lift the first two ribs and are of use in enforced inspiration. In quiet inspirations they serve to fix the first two ribs.

Relations.—The longus colli lies medial to the scalenus anterior. Dorsally the scalene muscles; medially the pharynx, thyroid gland, and trachea; ventrolaterally the sternocleidomastoid, infrahyoid, and subclavius muscles and the clavicle bound a space filled with dense fatty areolar tissue in which are contained the subclavian and carotid arteries, the subclavian and internal jugular veins, the vagus, phrenic, and sympathetic nerves, and numerous smaller blood-vessels and nerves. The main branches of the lower five cervical nerves pass laterally between the scalenus anterior and medius. The subclavian artery passes behind, the subclavian vein in front, of the attachment of the scalenus anterior. The scalenus medius above and the scalenus posterior below enter into relations dorsally with the levator scapulæ and the intrinsic dorsal musculature, from which they are separated by fascial septa.

Variations.—The scaleni present numerous variations in the extent of the costal and vertebral attachments. The degree of fusion of the various fasciculi likewise varies so much that different authors have described varying numbers of muscles into which the scalenus mass should be subdivided. A muscle frequently present is the **scalenus minimus.** This arises from the anterior tubercle of the sixth or sixth and seventh cervical vertebræ, and is inserted into the first rib behind the sulcus for the subclavian artery. It sends a process (Sibson's fascia) to the pleural cupola and serves to make the pleura tense. Zuckerkandl found it in 22 out of 60 bodies on both sides; 12 times on the right side only, 9 times on the left. It is innervated by the eighth cervical nerve. When absent, a ligamentous band takes its place. An *intertransversarius lateralis longus,* may extend from the posterior tubercles of the 3–5 transverse processes to the tip of the seventh transverse process and divide the muscle fasciculi near their origin into dorsal and ventral divisions.

8. THE PREVERTEBRAL MUSCULATURE

(Fig. 414)

This deep-seated musculature extends along the ventrolateral surfaces of the three upper thoracic and the cervical vertebræ to the skull. It is composed of two muscles. The **longus colli** arises from the bodies of the first three thoracic and last three cervical vertebræ, and from the transverse processes of the third to the sixth cervical vertebræ. It is inserted into transverse processes and bodies of the cervical vertebræ. The **longus capitis** (rectus capitis anterior major) arises from the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ and is inserted into the basilar process of the occipital bone. These muscles flex, abduct, and rotate the head and neck. All of them are supplied by direct branches from the anterior divisions of the cervical nerves. They are probably specialized from the ventrolateral portions of the cervical myotomes Similar muscles are found in all vertebrates with well-developed necks. The rectus capitis anterior (minor) represents an anterior cervical intertransverse muscle.

FASCIA

The muscles are firmly bound to the vertebral column by the prevertebral fascia described in connection with the scalene muscles and by the septa which extend in between the muscles of this group and between them and the scalenus anterior.

MUSCLES

(Fig. 414)

The **longus colli.**—This muscle may be compared to a triangle, the base of which extends from the anterior tubercle of the atlas to the body of the third thoracic vertebra and the apex of which is the transverse process of the fifth cervical vertebra. The complex construction of the muscle makes it advisable to consider it as divided into three parts.

The **superolateral portion** consists of fasciculi which arise from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ and from the body of the third thoracic and become fused into a belly which is inserted into the anterior tubercle of the atlas.

The **medial portion** is formed of muscle fasciculi which arise from the anterolateral parts of the bodies of the first three thoracic vertebræ and the last three cervical vertebræ by tendinous processes. These fasciculi fuse into a belly which terminates by three flat tendinous fasciculi on the anterolateral surfaces of the bodies of the second, third, and fourth cervical vertebræ

The **inferolateral portion** is applied to the inferior lateral surface of the medial portion. It arises from the lateral parts of the bodies of the first three thoracic vertebræ and is inserted by tendinous processes into the transverse processes of the fifth and sixth cervical vertebræ.

Nerve-supply.—By branches from the second to sixth cervical nerves which send rami to the various constituent fasciculi of the muscle.

The **longus capitis** (rectus capitis anterior major).—*Origin.*—By cylindrical tendons from the tips of the anterior tubercles of the third, fourth fifth, and sixth cervical vertebræ. The tendons send up aponeurotic expansions on the outside of the fasciculi, which arise from them. These fasciculi fuse into a dense muscular belly to which is usually added a fasciculus from the longus colli. The *insertion* takes place into the impression on the inferior surface of the basilar portion of the occipital bone, extending lateral to the pharyngeal tubercle outward and forward. The insertion of the fiber-bundles from the third vertebra is direct; the other fiber-bundles are inserted largely into a tendinous lamina which covers the middle of the ventral surface of the muscle and from which, in turn, other fiber-bundles arise. It is an incomplete digastric muscle. *Nerve-supply.*—The first, second, third, and fourth cervical nerves send branches into the ventral surface of the muscle.

Actions.—The longus colli serves to bend the neck forward; the superolateral portion, when acting on one side only, serves slightly to bend the neck toward that side and to rotate it toward the same side. The inferolateral portion serves especially to prevent hyperextension and rotates the neck slightly toward the opposite side. The longus capitis bends the head forward; one side acting alone rotates the head toward that side.

Variations.—There is considerable variation in the number of vertebræ to which the tendons of origin and insertion of the longus colli and longus capitis may be attached and in the extent of fusion of the different fasciculi composing them. There may be fusion with the scalenus anterior. The *atlantico-basilaris internus* in 4 per cent. of cases extends from the anterior tubercle of the atlas to the base of the skull.

9. ANTERIOR AND LATERAL INTERTRANSVERSE MUSCLES

(Fig. 414)

The **anterior intertransverse** muscles extend successively between the anterior tubercles of the cervical vertebræ. They lie in front of the anterior divisions or the cervinal cerves and are supplied by branches from these divisions. They

are usually more or less bound up with the insertions of the scalene and prevertebral muscles into these tubercles. The muscle between the atlas and epistropheus is frequently missing; when present, it passes in front of the lateral articulation between these vertebræ. The lowest muscle may extend between the seventh cervical vertebra and the first rib. The **rectus capitis anterior** (minor) may be considered an upward continuation of the series. This muscle arises from the lateral mass of the atlas and is inserted into the base of the occipital bone. The **lateral intertransverse** muscles lie immediately behind the ventral divisions of the spinal nerves and lateral to the dorsal divisions and are supplied by branches

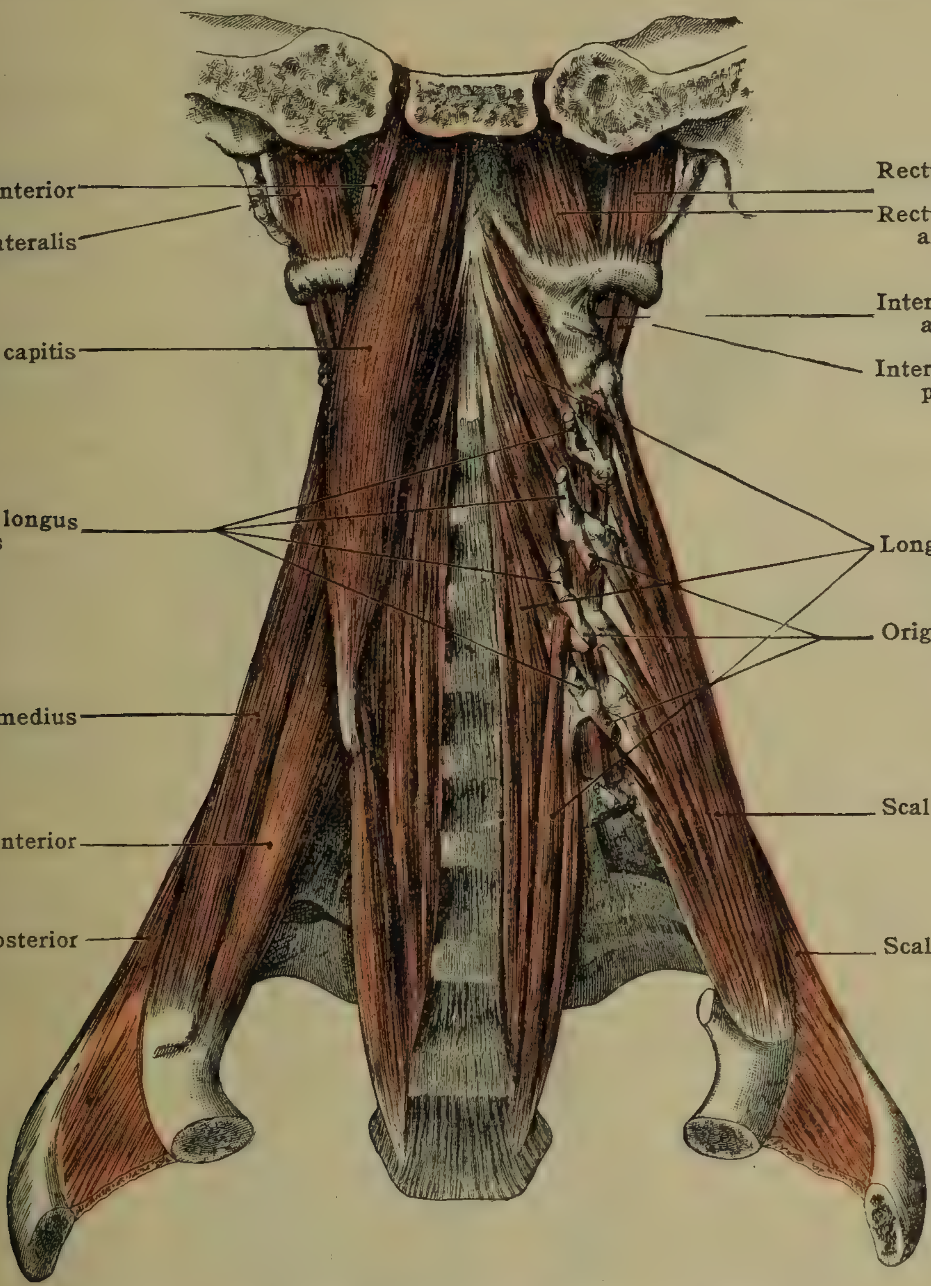


Fig. 414.—The Deep Ventral Muscles of the Neck.

from the ventral divisions. The **rectus capitis lateralis** belongs to this series. This muscle runs from the transverse process of the atlas to the lateral part of the occipital. For the posterior intertransverse muscles see p. 484.

The **rectus capitis anterior** (minor).—This *arises* from the upper surface of the lateral mass of the atlas in front of the articular process and partly from the neighboring transverse process. From a tendon the fiber-bundles extend in a nearly parallel direction upward and medially to be *inserted* on the inferior surface of the basilar portion of the occipital bone in front of the condyle. *Nerve-supply.*—From the first (and second) cervical nerves. *Action.*—The rectus capitis anterior (minor) serve to bend the head forward and, when the muscles on one side only are contracted, to rotate the head toward the same side.

Relations.—The anterior intertransverse and the rectus capitis anterior muscles are closely applied to the vertebral column. Between the fascia covering them and the fascia surrounding the pharynx which lies in front is a region in which merely a slight amount of loose areolar tissue is found. Dorsomedially the longus colli below and the longus capitis above help to bound the space in which the chief vessels and nerves extend between the thorax and the head.

The **rectus capitis lateralis** (fig. 414).—*Origin.*—From the upper surface of the transverse process of the atlas.

Structure and insertion.—The fiber-bundles give rise to a quadrilateral sheet which passes upward to be inserted on the under surface of the pars lateralis of the occipital bone.

Nerve-supply.—The ventral branch of the suboccipital (first cervical) nerve gives twigs to its ventral surface.
Action.—To flex the head laterally.

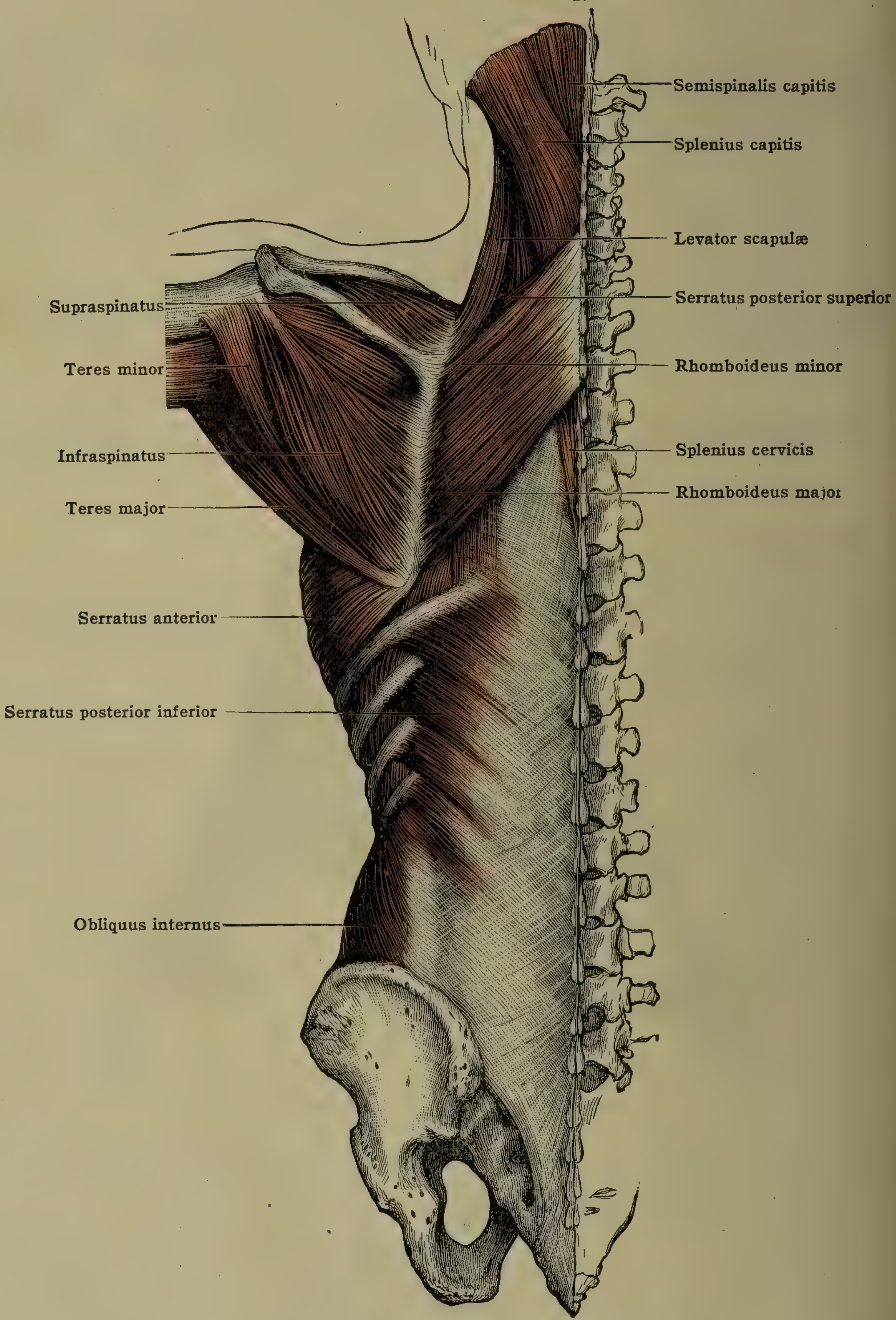


Fig. 415.—Levator Scapulæ and Rhomboid Muscles.

Relations.—In front lie the anterior primary division of the suboccipital nerve and the internal jugular vein. Behind the muscle lie the superior oblique and the longissimus capitis (trachelomastoid) muscles and the atlanto-occipital joint.

10. DEEP MUSCULATURE OF THE SHOULDER-GIRDLE

(Figs. 410, 415, 416, 452)

To this group belong four muscles which arise in the lateral cervical region during embryonic development and become secondarily attached to the vertebral

margin of the scapula. One of these muscles, the band-like **levator scapulæ** (fig. 415), remains in the cervical region. It extends beneath the sternocleidomastoid, the trapezius, and the intervening fascia from the transverse processes of the first four cervical vertebræ to the medial angle of the scapula. A second, the large, quadrilateral **serratus anterior** (magnus) (figs. 415, 416), comes to lie beneath the scapula and wanders with this to the thoracic region. It arises, in the adult, from the first nine ribs and is inserted into the vertebral margin of the scapula. The flat, quadrangular **rhomboideus major** and **rhomboideus minor** (fig. 415) arise from the spines of the last cervical and first four or five thoracic vertebræ, pass obliquely downward across the deep dorsal muscles beneath the trapezius and are inserted into the vertebral margin of the scapula. The third to the seventh cervical nerves supply this set of muscles. The levator scapulæ is supplied by the third and fourth cervical nerves, the rhomboids by the fifth (dorsal scapular), the serratus anterior by the fifth to the seventh (long thoracic nerve). The muscles of this group elevate the scapula, rotate it, and draw it backward (rhomboidei) or forward (serratus anterior). When all contract together they raise the thorax.

The levator scapulæ and the serratus anterior (magnus) are two differentiated parts of a muscle which is a continous mass in many of the lower mammals. A muscle corresponding to the rhomboideus is found in some of the reptiles and many of the higher vertebrates. In some of the mammals it has a more extensive cervical attachment than in man.

FASCIÆ

The fasciæ investing these muscles are shown in cross-section in fig. 419.

The levator scapulæ is invested by fascial membranes, the external and stronger of which is continued dorsally from the fascial investment of the scalene muscles. The thinner layer on its deep surface lies next the fascial investment of the intrinsic muscles of the back. Cranialward from the rhomboid muscles the fascial investment of the levator scapulæ is fused dorsally with the fascia covering the splenius cervicis. Where the dorsal margin of the levator comes in contact with the rhomboideus minor, the fascia is continued over into the thin fascial membrane which invests both surfaces of the rhomboidei. Similarly the investing fascia of the levator is continued ventrally into the fascia investing both surfaces of the serratus anterior (magnus). Within the internal fascial investment of this group of muscles, near the insertion of the levator, run the transversa colli artery and the dorsal scapular nerve.

MUSCLES

The **rhomboideus minor** (fig. 415).—*Origin.*—Lower part of the ligamentum nuchæ, the spines of the seventh cervical and first thoracic vertebræ, and the intervening supraspinous ligament. *Insertion.*—Vertebral border of the scapula near the spine.

The **rhomboideus major** (fig. 415).—*Origin.*—Spines of the first four or five thoracic vertebræ. *Insertion.*—Vertebral border of the scapula opposite the infraspinous fossa.

Structure.—The two muscles are included between two adherent fascial layers which bridge over the greater or less space that may intervene between them. The fiber-bundles take a parallel course obliquely downward and lateralward from the vertebræ. From the vertebral spines the muscles arise by an aponeurosis which varies in width. The attachment to the scapula is by short tendinous processes. The attachment of the rhomboideus major is firmest toward the inferior angle of the scapula.

Nerve-supply.—The dorsal scapular nerve, which usually arises chiefly from the fifth cervical nerve, enters the superior margin of the rhomboideus minor and then courses downward near the deep ventral surface of the two muscles and about midway between the tendons of origin and insertion.

Action.—The two muscles drawn the scapula upward and medialward toward the spine and rotate it so as to depress the shoulder.

Relations.—Over the muscles lies the trapezius. Under them lie the serratus posterior superior and the splenius cervicis, the longissimus dorsi, the iliocostalis, levatores costarum and external intercostal muscles. The descending ramus of the transverse cervical artery descends on the deep surface. Blood-vessels for the trapezius pass to this muscle between the two rhomboids.

Variations.—There is much variation in the extent of the vertebral attachment. The minor is frequently, the major occasionally, absent. The two rhomboids are frequently fused with one another (hence only one muscle, M. rhomboides is recognized by the NK) or may be divided into several distinct fasciculi. Frequently (80 per cent., Balli) a fasciculus extends obliquely on the deep surface of the *R.* major from the cranial part of the origin to the distal part of the insertion. Slips may be sent to the latissimus dorsi or the teres major. An accessory slip may pass between the trapezius and splenius muscles to the occipital bone (**occipito-scapularis**). A muscle corresponding to this fasciculus is normally found in many mammals.

The **levator scapulæ** (figs. 415, 452).—*Origin.*—By short tendons from the dorsal tubercles of the transverse processes of the first four cervical vertebræ, between the attachments of the splenius cervicis and scalenus medius muscles. The tendons from the third and fourth cervical vertebræ are fused for a short distance with those of the longissimus cervicis. *Structure and insertion.*—The fibers run in parallel bundles in a dorsolateral direction downward to the vertebral border of the scapula opposite the supraspinous fossa. The fiber-bundles are inserted

directly into the periosteum. As a rule, the flat fasciculi arising from the different vertebræ are easily separated.

Nerve-supply.—By rami chiefly from the third and fourth cervical nerves. These rami enter the ventral margin of the muscle and extend obliquely across the dorsal surface of the constituent fasciculi about midway between the tendons of origin and insertion. Frequently anastomosing branches pass between the nerves. The lowest fasciculus is usually supplied by branches from the nerve to the rhomboid muscles (dorsal scapular).

Action.—Draws the scapula upward and tends to rotate it so that the inferior angle approaches the spine. When the scapula is fixed, the muscle serves to bend the neck laterally and slightly to rotate it toward the same side and extend it.

Relations.—Externally the sternocleidomastoid and, in part, the splenius capitis cover it above; the trapezius, below; and the external cervical fascia, its middle portion. Internally lie the splenius cervicis, longissimus and iliocostalis cervicis (transversalis cervicis), and serratus posterior superior muscles and the ramus descendens of the transversa colli artery. In front lie the scalene muscles.

Variations.—The number of cervical vertebræ from which the muscle springs varies from two to seven. The most constant are the slips of origin from the first two vertebræ. The muscle may send slips to the temporal or the occipital bone or to the trapezius, the serratus anterior (magnus), serratus posterior superior, and other muscles, or to the clavicle, first or second rib, etc. Often the parts of the muscle running to each vertebra are separated for the whole distance. A bundle of fibers that appears to be a detached slip of the levator scapulæ

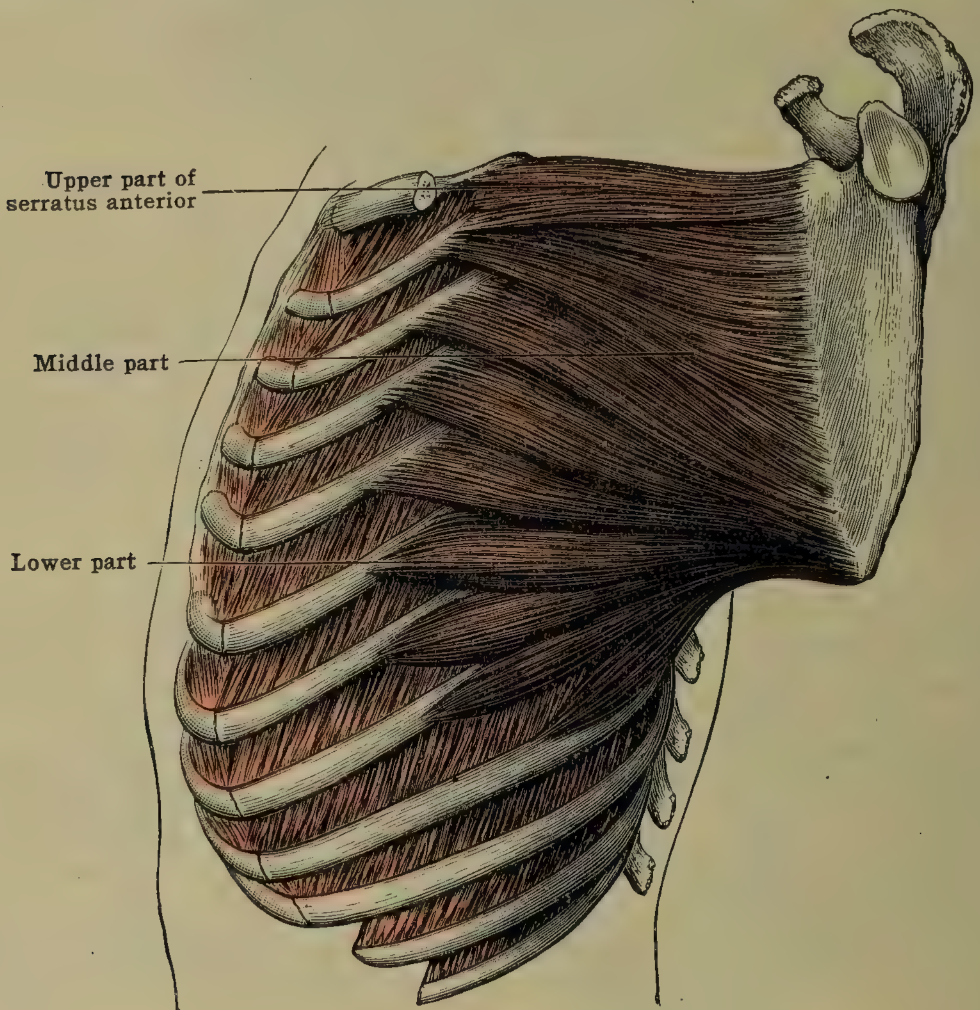


FIG. 416.—THE SERRATUS ANTERIOR.

may run from the first two or from lower cervical vertebræ to the lateral end of the clavicle and to the acromion. This represents the **levator claviculæ** found normally in many vertebrates. According to Le Double, it is innervated by a branch from the cervical branches to the trapezius group.

The **serratus anterior** (magnus) (figs. 416, 452).—*First Part.*—The origin is by two digitations from the first and second ribs and from a fibrous arch uniting these two attachments. The fiber-bundles converge to be inserted on an oval space on the costal surface of the scapula near its medial angle. *Second Part.*—This arises by two or three digitations from the second, third, and sometimes the fourth ribs. The fiber-bundles spread out into a thin sheet which is inserted along the vertebral border of the scapula. *Third Part.*—This, the strongest part of the muscle, arises by digitations from the fourth or fifth to the eighth or ninth ribs. The attachments of the digitations are longest on the upper border of each rib They interdigitate with the attachments of the external oblique muscle of the abdomen. The fiber-bundles converge to be inserted on the large oval space on the costal surface near the inferior angle of the scapula.

Nerve-supply.—From the proximal portions of the anterior divisions of the fifth, sixth, seventh, and sometimes the eighth cervical nerves branches arise which fuse into the long thoracic nerve. This nerve usually passes laterally through or behind the scalenus medius muscle, courses along the outer surface of the serratus anterior midway between the origin and insertion, and gives rise to numerous twigs to supply the various divisions. The fibers to the

upper portion come mainly from the fifth cervical nerve; those to the middle from the fifth and sixth; and those to the lower from the sixth and seventh.

Action.—The muscle holds the scapula against the thorax and draws it forward and laterally and, by its highly developed inferior portion, rotates the bone so as to raise the point of the shoulder. It is of especial importance in abduction of the arm. It also aids, to a slight degree, in forced inspiration.

Relations.—Superficial to the muscle lie the pectoralis major and minor, subscapularis, teres major, and latissimus dorsi muscles, the subclavian and axillary vessels, and the brachial plexus. Between the latissimus dorsi and pectoral muscles it is covered by skin and fascia inferiorly, and superiorly by the fatty areolar tissue of the axillary fossa. Under it lie the external intercostal, serratus posterior superior, and the lower extremity of the scalenus medius and posterior muscles.

Variations.—The digitations may extend to the tenth or only to the seventh rib. The muscle may be continuous with the levator scapulæ as it is in the carnivora, or some of its upper digitations may be wanting. Slips may be continued into neighboring muscles. The lower digitations may be partially replaced by digitations innervated by intercostal nerves.

II. MUSCULATURE OF THE UPPER LIMB

The upper limbs in man, relieved of the function of locomotion which is their chief office in most of the lower mammals, have become endowed with great freedom of movement which permits their developing many important functions. Primitively of value in climbing, in seizing food, preparing it for eating and carrying it to the mouth, in attack and defense, their importance has been greatly increased through the invention and use of tools. They are also used as a means of social expression, as seen primitively in the shrugging of the shoulders, or in the varied movements of the arms which accompany heated discourse, and as finally developed in the art of writing.

In order to understand the muscles which are called into play in the performance of these varied functions it is necessary to consider the various types of movement which take place at each of the joints. Since, however, most muscles act on more than one joint and the different parts of a muscle may act differently on the same joint, it is convenient to take up the muscles of each region of the limb in groups, based not so much upon the action of the muscles on any one joint as upon the development of the group and the innervation of the muscles composing it.

Physiology.—Movement of the scapula is of essential importance in the movements of the arm. The scapula is kept against the thorax by muscular attachments and atmospheric pressure, but it may be moved forward, backward, upward, and downward, and may be rotated so that the glenoid fossa, with which the head of the humerus articulates, is pointed forward when the arms are carried forward, lateralward when the arms are abducted, upward when the arms are raised high and somewhat downward when the arms are carried backward, thus greatly increasing the extent of movement in these various directions. The acromioclavicular and sternoclavicular joints both allow limited movements in various directions so that they resemble physiologically limited ball and socket joints. The part played by the superficial and deep shoulder-girdle muscles in the various movements has been described above in connection with these groups of muscles. The action of these muscles is aided by the pectoral muscles, (fig. 422) and by the latissimus dorsi (fig. 417) described below. These muscles depress the scapula. The upper sternal part of the pectoralis major, however, acting alone elevates the scapula; the latissimus dorsi draws the scapula backward, the pectoral muscles draw it forward.

At the humeroscapular or shoulder-joint the arm may be carried outward or abducted, bodyward or adducted, forward or flexed and backward or extended. The last is much more limited in degree than the other two. The arm may also be rotated at this joint. These various movements are brought about by the scapulohumeral muscles (figs. 417, 418, 425) and by the latissimus dorsi (fig. 417) and the pectoralis major (fig. 422), assisted by the muscles of the arm which arise from the scapula. They are produced in association with the movements of the scapula described above.

At the ulnohumeral joint the movements are relatively simple, consisting of flexion and extension. Extension is produced at the elbow by the dorsal muscles of the arm (fig. 425), flexion is produced not only by the ventral muscles of the arm, which are inserted into the radius and ulna (fig. 426), but also by the more superficial of both the main groups of muscles of the forearm.

The pronation of the forearm, whereby the palm is turned downward, and supination, whereby it is turned upward, take place in the joints between the radius and ulna at each extremity and between the radius and the lower end of the humerus. At the upper radioulnar joint the radius is turned on its long axis, at the lower joint it is carried about the lower end of the ulna. Pronation is produced chiefly by muscles belonging to the ulnovolar group of forearm muscles (fig. 433); supination is produced by the biceps of the arm (fig. 426) in conjunction with some of the muscles of the radiodorsal group of the forearm (fig. 430).

At the wrist joints (radiocarpal, intercarpal), the movements are those of flexion, extension, radial abduction and ulnar abduction. Volar flexion takes place chiefly at the radiocarpal joint, dorsal flexion at the intercarpal joint (Frohse). Extension is produced by those muscles of the radiodorsal group of the forearm which sends tendons to the wrist and digits, flexion by the corresponding muscles of the ulnovolar group, radial abduction is produced by the radial carpal extensor muscles (fig. 430), and ulnar abduction by the ulnar carpal extensor and flexor (fig. 433).

The varied movements of the thumb and fingers, flexion, extension, abduction, and adduction are produced partly by muscles of the two chief groups of forearm muscles, partly by the intrinsic muscles of the hand. Of chief interest here are the free movements of the metacarpal of the thumb and the limited movements of the other metacarpals, that of the little finger being the most movable, as seen in spreading or cupping the hand. In flexion and extension of the metacarpal of the thumb the movement is such as to bring the thumb into opposition to the fingers. In the metacarpophalangeal joints those of the fingers admit of much greater freedom of movement, flexion, extension, abduction, and adduction, than that of the thumb. The interphalangeal joints are pure hinge joints and permit merely flexion and extension.

Divisions.—The muscles described in this section as the muscles of the upper limb are all differentiated from the blastema of the embryonic limb bud. Most of them are differentiated in connection with the skeleton of the limb and extend between the various bones which compose it, but a few grow out from the limb bud over the trunk and become secondarily attached at one extremity to the trunk, while the other extremity remains attached to the skeleton of the limb. Thus the pectoral muscles (fig. 422), extend from the limb bud over the front of the thorax and the latissimus dorsi extends over the side and back of the trunk as far as the iliac crest (fig. 417). The muscles of the limb may be divided into two great divisions, a dorsal division, innervated by nerves arising from the back of the brachial plexus (supra- and subscapular, axillary and radial nerves) and a ventral division innervated by nerves arising from the front of the plexus (subclavian, anterior thoracic, musculocutaneous, median and ulnar). The former, which correspond with the musculature on the back of the shark's fin, are in the main extensors; the latter, which correspond with the musculature on the front of the shark's fin are in the main flexors. The bellies of the muscles of each division are found in the region of the shoulder and thorax, the arm, the forearm, and the hand.

The **shoulder muscles** belong to the dorsal division, the **pectoral** to the ventral division. In the **arm** the **dorsal division** is represented by the triceps and anconeus (fig. 425). The **ventral division** is made up of the coracobrachialis (fig. 427); the biceps (fig. 426); and the brachialis (fig. 427). The two main divisions of the musculature of the **forearm** give rise to the prominences on each side of the elbow-joint. Their peculiar arrangement with respect to the humerus is because in man, as in most tetrapods, the normal position of the forearm is one of pronation and in this position the back of the forearm is in line with the radial epicondyle, the front with the ulnar epicondyle. The dorsal or extensor muscles, springing from the lower end of the humerus (fig. 430), get the most direct purchase when attached to the radial epicondyle, and the ventral or flexor muscles (fig. 433), the most direct purchase when attached to the ulnar epicondyle. The two divisions of the musculature may therefore here be designated the radiodorsal and the ulnovolar or volar divisions. The main bulk of the musculature is found in the upper part of the forearm. At the wrist numerous tendons pass over to the wrist, palm and digits. This arrangement facilitates movement of the hand. In the **hand**, all intrinsic muscles belong to the volar division.

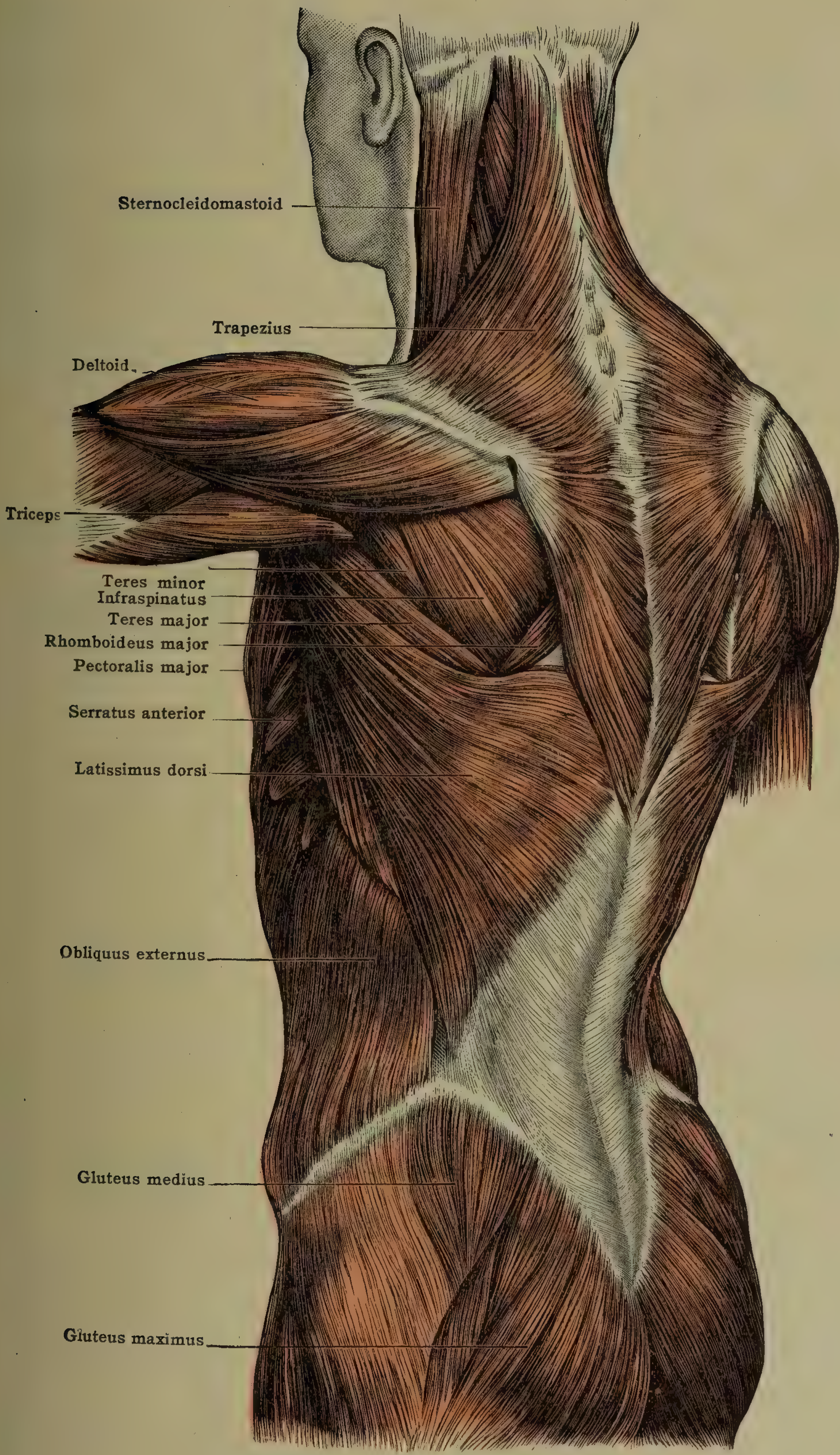


FIG. 417.—FIRST LAYER OF MUSCLES OF THE BACK.

Fasciæ.—The muscle fasciæ of the upper extremities are well developed. The deltoid and latissimus dorsi are contained in a fascial sheet which extends between them. The deeper muscles which arise from the scapula are covered by strong fasciæ. Of the pectoral muscles the pectoralis major is covered by a delicate fascia, while the subclavius and pectoralis minor are contained within the dense *costocoracoid membrane* (fig. 420) which extends into the fascia covering the axillary fossa. The latter (fig. 421), is thin and is intimately fused to the tela subcutanea. The muscles of the arm are enveloped in a cylindrical sheath which in the lower half of the arm is united to the humerus by intermuscular septa.

In the forearm near the wrist and on the back of the hand the tela subcutanea contains little fat. The antibrachial fascia forms a cylindrical enclosure for the muscles of the forearm. Near the wrist it becomes strengthened dorsally to form the dorsal ligament of the carpus (posterior annular ligament). This ligament converts the grooves on the back of the radius into canals for the tendons of the extensors of the wrist and fingers. On the back of the hand and fingers the fascia is intimately connected with these tendons. On the volar side near the wrist the fascia is strengthened to form the volar ligament of the carpus. Beneath the ligament lies the transverse ligament of the carpus which extends from the pisiform and hamate bones to the tuberosities of the navicular and greater multangular bones. It completes an osteofibrous canal for the tendons of the long flexors of the fingers. On the palm of the hand the fascia is firmly bound to the bones by intermuscular septa, which separate the thenar and hypothenar regions from a central palmar region. On the volar sides of the fingers the fascia forms the vaginal ligaments of the flexor tendons.

A. MUSCULATURE OF THE SHOULDER

(Figs. 417–419, 425, 452)

The muscles belonging to this group are the deltoid, the teres minor, the infra- and supraspinatus, the latissimus dorsi, the teres major, and the subscapularis.

The **deltoid** (fig. 417) is a large, shield-shaped muscle which covers the shoulder. It arises from the spine of the scapula, the acromion, and lateral third of the clavicle and is inserted into the deltoid tubercle of the humerus. It abducts, rotates, flexes and extends the arm.

The teres minor, infra- and supraspinatus form a group of muscles (fig. 425) which arise from the back of the scapula, pass over the capsule of the shoulder-joint, to which their tendons are adherent, and, under cover of the deltoid, are inserted into the top and the dorsal margin of the great tubercle of the humerus. The band-like **teres minor** arises from the upper two-thirds of the axillary border of the scapula, and has the lowest insertion on the tubercle. The triangular **infraspinatus** (fig. 425) arises from the whole infraspinous fossa except the axillary border, and is inserted above the teres minor. The pyramidal **supraspinatus** (fig. 425) arises under cover of the trapezius from the supraspinous fossa, and has the highest insertion on the tubercle. The teres minor, supraspinatus and infraspinatus act as lateral rotators of the arm, the supraspinatus also as an abductor.

The latissimus dorsi, the teres major, and the subscapularis form a group of muscles attached to the lesser tubercle of the humerus and to the crest which extends distally from this on the medial side of the intertubercular (bicipital) groove. The **latissimus dorsi** (figs. 417, 418) is a large, flat, triangular muscle, which arises from an aponeurosis covering the lumbar and the lower half of the thoracic regions of the back and from the posterior part of the iliac crest, and is inserted into the intertubercular (bicipital) groove. The **teres major** (figs. 417, 418) is a thick, ribbon-shaped muscle which arises from the dorsal surface of the inferior angle of the scapula and is inserted behind the latissimus dorsi into the distal two-thirds of the crest of the small tubercle of the humerus. The **subscapularis** (fig. 418) is a thick, triangular muscle which extends from the subscapular fossa to the small tubercle of the humerus. These muscles adduct the arm and rotate it medialward. The latissimus dorsi is also the chief extensor of the arm.

Near their humeral attachments these two groups of muscles are separated below by the long head of the triceps. The supraspinatus is separated from the subscapularis by the base of the coracoid process and by the intertubercular (bicipital) groove. The tendons of the latissimus dorsi, teres major, and subscapularis are crossed ventrally by the main vessels and nerves of the arm and by the short head of the biceps and the coracobrachialis.

The supra- and infraspinatus muscles are supplied by the suprascapular nerve. The deltoid and the teres minor are supplied by the axillary (circumflex). The subscapularis, the teres major, and the latissimus dorsi are supplied by subscapular nerves. That to the latissimus dorsi is called the thoracodorsal nerve.

The deltoid in many of the mammals and the lower vertebrates is represented by separate scapulohumeral and cleidohumeral portions. The cleidomastoid in some mammals is continued into the deltoid The teres minor, which is innervated by the same nerve, may be looked upon as a derivative of the deltoid although in man it is anatomically more intimately connected with the infraspinatus. The teres major may be looked upon as a specialised portion of the more primitive latissimus dorsi. The comparative anatomy of the shoulder muscles throughout the vertebrate series is a somewhat intricate subject, owing to the great variations exhibited in the form and attachment of the shoulder girdle.

The muscles of this group show more or less marked resemblances to certain muscles of the lower limb. The deltoid and the teres minor probably represent the tensor fasciæ latæ, the gluteal fascia, and the upper part of the gluteus maximus; the latissimus dorsi and teres major, the lower portion of the gluteus maximus; and the subscapularis, the gluteus medius and minimus, and the piriformis. The subscapular and axillary nerves, which supply the arm muscles mentioned, therefore represent in the main the nerves to the gluteal muscles, and the gluteal branch of the posterior cutaneous nerve of the thigh. The infraspinatus muscle probably represents the iliacus; the supraspinatus possibly the pectineus muscle of the lower limb.

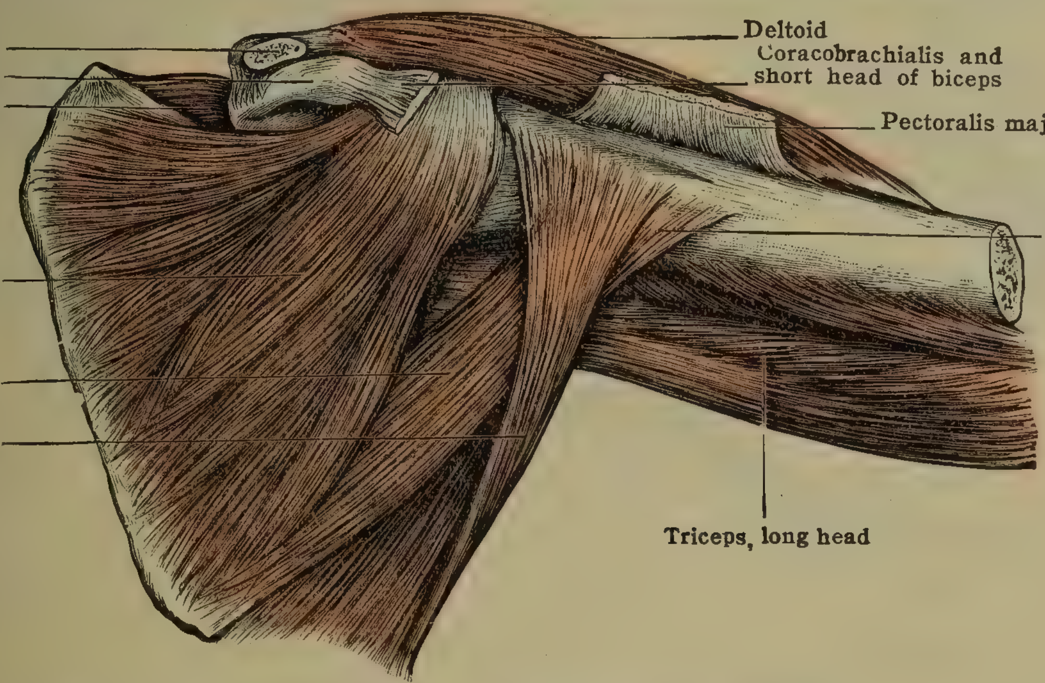


FIG. 418.—FRONT VIEW OF THE SCAPULAR MUSCLES.

FASCIÆ

(Figs. 413, 419, 420, 421, 424)

The **tela subcutanea** covering the regions occupied by these muscles contains considerable fat. In most regions it is not readily separable into two distinct layers. In the neighborhood of the shoulder-joint it is adherent to the underlying musculature and the axillary fasciæ. Over the acromion there is a well-marked subcutaneous bursa, **bursa subcutanea acromialis.**

Muscle fasciæ.—The deltoid and latissimus dorsi muscles are throughout the greater part of their extent superficially placed. They are covered by an adherent fascial layer, which above is attached to the clavicle and to the spine of the scapula. Ventrally it is continued over and fuses with the fascia covering the pectoralis major, serratus anterior, and external oblique muscles. On the back it extends as a thin sheet between the dorsal margin of the deltoid and the upper margin of the latissimus dorsi, and is continued dorsally into the fascial investment of the rhomboid muscles. The lateral fascial extension of the trapezius becomes fused to the dorsal surface of this sheet. Toward the armpit the fascial investment of the deltoid and latissimus dorsi muscles is continued into the axillary fascia, and on the back of the arm it is continued into the fascial investment of the triceps.

The supraspinatus muscle lies beneath the trapezius. It is covered by a dense adherent fascial layer which is separated from the trapezius by loose connective tissue which usually contains a considerable amount of fat.

The infraspinatus and the two teres muscles lie beneath the musculofascial layer composed of the deltoid, the latissimus dorsi, and the fascial sheet described above. Each of the three muscles has a special fascal investment which is bound to the scapula about the region of attachment of the muscle to the bone Where two of the muscles adjoin, their fasciæ give rise to intermucular septa. Septa of this nature are found between the infraspinatus and each of the teres muscles, and between the teres minor and the teres major. The intermuscular septum between the infraspinatus and teres minor muscles is often incomplete. The fascia covering the teres major is so delicate as hardly to deserve the name, except near the origin of the muscle. Near the spine the fascia covering the deep surface of the deltoid is often fused to that covering the infraspinatus.

The subscapularis muscle is invested by a moderately dense fascia which is bound to the scapula along the periphery of the attachment of the muscle. For a short distance this fascia is fused with the fascial investment of the teres major near the origin of the latter muscle, so that an intermuscular septum is formed. From the ventrolateral margin of the fascia covering the subscapularis muscle a sheet of fascia is continued below the axillary fascia into the fascia covering the serratus anterior (magnus).

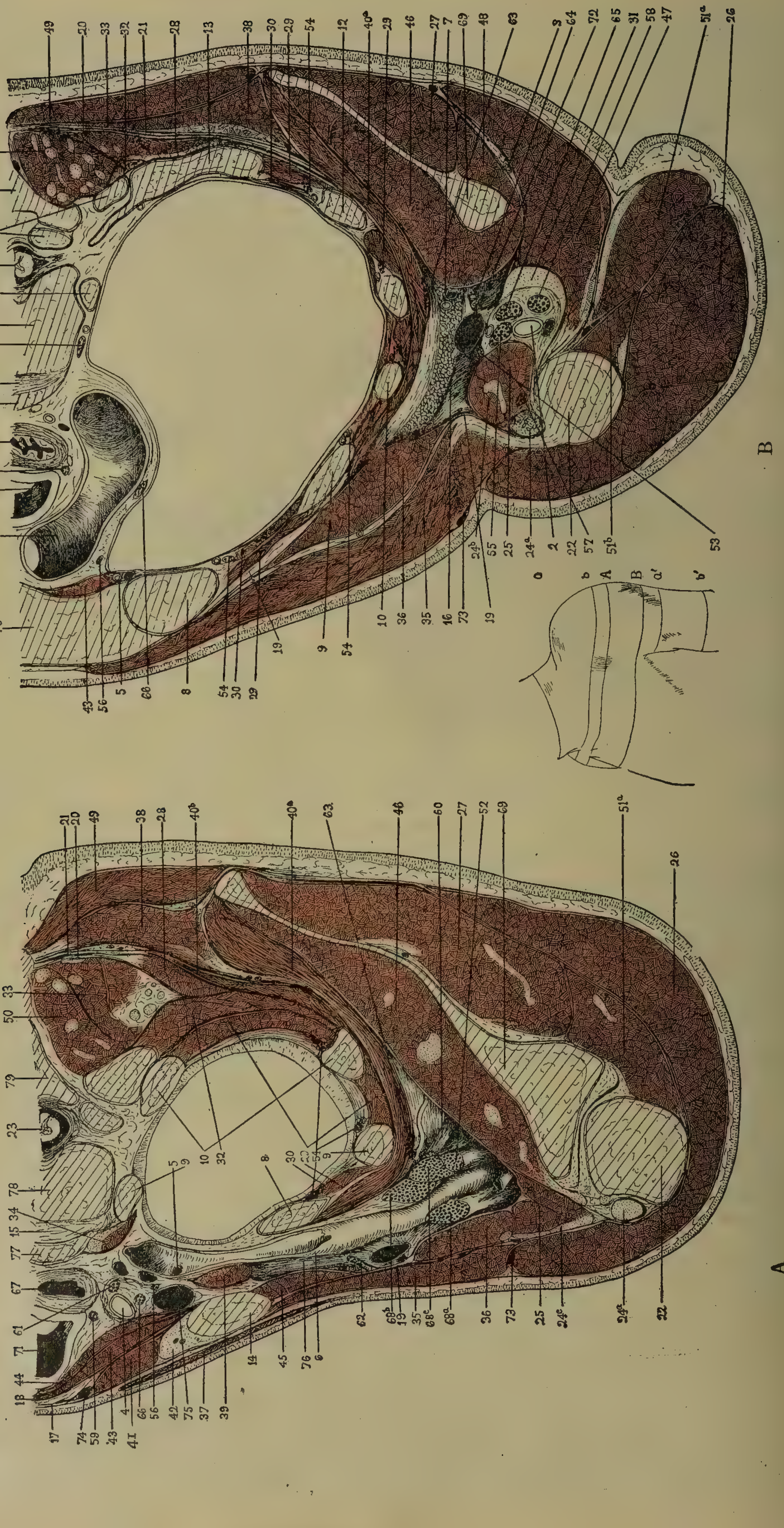


FIG. 419.

SHOULDER MUSCLES

The **deltoideus** [M. deltoides] (figs. 417, 420, 422).—*Origin.*—Fleshy from the lateral border and upper surface of the acromion and from the ventral border and upper surface of the lateral third of the clavicle, and tendinous from the spine of the scapula. Some fiber-bundles also at times arise from the deep fascia of the muscle where it overlies and is fused to the fascia of the infraspinatus muscle near the spine.

Insertion.—Into the deltoid tuberosity of the humerus by a strong tendon arising from numerous tendinous bands within the muscle (fig. 426).

Structure.—In structure the deltoid muscle is complex. Three portions may be recognized: —a clavicular, an acromial, and a spinous. The first and last are composed of long fiber-bundles which take a slightly converging course and are inserted by aponeurotic tendons respectively on the front and back of the V-shaped area of insertion of the muscle. The acromial portion, on the other hand, is multipenniform in composition. Four or five tendinous expansions descend into the muscle from the acromion, and three up into the muscle from the tendon of insertion. From the acromion and from the descending tendinous processes fiber-bundles run to be inserted on the sides of the ascending processes and into the tendons of insertion of the clavicular and spinous portions of the muscle.

Nerve-supply.—The axillary (circumflex) nerve passes across the costal surface of the muscle near the tendon of insertion and gives off rami which enter lateral to the middle of the muscle. The nerve fibers are derived from the (fourth), fifth, and sixth cervical nerves.

Action. When the whole muscle contracts, the arm is abducted (raised laterally), to a horizontal position. When the clavicular and acromial parts act, the arm is raised and flexed (brought forward toward the chest). When the acromial and spinous parts act, the arm is raised and extended (carried toward the back), but in this instance the arm is not brought to a level with the shoulder-joint, but only about 45° from the hanging position. The inferior part of the serratus anterior and the trapezius act in conjunction with the deltoid in abduction. Abduction is greatest when the arm is rotated lateralward. The ventral portion rotates the arm medially, the dorsal portion laterally. When the arm is fixed, the deltoid carries the inferior angle of the scapula toward the spinal column and away from the thorax.

Relations.—On its ventral border the deltoid is in contact with the pectoralis major muscle. Near the clavicle the cephalic vein and a small artery pass between the two muscles. Its dorsal border is continued into a dense fascial sheet which overlies the infraspinatus muscle. Its tendon of insertion passes between the biceps and triceps muscles. The deltoid overlies the coracoid process and upper extremity of the humerus, the coracoclavicular and coraco acromial ligaments, and the insertions of the supraspinatus, infraspinatus, and teres minor muscles, the origins of the biceps and coracobrachialis, and a part of the long and lateral heads of the triceps. Beneath it run the posterior circumflex artery and axillary (circumflex) nerve.

Variations.—The clavicular portion is frequently separate from the rest of the muscle. The three portions may be distinctly separate—a condition normal in some of the lower mammals. The clavicular and acromial portions have been found missing. The deep portion of the muscle may be separated as a distinct layer and inserted either into the capsule of the joint or into humerus. Accessory fasciculi may pass into the muscle from the fascia over the infraspinatus and from the vertebral and axillary borders of the scapula. Not infrequently fasciculi are con-

---

FIG. 419.—A AND B.—TRANSVERSE SECTIONS THROUGH THE LEFT SHOULDER IN THE REGIONS INDICATED IN THE DIAGRAM.

In the neighborhood of the brachial plexus in each section some of the adipose and lymphatic tissue has been removed. In section B the fascia covering the apex of the axillary fossa is thus revealed from above. *a* and *b* in the diagram indicate the regions through which pass sections A and B, fig. 413; *a′* and *b′*, the regions through which pass sections A and B, fig. 424.

1. Aorta. 2. Arteria brachialis. 3. A. circumflexa scapulæ (dorsalis scapulæ). 4. A. carotis communis. 5. A. mammaria interna. 6. A. subclavia. 7. A. thoracalis lateralis (long thoracic). 8. Costa I. 9. Costa II. 10. Costa III. 11. Costa IV. 12. Costa V. 13. Costa VI. 14. Clavicle. 15. Fibrocartilago intervertebralis. 16. Fascia axillaris. 17. Fascia cervicalis (superficial layer). 18. Fascia cervicalis (middle layer). 19. F. coracoclavicularis. 20. F. lumbodorsalis. 21. Fascia of posterior serrati. 22. Humerus. 23. Medulla spinalis (spinal cord). 24. Musculus biceps—*a*, long head; *b*, short head; *c*, tendon of short head. 25. M. coracobrachialis. 26. M. deltoideus. 27. M. infraspinatus. 28. M. iliocostalis dorsi (accessorius). 29. M. intercostales externi. 30. M. intercostales interni. 31. M. latissimus dorsi, tendon. 32. M. levator costæ. 33. M. longissimus dorsi. 34. M. longus colli. 35. M. pectoralis major. 36. M. pectoralis minor. 37. M. platysma. 38. M. rhomboideus major. 39. M. scalenus anterior. 40*a*. M. serratus anterior. 40*b*. M. serratus posterior superior. 41. M. sternomastoideus. 42. M. cleidomastoideus, insertion. 43. M. sternohyoideus. 44. M. sternothyreoideus. 45. M. subclavius. 46. M. subscapularis. 47. M. teres major. 48. M. teres minor. 49. M. trapezius. 50. M. transversospinales. 51. M. triceps—*a*, long head; *b*, lateral head. 52. Nervus axillaris 53. N. cutaneus antibrachii medialis (internal cutaneous). 54. *a–e*, Nn. intercostales I–V. 55. N. medianus. 56. N. phrenicus. 57. N. musculocutaneus. 58. N. radialis. 59. N. recurrens. 60. N. subscapularis. 61. Sympathetic trunk. 62. N. thoracalis anterior. 63. N. thoracalis longus. 64. N. thoracodorsalis (long subcapular). 65. N. ulnaris. 66. N. vagus. 67. Esophagus. 68. Plexus brachialis —*a*, lateral fasciculus; *b*, medial; *c*, posterior. 69. Scapula. 70. Sternum. 71. Trachea. 72. Venæ brachiales. 73. V. cephalica. 74. V. jugularis anterior. 75. V. jugularis inferior. 76. V. subclavia. 77. Vertebra I. 78. Vertebra II. 79. Vertebra III. 80. Vertebra IV. 81. Vertebra V. 82. Vertebra VI.

tinued into the muscle from the trapezius—a condition normal in animals with ill-developed clavicles. An accessory tendon of insertion may extend to the radial side of the forearm. Bundles of fibers from the axillary border of the scapula have been seen to cross the deep surface of the deltoid and be inserted into the deltoid fascia. The deltoid may be fused with neighboring muscles, the pectoralis major, trapezius, infraspinatus, brachialis, brachioradialis.

The teres minor (fig. 425).—*Origin.*—From the upper two-thirds of the axillary border of the infraspinous fossa, and from the septa lying between it and the infraspinatus on the one side and the teres major and subscapularis on the other. The origin is in part fleshy, in part from an aponeurotic band on its ventral surface toward the subscapularis muscle.

Structure and insertion.—The fiber-bundles from this origin take a slightly converging course toward a tendon of insertion which extends for some distance on the dorsal surface of the muscle. The muscle is adherent to the capsule of the joint, and terminates on the inferior of the three facets of the great tubercle of the humerus and the posterolateral aspect of that bone for two or three centimeters below the facet.

Nerve-supply.—From a branch of the axillary (circumflex) nerve which enters the muscle on its lateral margin about midway between its extremities. A branch from the nerve to the teres major has also been reported. The nerve fibers are derived from the fifth cervical nerve.

Action.—It acts conjointly with the infraspinatus to rotate the arm laterally. It is a flexor when the arm is down and an extensor when the arm is abducted. It is also an adductor.

Relations.—The muscle is in part covered by the deltoid. Ventrally it enters into relations with the long head of the triceps, the teres major, and the subscapularis. Superiorly, the circumflex (dorsal) scapular vessels run between it and the axillary border of the scapula.

Variations.—Aside from its frequent fusion with the infraspinatus there has also been reported an isolation of a special fasciculus to the subtubercular attachment.

The infraspinatus (fig. 425).—*Origin.*—From the vertebral three-fourths of the infraspinous fossa, from the under surface of the spine, from the enveloping fascia and from intermuscular septa between it and the two teres muscles.

Structure and insertion.—The fiber-bundles converge toward the lateral angle of the scapula to be attached to a deep-seated tendon which is adherent to the capsule of the joint and is attached to the middle facet of the great tubercle. The fiber-bundles arising from the inferior surface of the spine and the fascia near this form a distinct fasciculus which descends on and covers the tendon of insertion.

Nerve-supply.—From the suprascapular nerve, which passes beneath the supraspinatus muscle and enters the deep surface of the infraspinatus in the lateral part of the middle third of its upper margin. From here rami spread out toward the vertebral border of the muscle and toward the humeral insertion. The nerve fibers are derived from the fifth and sixth cervical nerves.

Action.—This muscle is the chief lateral rotator of the arm, a movement that can be carried through 90°. The upper part of the muscle is an abductor, the lower part an adductor of the arm. The muscle is also a flexor.

Relations.—The deltoid and trapezius, and sometimes the latissimus dorsi muscles, cover a portion of the dorsal surface. Over most of it extends the complex fascia described above. Laterally it adjoins the teres minor and major muscles. Under the muscle lie the transverse (suprascapular) and circumflex (dorsal) scapular vessels.

Variations.—These are rare, aside from a greater or less independence of the bundles arising from the spine and a greater or less complete fusion with the teres minor. A fasciculus has been seen extending to the muscle from the deltoid.

The supraspinatus (fig. 425).—*Origin.*—Fleshy from the medial two-thirds of the supraspinous fossa and from the deep surface of the enveloping fascia near the vertebral end.

Structure and insertion.—The fiber-bundles converge upon a deep-seated tendon nearly to its attachment into the highest of the three facets on the great tubercle of the humerus.

Nerve-supply.—Two branches from the suprascapular nerve enter the middle third of the deep surface of the muscle. The nerve fibers are derived from the fifth cervical nerve.

Action.—It aids the deltoid in abducting the arm. It is also a weak lateral rotator and flexor. It keeps the head of the humerus in place during abduction of the arm.

Relations.—The muscle is covered by the trapezius, the acromion, and the coracoacromial ligament. Beyond the base of the spine of the scapula it comes into contact with the infraspinatus muscle. Beneath the muscle pass the suprascapular nerve and transverse scapular (suprascapular) vessels.

Variations.—The muscle shows slight variations. Its tendon may be fused with that of the infraspinatus. Its belly may be reinforced by fiber-bundles from the coracoacromial ligament.

The latissimus dorsi (figs. 417, 418, 451, 452).—*Origin.*—(1) From an aponeurosis attached to the spines and interspinous ligaments of the five or six last thoracic and the upper lumbar vertebræ, to the lumbodorsal fascia, and to the posterior third of the external lip of the crest of the ilium; (2) from the external surface and upper margin of the last three or four ribs by muscular slips which interdigitate with those of the external oblique. In the lumbar region the aponeuroses of the right and left muscles are connected by fibrous fasciculi which cross the mid-dorsal line above the supraspinous ligament.

Structure and insertion.—From this extensive area of the origin fiber-bundles converge toward the tendon of insertion. In the region of the dorsal wall of the axillary fossa the muscle is concentrated into a thick, ribbon-like band which winds about the teres major and passes to the ventral surface of that muscle. As this takes place the fiber-bundles become applied to each surface of a flat tendon, which, after emerging from the muscle, is six to eight cm. long and three to five cm. broad, and is inserted into the ventral side of the crest of the lesser tubercle of the humerus and into the depth of the intertubercular (bicipital) groove immediately ventral to the tendon of the teres major. With this it is more or less closely bound, although between the tendons there lies a serous bursa. Some of the fasciculi of the tendon extend to the crest of the greater tubercle. Frequently a tendon slip passes from the inferior margin of the tendon

to the tendon on the posterior surface of the long head of the triceps or into the brachial fascia (see *latissimo-condyloideus*, p. 445).

Like the teres major, with which it is closely associated, the latissimus dorsi muscle undergoes a torsion between its origin and its insertion, so that the dorsal surface of the muscle is continued into the ventral surface of the tendon and the most cranially situated of the fiber-bundles are most distally attached to the humerus, and *vice versa*. The muscle either directly or through its fascial extension is often adherent to the inferior angle of the scapula.

Nerve-supply.—From the thoracodorsal (long subscapular) nerve (from the sixth, seventh and eighth cervical nerves). This nerve, which may arise in conjunction with the axillary nerve, passes to the deep surface of the muscle in the lower part of the axilla, and here gives rise to rami which diverge as the muscle expands toward its tendons of origin. Though soon embedded in the muscle substance, two main branches may be followed for a considerable distance near the deep surface of the muscle. One usually extends near the lateral, the other near the superior, border of the muscle, and from these large rami pass into the intervening region. Branches of the dorsal thoracic artery and vein accompany the nerve.

Action.—With the trunk fixed, the latissimus dorsi draws the raised arm down and backward and rotates it medialward (swimming movement). When the arm is hanging by the side, the action of the muscle is on the scapula. The upper third of the muscle draws the scapula toward the spine, the inferior two-thirds depress the shoulder. When the humerus is fixed, the latissimus serves to lift the trunk and pelvis forward, as in climbing. It also aids in forced inspiration through its costal attachments.

Relations.—The trapezius covers a small portion of the muscle in the midthoracic region of the back. Over a large area it is subcutaneous, and its fascial investment is adherent to the skin. As it winds about the teres major its tendon comes to lie behind the coracobrachialis muscle. The main nerves and vessels of the arm here pass across its ventral surface. The muscle covers in part the rhomboideus major, the infraspinatus, teres major, serratus posterior inferior, the lower ribs, the external intercostal muscles, the dorsal border of the external and internal oblique muscles, and the lower dorsal part of the serratus anterior (magnus).

Variations.—It may show considerable variation in the extent of its fleshy portion and in the attachment of its aponeurosis to the vertebral column, crest of the ilium, the ribs, and the scapula. Its origin may be merely from the ribs. It may be divided into separate fasciculi. Frequently a fasciculus arises from the inferior angle of the scapula. The muscle is often intimately united to the teres major. For an account of the muscular slip which extends from the latissimus dorsi across the axillary fossa to the tendon of the pectoralis major near the intertubercular (bicipital) groove see the latter muscle (p. 438); and for the slip continued from the tendon of the latissimus dorsi to the olecranon see the Triceps Muscle (p. 444).

The teres major (figs. 418, 452).—*Origin.*—Directly from the dorsal surface of the inferior angle of the scapula and from the septa which lie between this muscle and the subscapularis, teres minor, and infraspinatus muscles.

Insertion.—For about five or six cm. from the lower border of the small tubercle of the humerus, along the medial lip of the intertubercular (bicipital) groove. Proximally the fiber bundles are attached directly to the tubercle; more distally the attachment is by means of a flat tendon which extends for some distance on the dorsal surface of the muscle.

Structure.—The nearly parallel fiber-bundles pass upward in a spiral direction so that the muscle undergoes a torsion on its axis. The fiber-bundles which have the highest attachment to the scapula have the lowest humeral attachment, and *vice versa*.

Nerve-supply.—By a branch of the lower subscapular nerve which enters the muscle near the middle of its scapular border. The nerve fibers are derived from the fifth, sixth (and seventh) cervical nerves.

Action.—It aids the latissimus dorsi in adducting the arm, and in some positions of the arm acts as a medial rotator and as an extensor.

Relations.—Dorsally the muscle is covered by the latissimus dorsi and by the fascia which extends from this muscle to the deltoid and rhomboid muscles. It is also crossed by the long head of the triceps. Its lower border and ventral surface are largely covered by the latissimus dorsi and its tendon. Its upper border helps to bound a triangular space the other sides of which are the borders of the scapula and the humerus. In front lies the subscapularis, and behind, the teres minor. Across this space passes the long head of the triceps. Lateral to this head lie the humeral circumflex vessels and axillary (circumflex) nerve; and medial, the circumflex (dorsal) scapular artery.

Variations.—The teres major may be connected with the latissimus dorsi by a fasciculus, or it may be fused with that muscle or its tendon. Slips have also been seen extending to the triceps and into the fascia of the arm. The muscle is rarely absent.

The subscapularis (figs. 418, 452).—*Origin.*—The fiber-bundles spring—(1) directly and by means of tendinous bands from the costal surface of the scapula, except near the neck and at the upper and lower angles; and (2) from intermuscular septa between it and the teres major and teres minor muscles.

Insertion.—The tendon of insertion as it passes over the capsule of the joint is intimately bound to this. It is inserted into the lesser tubercle of the humerus and into the shaft immediately below this.

Structure.—The fiber-bundles arising from the tendinous bands attached to the bone converge upon several tendinous laminæ which extend into the muscle from the tendon of insertion, thus forming small penniform fasciculi. The fiber-bundles arising directly from the bone converge toward the extremities of the tendinous laminæ, thus forming triangular bundles interdigitating with the penniform fasciculi. The fasciculus which arises highest on the axillary border goes directly to the humerus.

Nerve-supply.—By two or three subscapular branches from the back of the brachial plexus. One or more of these may arise in association with the axillary (circumflex) nerve. From the main nerves rami spread out to enter the ventral surface of the muscle near the junction of the lateral and middle thirds. The nerve fibers come from the fifth and sixth cervical nerves.

Action.—It is the chief medial rotator of the arm. It strengthens the shoulder-joint by drawing the humerus toward the glenoid cavity. It is an extensor when the arm is at the side, a flexor when the arm is abducted. The upper portion of the muscle, however, acts as a flexor in both positions. The upper part acts as an abductor but when the arm is abducted the muscle is an adductor.

Relations.—Ventrally it forms the greater part of the posterior wall of the axillary fossa, and enters into relation with the serratus anterior (magnus) and the combined tendon of the coracobrachialis and biceps. On it lie the axillary vessels, the brachial plexus, and numerous lymph-vessels and glands. At its lateral border lie the teres major, the humeral circumflex vessels, axillary (circumflex) nerve, and circumflex (dorsal) scapular vessels. Behind it lie the long head of the triceps and the teres minor muscle.

Variations.—It may be divided into several distinct segments. A fasciculus may be sent to the tendon of the latissimus dorsi and another to the brachial fascia. The **subscapularis minor** arises from the axillary border of the scapula and is inserted into the articular capsule (capsular ligament) of the shoulder-joint or into the crest of the lesser tubercle of the humerus.

Bursæ

B. subacromialis.—A large bursa, nearly constantly found, between the acromion and coracoacromial ligament and the insertion of the supraspinatus muscle and capsule of the joint. Processes extend over the greater and lesser tubercles.

B. supracoracoidea.—A bursa sometimes found between the coracoid process and the clavicle and the deltoid muscle.

B. m. subscapularis.—Between the glenoid border of the scapula and the subscapularis muscle. Communicates with the joint cavity. A small portion of this bursa may be isolated adjacent to the base of the coracoid process (*b. subcoracoidea*).

B. m. infraspinati.—Between the tendon of the infraspinatus and the capsule of the joint or the great tubercle.

B. m. latissimi dorsi.—Constant between the tendons of the latissimus dorsi and the teres major.

B. m. teretis majoris.—Under the insertion of the tendon of the teres major muscle.

B. PECTORAL MUSCLES AND AXILLARY FASCIA

(Figs. 419–423, 452)

The muscles belonging to this group are the pectoralis major, pectoralis minor, and the subclavius. Of these, the largest and most superficial is the triangular **pectoralis major** (fig. 422), which arises from the second to the sixth ribs, the sternum, and the medial half of the clavicle and is inserted into the crest of the greater tubercle of the humerus (pectoral ridge). Its lateral margin adjoins the ventral margin of the deltoid. Beneath this muscle the much smaller triangular **pectoralis minor** (fig. 452) extends from near the ends of the second, third, fourth, and fifth ribs to the tip of the coracoid process, while the small **subclavius** (fig. 423) extends from the first rib upward and lateralward to the clavicle. The pectoralis major adducts and flexes the arm and rotates it medialward. The pectoralis major, pectoralis minor and subclavius muscles draw the glenoid cavity downward and forward. The nerve supply is from special branches from the front of the brachial plexus.

Of the muscles included in this group, the two pectoral muscles are morphologically the most closely related. They receive a nerve-supply from the same set of nerves, the anterior thoracic. With them the subclavius, which has a separate nerve of its own, is closely associated. Corresponding musculature, although variously modified in different forms, is found throughout the vertebrate series. In the lower forms it seems to be differentiated directly from the segmental trunk musculature and secondarily attached to the shoulder-girdle, like the superficial and deep musculature of the shoulder-girdle previously described. In man, however, the muscle mass from which these muscles arise is at all times in intimate union with the skeleton of the upper limb, and the nerves which supply it are in much more intimate union with the brachial plexus than are those of the shoulder-girdle muscles. For these reasons the three muscles are classed with the intrinsic muscles of the arm. They have no certain representatives in the lower limb, although the clavicular portion of the pectoralis major is considered by some to represent certain adductor muscles of the thigh. Possibly they correspond in their embryonic origin with the obturator internus group of the lower limb.

In many of the mammals a subcutaneous muscle arises from the pectoral muscle mass and extends over the axilla and the trunk. In man this musculature is frequently represented by abnormal slips of muscles, of which the 'axillary arch' and possibly the 'sternalis' are representatives. A list of some of the abnormal muscles which are innervated from the anterior thoracic nerves and are evidently derivatives of the pectoral muscle mass is given at the end of this section.

FASCIÆ

In the tela subcutanea of the pectoral region the mammary gland is embedded between two layers which ensheath the gland and are connected by dense fiber-bands. To a greater or less extent the platysma extends into the tela of this region from above the clavicle.

Muscle fasciæ.—The pectoralis major is invested with a thin, adherent membrane, **fascia pectoralis**, attached to the clavicle and the sternum and continued into the fascial investment of the external oblique, the serratus anterior (magnus), and the deltoid muscles and in to the axillary fascia. More important is the **coracoclavicular** (costocoracoid) **fascia** (fig. 420). This arises from two fascial sheets which invest the subclavius muscle and are attached to the clavicle. From the inferior margin of this muscle the membrane is continued to the superior margin of the pectoralis minor. Between the coracoid process and the first costal cartilage it is strengthened to form the **costocoracoid ligament.** Between this and the pectoralis minor it is thin. At the superior margin of this muscle it again divides to form two adherent fascial sheets, which, at the axillary margin of the muscle, once more unite to form a firm membrane continued into the fascial investment of the coracobrachialis and short head of the biceps and into the axillary fascia. Above, dorsally, the membrane is adherent to the sheath of the axillary vessels and nerves.

Axillary fascia (figs. 420, 421).—The **axilla** or **axillary fossa** is a pyramidal space above the (external) arm-pit and bounded by the pectoralis major and minor and coracobrachialis muscles in front; by the latissimus dorsi, teres major, and subscapularis muscles behind; by the subscapularis muscle toward the joint; and by the serratus anterior (magnus) toward the thoracic wall. In the groove between the coracobrachialis and the subscapularis and tendons of the latissimus dorsi and teres major muscles run the main nerves and vessels of the arm. These are surrounded by a considerable amount of connective tissue in which numerous blood-

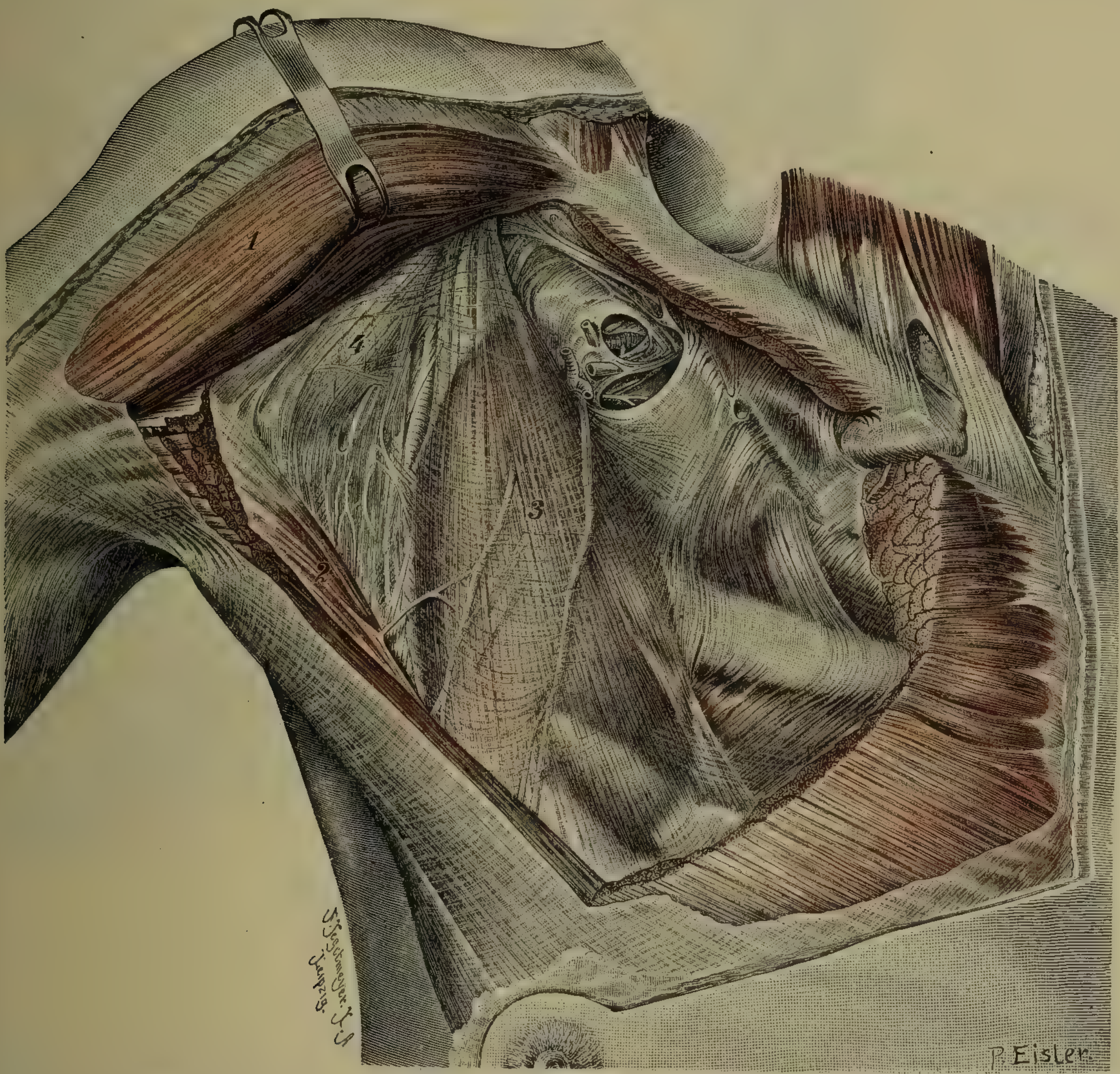


FIG. 420.—DEEP FASCIA OF THE BREAST. (AFTER EISLER). THE PECTORALIS MAJOR HAS BEEN IN LARGE PART REMOVED. 1, Deltoid; 2, pectoralis major, abdominal part; 3, pectoralis minor; 4, coracobrachialis.

and lymph-vessels, lymph-nodes, nerves, and masses of fat are embedded. For topography, see fig. 419.

Over this connective tissue the fascia covering the musculature of the neighboring portion of the shoulder and thorax is continued into the fascia covering the musculature of the medial side of the arm. Thus the fascia covering the pectoralis minor, the coracoclavicular fascia, strengthened by a reflection of the fascial investment of the pectoralis major and deltoid muscles is continued across the ventral margin of the axilla into the fascia which covers the coracobrachialis and biceps muscles in the arm. Similarly, dorsally, the fascia covering the latissimus dorsi and teres major is continued over the axilla into that covering the long head of the triceps in the arm. The ventral is connected with the dorsal fascia by a thin membrane which forms the floor of the axillary fossa (fig. 421), and is adherent to the connective tissue filling the axillary space and to the subcutaneous tissue. On the trunk this membrane, the **fascia axillaris,** becomes fused below the axillary fossa with the fascia of the serratus anterior (magnus). In the arm it becomes fused with the fascia over the biceps muscle. Owing to its adherence to the skin and the connective tissue of the axillary fossa, investigators have dissected out and figured the axillary fascia in different ways.

An **axillary abscess**, always to be opened early to avoid subsequent interference with the movements of the shoulder, is reached by an incision on the medial wall, midway between the anterior and posterior boundaries, so as to avoid the long thoracic and subscapular vessels, respectively, the back of the knife being directed toward the lateral wall. The only vessel on this wall is the superior thoracic, which lies high up. Additional safety is given by the use of Hilton's method. For **exploration** of the axilla the best incision is an angular one, the two limbs being placed in a line with the anterior margin of the great pectoral, and in the line of the axillary vessels. This runs from a point on the center of the clavicle (the limb being at a right angle to the trunk) to the medial margin of the coracobrachialis. If this be obliterated by swelling, the above line should be prolonged to the middle of the bend of the elbow, which will give the guide to the brachial vessels also.

Fig. 421.—Fascia of the Axillary Fossa. (After Eisler.)

MUSCLES

The **pectoralis major** (or superficialis NK) (fig. 422).—*Origin.*—(1) From the medial half of the clavicle; (2) from the side and front of the sternum as far as the sixth costal cartilage; (3) from the front of the cartilages of the second to the sixth ribs; and (4) from the upper part of the aponeurosis of the external oblique where this extends over the rectus abdominis muscle. The costal origin may in part take place from the osseous extremities of the sixth and seventh ribs.

Insertion.—Crest of the greater tubercle (outer lip of the bicipital groove) of the humerus from the tubercle to the insertion of the deltoid (fig. 221). Some of the tendon fibers are also continued into the tendon of the deltoid and adjacent fibrous septa and into the fibrous lining of the intertubercular sulcus.

Structure.—The muscle is divisible into a series of overlapping layers spread out like a fan. Of these, the clavicular portion forms the most cranial and superficial layer, and the portion of the muscle springing from the aponeurosis of the external oblique, the most caudal and deepest layer. This last layer has a special tendon, while the other layers are inserted into a combined tendon lying ventral to this. The two tendons are continuous at their distal margins. (W. H. Lewis.)

Nerve-supply.—From the lateral and medial anterior thoracic nerves, branches of which enter the sternocostal portion of the muscle about midway between the tendons of origin and insertion, and the clavicular portion in the proximal third. The nerve fibers are derived from the (fifth), sixth, seventh, and eighth cervical and first thoracic nerves.

Action.—With the thorax fixed, the muscle adducts and flexes the arm and rotates it medialward. The clavicular portion draws the arm forward, upward, and medialward; the sternocostal portion draws the arm downward, medialward, and forward. When the arm is pendent,

the upper portion elevates, the lower depresses, the shoulder. With the arm fixed, the muscle draws the chest upward toward it. It is of value in forced inspiration.

Relations.—It lies over the coracoid process, the subclavius, pectoralis minor, intercostal and serratus anterior (magnus) muscles, the coracoclavicular (costocoracoid) fascia, and the thoracoacromial vessels. It forms the main part of the ventral wall of the axillary fossa, and laterally it enters into relation with the deltoid, biceps, and coracobrachialis muscles.

Variations.—In considering variations the muscle may be looked upon as composed of four portions—a clavicular, a sternal, a costal, and an abdominal, the last being that portion which arises from the aponeurosis of the external oblique. These portions vary in the extent of their attachments and in the degree of separation which they present. The abdominal portion may extend to the umbilicus. Huntington considers this portion a derivative of the panicular muscle of the lower mammals. On the sternum the muscles of the two sides may decussate across the middle line. The sternocostal portions of the muscle are more frequently deficient or missing than the clavicular, but in rare cases the entire muscle is absent. The clavicular portion of the muscle may be fused with the deltoid. The sternocostal may extend laterally to the latissimus dorsi. There may be an intimate fusion of the abdominal portion with the rectus abdominis or the external oblique. Sometimes a slip may run from the pectoralis major to the biceps, the pectoralis minor, coracoid process, capsule of the joint, or brachial fascia.

The **pectoralis minor** (or profundus NK) (fig. 452).—*Origin.*—By aponeurotic slips from the second, third, fourth, and fifth ribs near the costal cartilages.

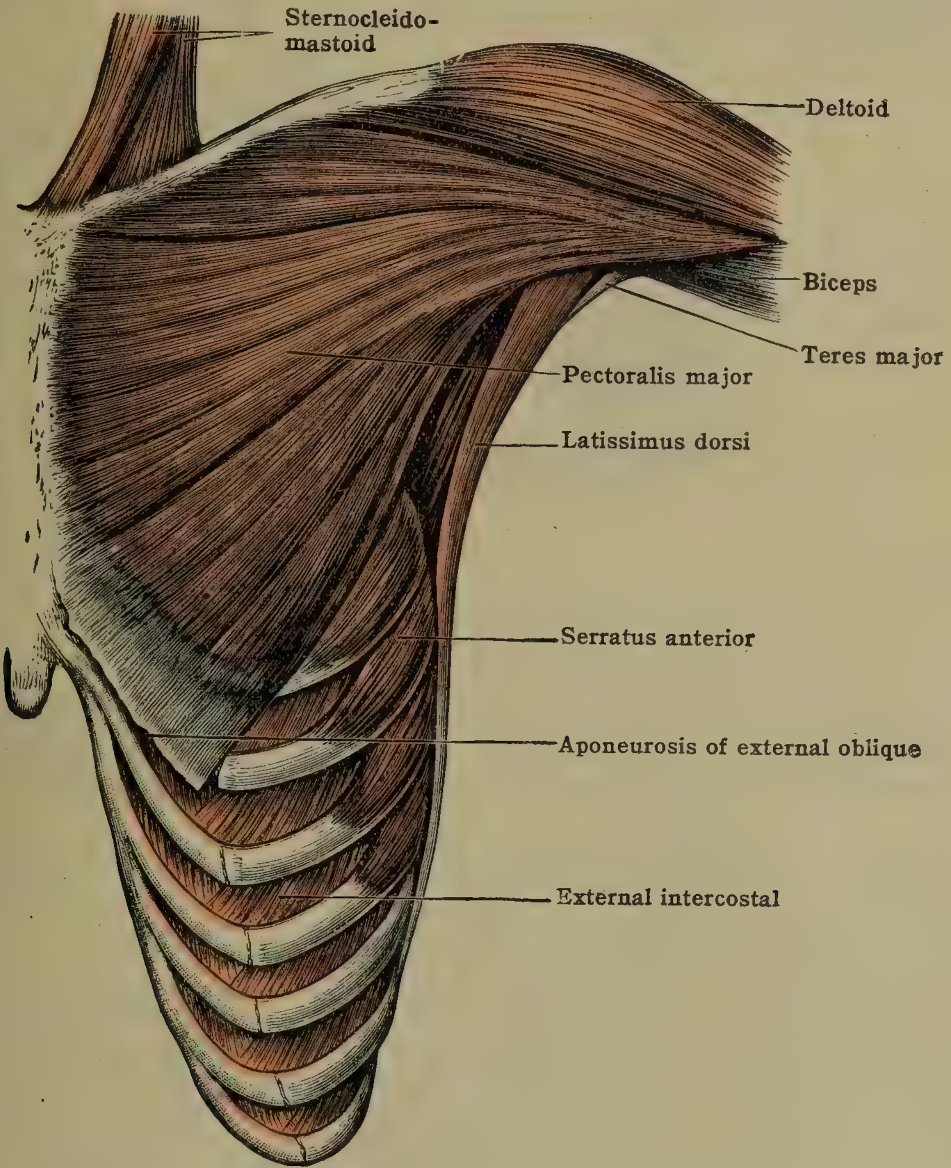


FIG. 422.—THE PECTORALIS MAJOR AND DELTOID.

Structure and insertion.—The fiber-bundles converge upward and outward to a flattened tendon which is attached to the medial border and upper surface of the coracoid process of the scapula.

Nerve-supply.—From the medial anterior thoracic nerve which enters the upper part of the middle third of the deep surface by several branches. Some of the branches extend through to the pectoralis major. The nerve fibers arise from the seventh and eighth cervical nerves.

Action.—When the thorax is fixed, the pectoralis minor pulls the scapula forward, the lateral angle of the bone downward, and the inferior angle dorsalward and upward. When the scapula is fixed, the muscle aids in forced inspiration.

Relations.—It is covered by the pectoralis major. Near its insertion the fibrous investment of the chief nerves and vessels of the arm is adherent to its enveloping fascia.

Variations.—The origin may extend to the sixth rib or may be reduced to one or two ribs. In the primates below man the insertion of the muscle takes place normally into the humerus. In man its insertion may be continued (in more than 15 per cent. of bodies—Wood) over the

coracoid process to the coracoacromial or coracohumeral ligaments, to the tendon of the subscapularis muscle, or to the great tubercle of the humerus. It may be divided into two superimposed fasciculi. Fasciculi may extend from the muscle to the subclavius or the pectoralis major.

The **subclavius** (fig. 423).—*Origin.*—From a flat tendon attached to the first rib and its cartilage near their junction.

Structure and insertion.—The fiber-bundles arise in a penniform manner from the tendon of origin which extends for some distance along the lower border of the muscle. They are inserted in a groove which lies on the lower surface of the clavicle between the costal tuberosity and the coracoid tuberosity. The medial fiber-bundles are inserted directly, the lateral by a strong tendon.

Nerve-supply.—By a branch which arises usually from the fifth or fifth and sixth cervical nerves and enters the middle of the back part of the muscle.

Action.—When the first rib is fixed, the subclavius depresses the clavicle and the point of the shoulder. When the clavicle is fixed, the muscle aids in forced inspiration. It also serves to keep the clavicle against the sternum.

Relations.—It is concealed by the clavicle and pectoralis major muscle. Behind it lie the subclavian vessels and the brachial plexus.

Variations.—It may be replaced by a ligament or by a pectoralis minimus muscle (see below). It may be doubled or may be inserted into the coracoid process, coracoacromial ligament, the acromion, or the humerus. The *subclavius posticus* arises near the subclavius, passes backward over the subclavian vessels and brachial plexus and is inserted into the cranial margin of the scapula near the base of the coracoid process.

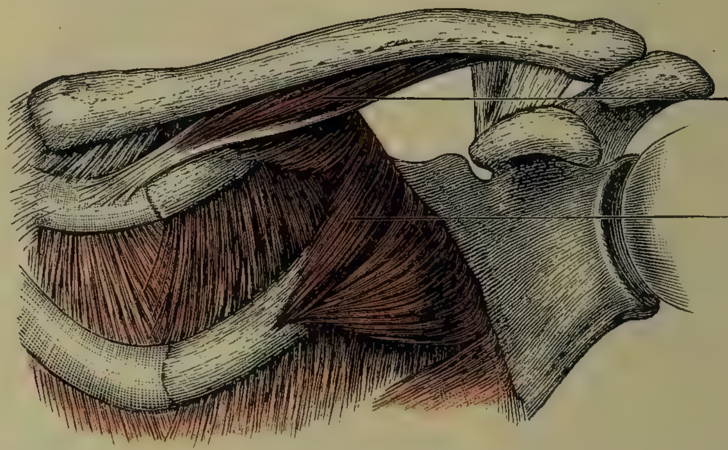


Fig. 423.—The Subclavius and the Upper Portion of the Serratus Anterior.

Abnormal Muscles of the Pectoral Group

The following muscles are usually innervated by the anterior thoracic nerves and are probably generally abnormal derivatives of the pectoral mass. Frequently they represent muscles normally found in lower mammals.

The **sternalis.**—A flat muscle somewhat frequently seen on the surface of the pectoralis major, usually nearly parallel to the sternum. It arises from the sheath of the rectus and from some of the costal cartilages (third to seventh) and terminates on the sternocleidomastoid, on the sternum, or on the fascia covering the pectoralis major. When present on both sides, the two muscles may be fused across the sternum. This muscle is found in 4 per cent. of normal individuals and 48 per cent. of anencephalic monsters. (Eisler.) Rarely, corresponding muscle slips have been found innervated by the intercostal nerves. These probably represent remains of a thoracic 'rectus' muscle.

The **pectorodorsalis (axillary arch).**—This muscle in its most complete form extends from the tendon of the pectoralis major over the axillary fossa to the tendon of the latissimus dorsi, to the fascia covering the latissimus dorsi, to the teres major or even more distally. It may, however, be more or less fused with either of the last two muscles mentioned, and it presents a great variety of forms. It may extend from the latissimus dorsi to the brachial fascia over the coracobrachialis or biceps, to the long tendon of the biceps, to the axillary fascia, to the axillary margin of the pectoralis minor, or to the coracoid process, etc. It is found in about 7 per cent. of bodies. (Le Double.) When supplied from the anterior thoracic nerves, it probably represents a portion of the thoracohumeral subcutaneous (pannicular) muscle of the lower primates. It is also sometimes supplied by the medial brachial cutaneous or the intercostobrachial (humeral) nerve and frequently is partly or wholly supplied by the thoracodorsal (long subscapular) nerve. The part of the muscle supplied by the thoracodorsal nerve is probably derived from the latissimus dorsi musculature.

The **costocoracoideus.**—A muscular slip which arises from one or more ribs or from the aponeurosis of the external oblique between the pectoralis major and latissimus dorsi muscles and is inserted in the coracoid process.

The **chondrohumeralis (epitrochlearis).**—This is a slip which springs from one or two rib cartilages or from the thoracoabdominal fascia beneath the pectoralis major, or from its lower border or tendon, and extends on the medial side of the arm to the intertubercular (bicipital) groove, the brachial fascia, the intermuscular septum, or the medial epicondyle. It is found in 12 to 20 per cent. of bodies (Le Double), and occurs normally in many of the lower mammals.

The **pectoralis minimus (sternochondroscapularis).**—From the cartilage of the first rib and sternum to the coracoid process.

The **sternoclavicularis.**—From the manubrium of the sternum to the clavicle between the pectoralis major and the coracoclavicular (costocoracoid) fascia. In 2 per cent. to 3 per cent. of bodies. (Gruber.)

The **scapuloclavicularis.**—From the coracoid process of the scapula to the lateral third of the clavicle.

The **infraclavicularis.**—From above the clavicular part of the pectoralis major to the fascia over the deltoid.

BURSÆ

B. m. pectoralis majoris.—Between the tendon of insertion of the pectoralis major and the long head of the biceps. Frequent.

C. MUSCULATURE OF THE ARM

(Figs. 417, 418, 424–427, 430, 433, 435)

The muscles included in this section are the triceps and anconeus, coracobrachialis, biceps, and brachialis. The *triceps* and *anconeus* (fig. 425) constitute a mass of musculature extending along the back of the arm from the scapula and humerus to the olecranon of the ulna. The *coracobrachialis*, *biceps*, and *brachialis* (figs. 426, 427) constitute a similar mass of musculature extending along the front of the arm from the scapula and the humerus to the humerus, and to the radius and ulna near the elbow. In the upper half of the arm the two groups are separated on the lateral side of the arm by the deltoid, pectoralis major, teres minor, supra- and infraspinatus muscles, and by the greater tubercle of the humerus. On the medial side they are separated by the chief nerves and blood-vessels of the arm and by the tendons of the latissimus dorsi, teres major, and subscapularis muscles. In the distal half of the arm they are separated medially by the medial intermuscular septum (described below) and by the medial epicondyle and the ulnovolar group of muscles of the forearm. On the lateral side of the arm they are separated by the lateral intermuscular septum, by the lateral epicondyle, and by the brachioradialis and the extensor muscles of the forearm which take origin from the lateral epicondyle.

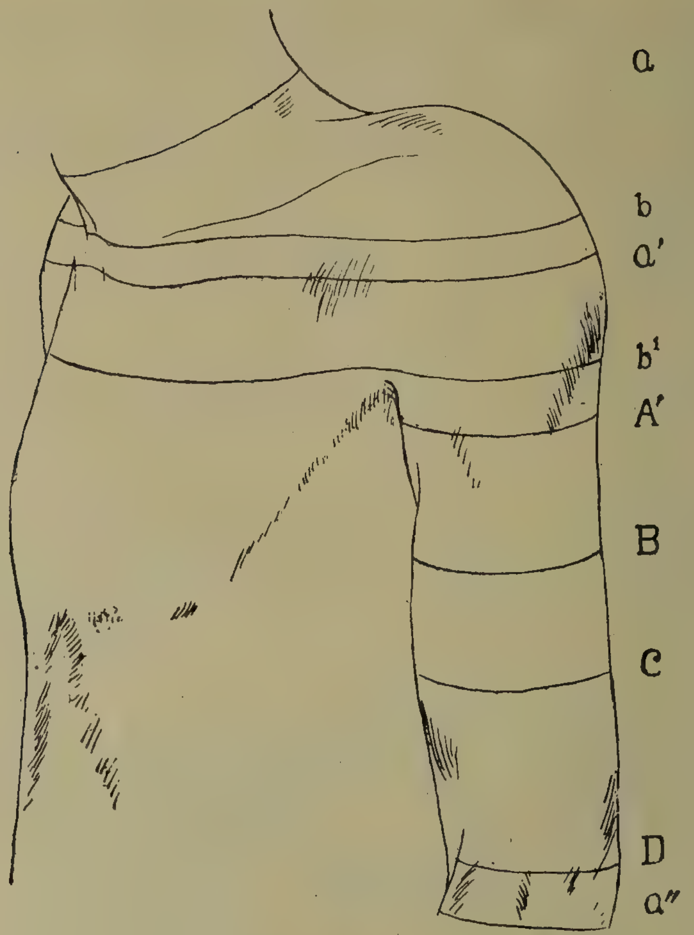
FASCIÆ

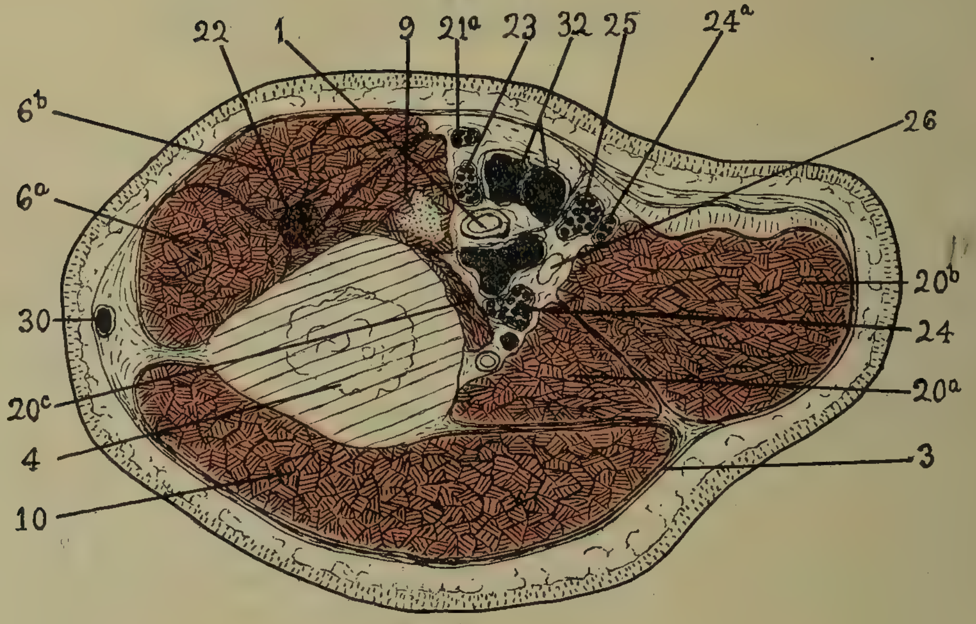
The **fasciæ** and the general relations of the muscles of the arm are shown in the cross-sections in fig. 424.

The **tela subcutanea** of the arm is fairly well developed and contains a considerable amount of fat, especially near the shoulder. It is but loosely bound to the muscle fascia, except near the insertion of the deltoid, where the union may be more intimate.

Bursæ.—**B. subcutanea epicondyli lateralis.**—Between the lateral epicondyle and the skin. Rare. **B. subcutanea epicondyli medialis.**—Between the medial epicondyle and the skin. Inconstant. **B. subcutanea olecrani.**—Between the olecranon process of the ulna and the skin. Nearly constant.

The **brachial fascia** forms a cylindrical sheath about the muscles of the arm. It contains circular and longitudinal fibers, the former being the better developed. The fascia is strong over the dorsal muscles, especially near the two epicondyles of the humerus. Proximally the fascia of the arm is continued into the axillary fascia and into the fascial investment of the pectoralis major, deltoid, and latissimus dorsi muscles; distally it is continued into the fascial investment of the forearm. It is intimately bound to the epicondyles and to the dorsal surface of the olecranon. It is separated by loose areolar tissue from the bellies of the muscles which it covers. From the tendons of the deltoid, pectoralis major, teres major, and latissimus dorsi muscles, however, fibrous bundles are continued into the brachial fascia. There are a number of orifices in the fascia for the passage of nerves and blood-vessels. Of these, the largest is that for the basilic vein and two or three large branches of the medial antibrachial (internal) cutaneous nerve. This lies on the ulnar margin of the arm in the lower third. On the radial margin lie the cephalic vein in a double fold of the fascia, orifices for branches of the musculocutaneous nerve, and more dorsally orifices for branches of the radial. From the fascia septa descend between the muscles which it invests. Of these septa, the most important are the medial and lateral intermuscular septa, which separate the dorsal group of muscles from the ventral in the distal half of the arm. The **medial intermuscular septum** is the stronger. It is attached to the medial epicondyle and to the medial margin of the humerus proximal to this. It is continued proximally into the tendon of insertion of the coracobrachialis and the investing fascia of this muscle. Into it longitudinal bundles of fibers descend from the tendon. It separates the brachialis and pronator teres muscles from the medial head of the triceps. The **lateral intermuscular septum** is attached to the lateral epicondyle and to the lateral margin of the humerus. It is continued proximally into the dorsal surface of the tendon of insertion of the deltoid muscle, and into the septa between the deltoid and the triceps. It separates the triceps from the brachialis in the third quarter of the arm and from the brachioradialis and extensor carpi radialis longus in the distal quarter. The median nerve and brachial vessels lie in front of the medial septum. The ulnar nerve and the superior ulnar collateral (inferior profunda) artery are bound to its dorsal surface.



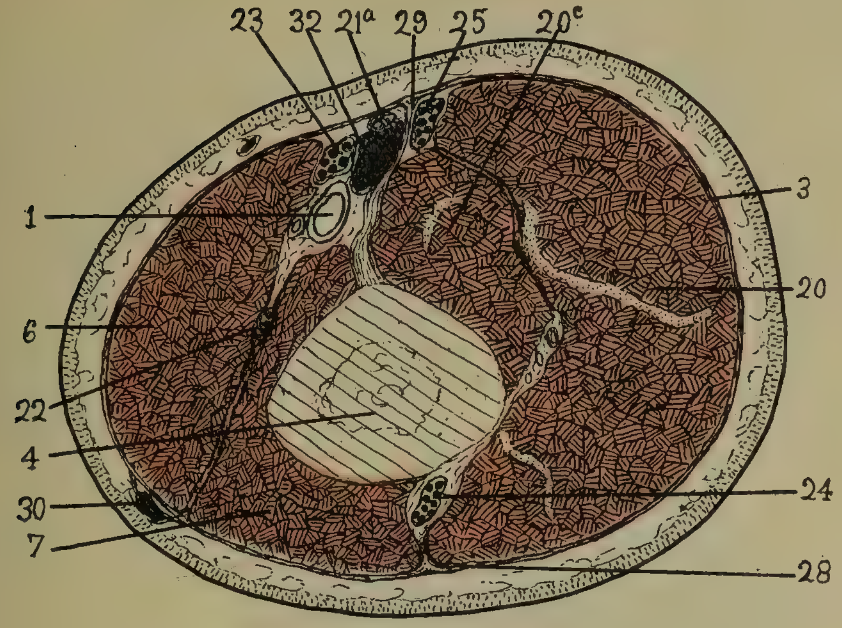


A

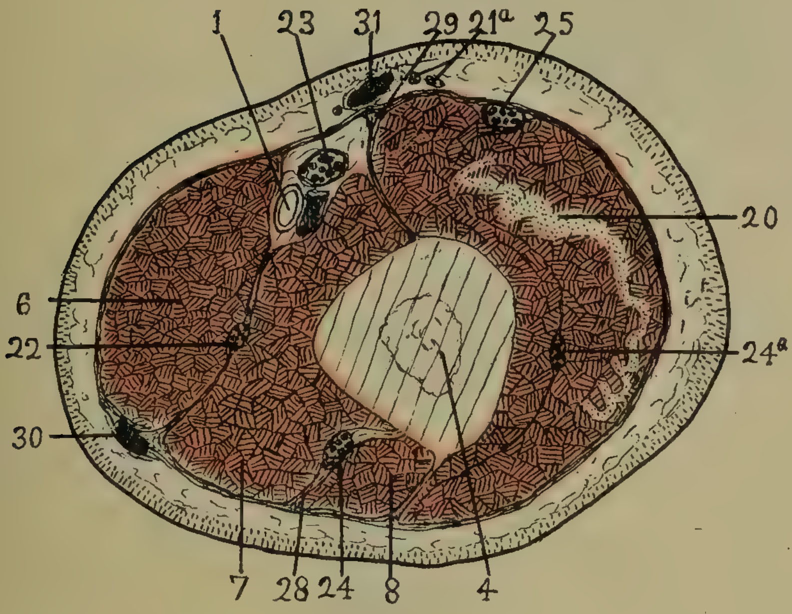
FIG. 424, A–D.—TRANSVERSE SECTIONS THROUGH THE LEFT ARM IN THE REGIONS SHOWN IN THE DIAGRAM.

a and *b* in the diagram indicate the regions through which pass sections A and B, fig. 413; *a′* and *b′*, the regions through which pass sections A and B, fig. 419; and *a″* the region through which passes section A, fig. 428.

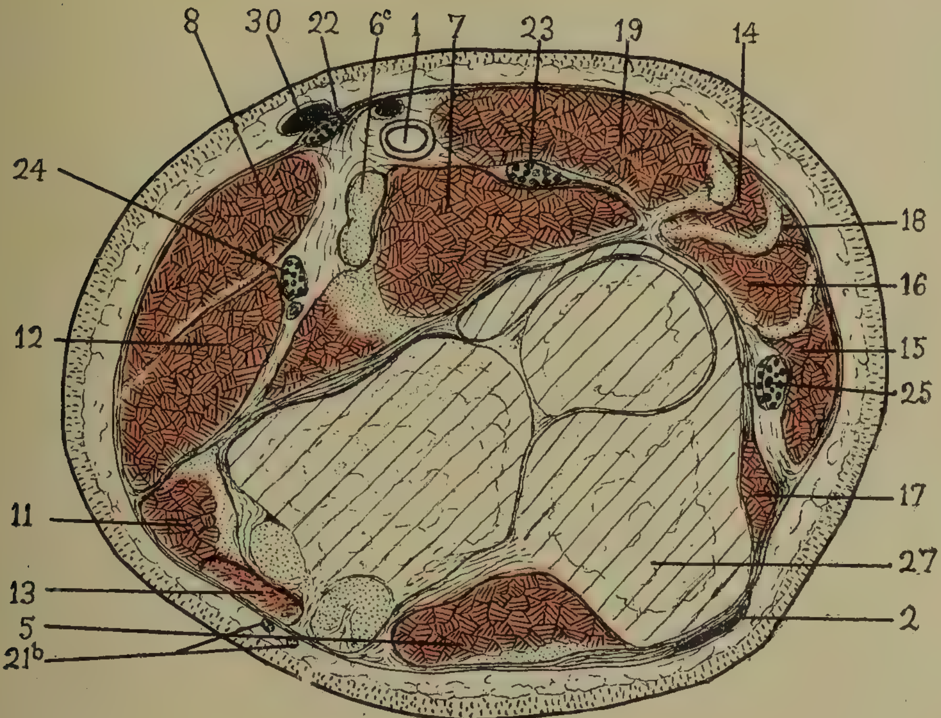
1. Arteria brachialis. 2. Bursa subcutanea olecrani. 3. Fascia brachialis. 4. Humerus. 5. Musculus anconeus. 6. M. biceps—*a*, long head; *b*, short head; *c*, tendon of insertion. 7. M. brachialis. 8. M. brachioradialis. 9. M. coracobrachialis. 10. M. deltoideus. 11. M. extensor carpi radialis brevis. 12. M. extensor carpi radialis longus. 13. M. extensor digitorum communis. 14. M. flexor carpi radialis. 15. M. flexor carpi ulnaris. 16. M. flexor digitorum sublimis. 17. M. flexor digitorum profundus. 18. M. palmaris longus. 19. M. pronator teres. 20. M. triceps—*a*, lateral head; *b*, long head; *c*, medial head 21*a*. N. cutaneus antibrachii medialis (internal cutaneous). 21*b*. N. cutaneus antibrachii dorsalis. 22. N. musculocutaneus. 23. N. medianus. 24. N. radialis—*a*, muscular branch. 25. N. ulnaris. 26. Lymphatic gland. 27. Olecranon. 28. Septum intermusculare laterale. 29. Septum intermusculare mediale. 30. Vena cephalica. 31. V. basilica. 32. Vv. brachiales.


23
32
21a
29
25
20c
1
3
20
6
22
4
24
30
7
28

B


1
23
31
29
21a
25
20
6
22
24a
30
7
28
24
8
4

C


8
30
22
6c
1
7
23
19
14
24
18
16
12
15
25
17
11
27
13
2
5
21b

D

ARM-MUSCLES

1. Dorsal or Extensor Group (Fig. 425)

Two muscles are included in this group, the triceps brachii and the anconeus. The **triceps** is a complex muscle in which proximally three heads, a long or scapular, a lateral humeral, and a medial humeral, may be distinguished. The long head arises from the infraglenoid tuberosity of the scapula, the lateral head from the humerus above and laterally to the groove for the radial nerve (musculospiral groove), the medial head from the lower half and medial margin of the posterior surface of the humerus. Distally these heads fuse and are inserted by a common tendon into the olecranon of the ulna. The **anconeus** lies chiefly in the forearm, but physiolgoically and morphologically it belongs with the triceps, and hence is described in connection with the muscles of the arm. It is a triangular muscle, which arises from the lateral epicondyle and is inserted into the olecranon and adjacent part of the shaft of the ulna. Both muscles are supplied by branches of the radial (musculospiral) nerve. They extend the forearm. The long head of the triceps also extends and adducts the arm at the shoulder.

The triceps, variously modified, is found in the amphibia and all higher vertebrates. The anconeus is found in the prosimians and all higher forms. The triceps muscle is homologous with the quadriceps of the thigh. The long head is equivalent to the rectus femoris. The anconeus is not represented in the lower limb.

The **triceps brachii** (figs. 417, 418, 425).—The **long head** (caput longum) *arises* from the infraglenoid tuberosity of the scapula by a strong, broad tendon, some of the fibers of which are connected with the inferior portion of the capsule of the shoulder-joint. The tendon soon divides into two lamellæ, which extend distally, one a short distance on the deep surface, the other much farther on the superficial surface of this head. The parallel fiber-bundles which arise from these lamellæ form a thick muscle-band which twists upon itself so that the ventral surface at the origin becomes dorso-medial at the insertion. At the insertion the long head becomes applied to an aponeurosis which extends upward from the main tendon of insertion of the triceps. The fiber-bundles extend for some distance on the medial side of this tendon and terminate about three-fourths of the way down the arm.

The **lateral head** (caput laterale) has a tendinous *origin* from the superior lateral portion of the posterior surface of the humerus along a line extending from the insertion of the teres minor as far as the groove for the radial (musculospiral) nerve, and from the aponeurotic arch formed by the lateral intermuscular septum as it crosses this groove. The constituent fiber-bundles descend, the superior vertically, the inferior obliquely, to be inserted on the dorsal and ventral surfaces of the proximolateral margin of the common tendon of insertion of the triceps.

The **medial head** (caput mediale) has a fleshy *origin* from the posterior surface of the humerus below the radial (musculospiral) groove and from the dorsal surfaces of the medial and lateral intermuscular septa. The greater part of the fiber-bundles arising from this extensive area are inserted into the deep surface of the common tendon, but some extend directly to the olecranon and the articular capsule of the elbow. The slip attached to the capsule is sometimes called the **subanconeus** muscle.

Insertion.—The tendon of insertion of the triceps forms a flat band covering the dorsal surface of the distal two-fifths of the muscle. It also extends proximally between the long and lateral heads and on the deep surface of the former. This tendon is inserted into the olecranon and laterally, by a prolongation over the anconeus, into the dorsal fascia of the forearm.

Nerve-supply.—From the radial (musculospiral) nerve. The branch to the long head arises in the axilla and enters that margin of the muscle which is prolonged down from the lateral edge of the tendon, but which, because of the torsion of the muscle, comes to lie on the medial side. The nerve usually enters through several rami about the middle of the free portion of the long head. Somewhat more distally the radial nerve gives off a branch that enters, by two or three branches, the proximal portion of the medial head. A similar branch is given to the lateral head and other branches are given to the lateral and medial heads from that portion of the radial (musculospiral) nerve lying in the radial (musculospiral) groove. The nerve fibers arise from the sixth, seventh, and eighth cervical nerves.

Relations.—Near the shoulder the triceps is covered by the deltoid muscle. The long head passes between the teres major and teres minor muscles. The circumflex (dorsal) scapular vessels here pass medial, the circumflex humeral vessels and the axillary (circumflex) nerve lateral, to this head. More distally the muscle lies beneath the brachial fascia. It covers the radial groove of the humerus, in which run the radial (musculospiral) nerve and (superior) profunda brachii artery. Ventrolateral to the muscle lie the deltoid, brachialis, brachioradialis, and extensor carpi radialis muscles; ventromedial, the coracobrachialis, biceps, and brachialis muscles.

Action.—It extends the forearm. The leverage is of such a nature that force is sacrificed for speed of movement. The long head of the triceps also serves to extend and to adduct the arm and to hold the head of the humerus in the glenoid cavity.

Variations.—The scapular attachment may extend for a considerable distance down the axillary border of the scapula. Each of the heads may be more or less fused with neighboring muscles. Frequently a fourth head is found. This may arise from the humerus, from the axillary margin of the scapula, from the capsule of the shoulder-joint, from the coracoid process, or from the tendon of the latissimus dorsi.

The *latissimo-condyloideus* (dorsoepitrochlearis).—This muscle is found in about 5 per cent. of bodies. When well developed, it extends from the tendon of the latissimus dorsi to the brachial fascia, the triceps muscle, the shaft of the humerus, the lateral epicondyle, the olecranon, or the fascia of the forearm. It is innervated by a branch of the radial (musculospiral) nerve. It is a muscle normally present in some one of the forms above mentioned or in some similar form, in a large number of the inferior mammals. In the human body it is normally represented by a fascial slip from the tendon of the latissimus to the long head of the triceps or the brachial fascia.

The **anconeus.**—*Origin.*—By a short narrow tendon from the distal part of the back of the lateral epicondyle and the adjacent part of the capsular ligament of the elbow-joint.

Structure and insertion.—The tendon of origin is prolonged on the deep surface and lateral border of the muscle. From this the fiber-bundles spread, the proximal transversely, the more distal obliquely, to be inserted into the radial side of the olecranon and an adjacent impression on the shaft of the ulna. Its superior fiber-bundles are usually continuous with those of the medial head of the triceps.

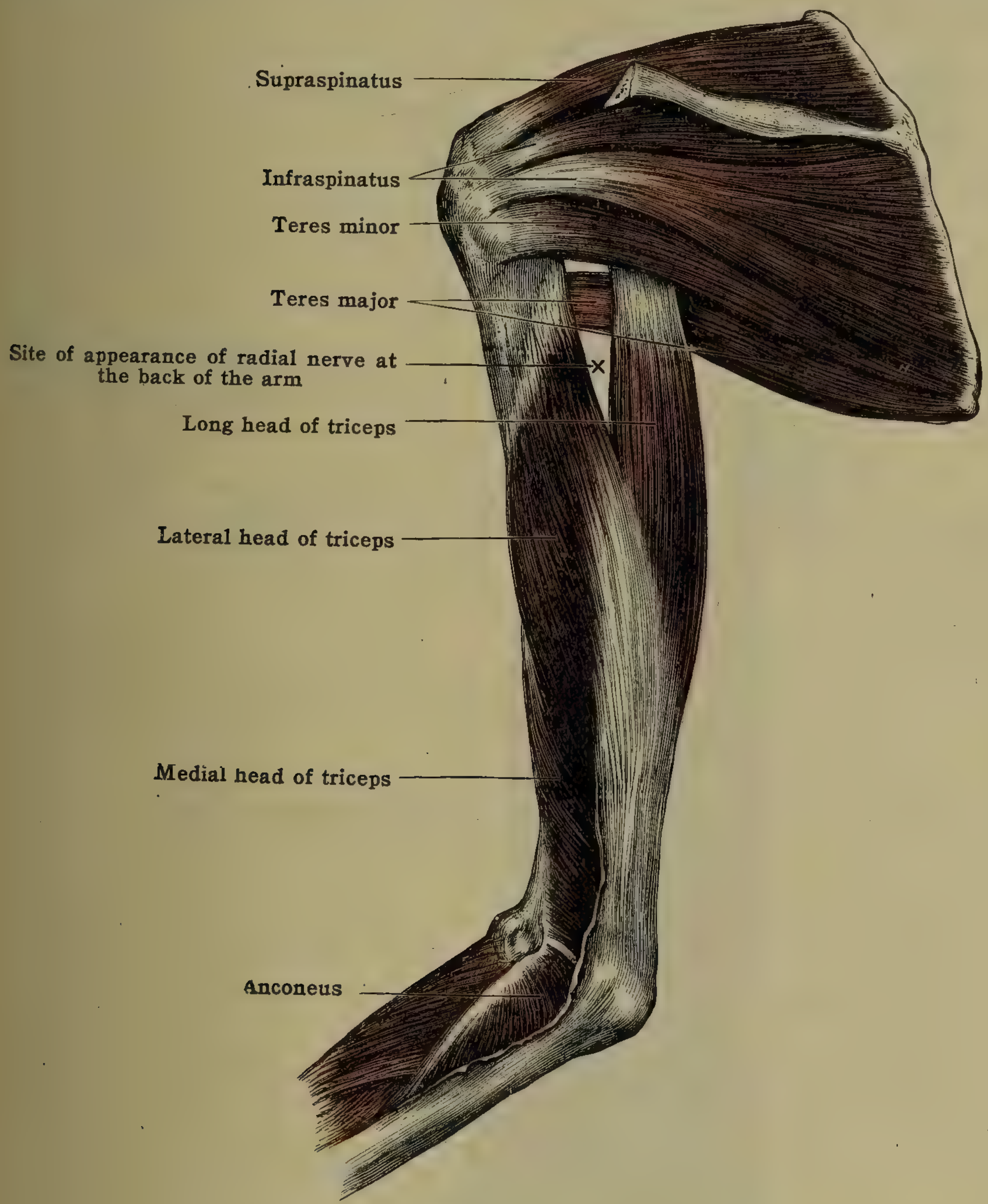


Fig. 425.—Dorsal View of the Scapular Muscles and Triceps.

Nerve-supply.—By a long branch which arises in the radial (musculospiral) groove from the radial (musculospiral) nerve, passes through the medial head of the triceps, to which it gives branches, and enters the proximal border of the anconeus. The nerve fibers arise from the seventh and eighth cervical nerves.

Action.—It aids the triceps in extending the forearm and draws the ulna laterally in pronation of the hand.

Relations.—The muscle lies immediately beneath the antibrachial fascia. It extends over the head of the supinator (brevis) and the elbow-joint and upper radioulnar joint.

Variations.—The extent of fusion of the muscle with the medial head of the triceps varies a good deal. It may also be fused with the extensor carpi ulnaris. It has been reported missing

BURSÆ

B. intratendinea olecrani.—Within the tendon of the triceps near its insertion. More frequent than the following:—

B. subtendinea olecrani.—Between the tendon of the triceps and the olecranon and dorsal ligament of the elbow-joint. Inconstant.

B. epicondyli medialis dorsalis.—Between the medial epicondyle, the edge of the triceps, and the ulnar nerve. Rare.

B. m. anconei.—Between the tendon of origin of the muscle and the head of the radius. Frequent.

2. VENTRAL OR FLEXOR GROUP
(Figs. 426, 427, 433–435)

The muscles of this group are the coracobrachialis, the biceps, and the brachialis. The **coracobrachialis** (fig. 427) is a band-like muscle which arises from

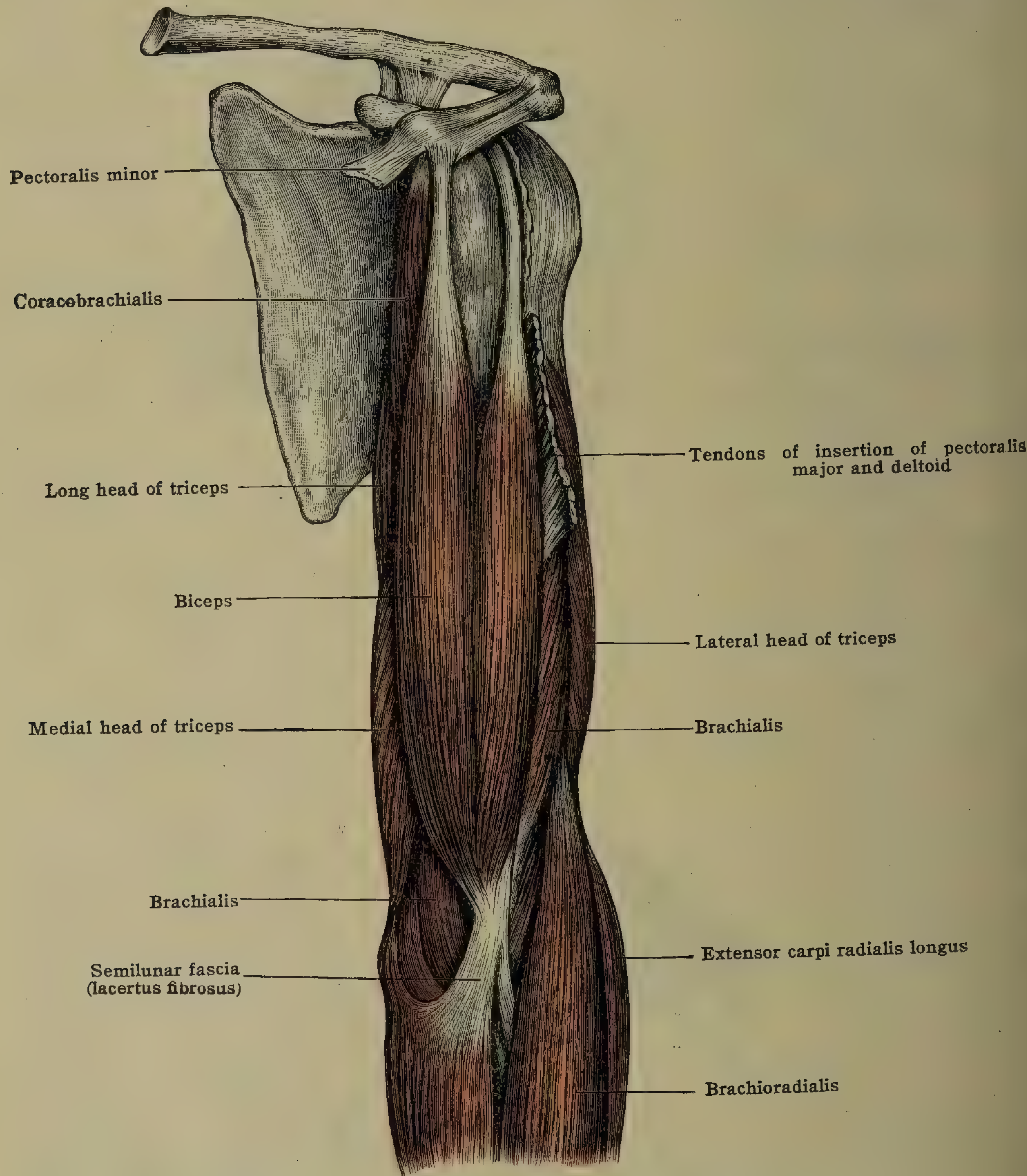


Fig. 426.—Superficial Muscles of the Front of the Arm.

the coracoid process and is inserted into the middle third of the shaft of the humerus. The **biceps** (fig. 426) arises by two heads: a short head, closely associated with the coracobrachialis, from the coracoid process; a long head, by an extended tendon, from the supraglenoid tuberosity of the scapula. The fusiform belly which arises from the fusion of these two heads is inserted into the radius and into the fascia of the forearm. The **brachialis** (fig. 427) extends under cover of the biceps from the lower three-fifths of the shaft of the humerus to the coronoid process of the ulna. The muscles of this group are supplied by the musculo-

cutaneous nerve. The brachialis also usually receives a branch from the radial nerve. The coracobrachialis and short head of the biceps flex and adduct the arm at the shoulder; the biceps and brachialis flex the forearm at the elbow. The long head of the biceps abducts the arm at the shoulder. The biceps is a powerful supinator of the forearm.

The muscles of this group are found in most of the limbed vertebrates. In many of the lower forms the coracobrachialis, which appears farther down in the vertebrate series than the biceps, has a more extensive insertion than in man. It may extend to the ulna (lizards) and may be subdivided into various muscles which correspond with the adductors of the thigh. The biceps, the place of which is taken in the lower vertebrates by a coracoradial muscle, in most of the mammals presents two heads, the more lateral of which is attached by a tendon to the

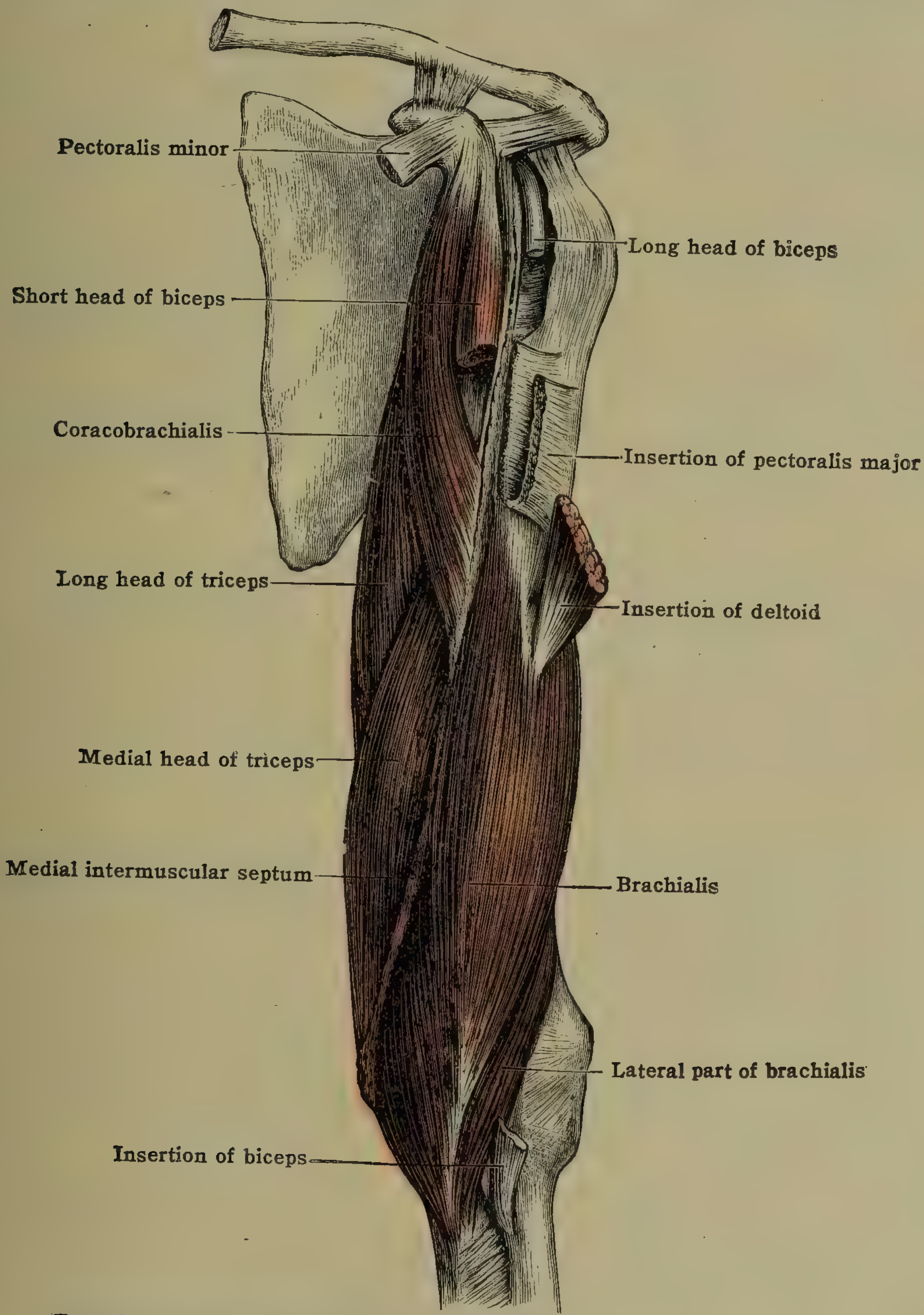


FIG. 427.—DEEP MUSCLES OF THE FRONT OF THE ARM.

scapula above the shoulder-joint. This long tendon of the biceps lies primitively outside capsule of the shoulder-joint, but in some of the higher mammals has come to lie within the capsule. In the biceps four elements may be recognized:—a coracoradial, coracoulnar, glenoradial, and glenoulnar. (Krause.) The development of these elements varies in different mammals.

The coracobrachialis (fig. 427).—*Origin.*—(1) By a short tendon from the tip of the coracoid process of the scapula and (2) from the tendon of the short head of the biceps.

Insertion.—(1) By means of a strong tendon into the medial surface of the humerus immediately proximal to the middle of the shaft, and (2) often above this also into an aponeurotic band which extends from the tendon along the medial margin of the humerus, arches over the tendons of the latissimus dorsi and teres major, and is attached to the lesser tubercle of the humerus. When the attachment to the tubercle does not take place, the band becomes closely applied to the deep surface of the muscle.

Structure.—From the tendons of origin, which are usually closely associated, the fiber bundles take an oblique, nearly parallel, course and are attached to the aponeurotic band above mentioned and to both surfaces of the flat tendon of insertion. This extends high into the muscle. The belly of the muscle usually shows some separation into a superficial and a deep portion, between which runs the musculocutaneous nerve. When this separation is well marked, the tendon of origin of the superior fasciculus may be distinct from that of the inferior fasciculus and the short head of the biceps, and the tendon of insertion may give a separate lamina to each fasciculus.

Nerve-supply.—A branch of the musculocutaneous nerve, or of the brachial plexus near the origin of this nerve, enters the upper third of the medial border of the muscle, and passes across the constituent fiber-bundles about midway between their attachments. The nerve fibers arise from the sixth and seventh cervical nerves.

Action.—Adducts and flexes the arm at the shoulder and helps to keep the head of the humerus in the glenoid fossa. When the arm has been rotated lateralward, it acts as a medial rotator. It may help to increase extreme abduction.

Relations.—The coracobrachialis is largely covered by the deltoid and pectoralis major muscles. Below the inferior border of the latter it becomes superficial. Near its origin it lies between the pectoralis minor and the subscapularis muscles. More distally it lies medial to the humerus and in front of the chief brachial vessels and nerves. The musculocutaneous nerve usually runs through it.

Variations.—The humeral insertion of the muscle varies considerably. According to Wood, the coracobrachialis consists primitively of three parts, which arise from the coracoid process and are inserted respectively into the upper, the middle, and the distal part of the humerus along the medial side. The superior division is most deeply, the inferior the most superficially placed. In man the muscle is composed of parts of the middle and inferior divisions. The inferior division may be completely developed as far as the medial epicondyle. The superior division of the muscle is occasionally found. Slips from the coracobrachialis to the brachialis have been seen. Complete absence of the muscle has been recorded.

The **biceps brachii** (figs. 426, 433).—The **short head** *arises* by a flat tendon closely associated with that of the coracobrachialis from the coracoid process. From the dorsomedial surface of this tendon the fiber-bundles descend nearly vertically, though increasing in number, toward their attachment to the tendon of insertion. The fiber-bundles which arise highest on the tendon of origin are inserted highest on the tendon of insertion, while those which have the lowest origin have the lowest insertion.

The long **head** *arises* from the supraglenoid tuberosity and from the glenoid ligament by a long tendon (9 cm.) bifurcated at its origin. The tendon at first passes over the head of the humerus within the capsule of the joint, and then passes into the intertubercular (bicipital) groove, which is covered by the capsule of the joint and an expansion from the tendon of the pectoralis major. To this point the tendon is surrounded by the synovial membrane of the joint. After emerging from this the tendon slowly expands and from its dorsal concave surface arise fiber-bundles which, increasing in number, extend, somewhat obliquely, toward the tendon of insertion. As in case of the short head, here also the fiber-bundles which arise highest on the tendon of origin have the highest insertion.

Insertion.—The tendon of insertion begins usually in the distal quarter of the arm as a vertical septum between the two heads of the muscle. More distally this broadens out on each side into a flattened aponeurosis. The fiber-bundles are inserted into the sides of the septum and on each surface of the aponeurosis—those of the long head chiefly on the deep surface, those of the short head chiefly on the superficial surface. The aponeurosis is continued into a strong, flattened tendon which descends between the brachioradialis and pronator teres muscles to be inserted on the dorsal half of the bicipital tuberosity of the radius. From the medial border of the tendon an aponeurotic expansion, the **lacertus fibrosus** (semilunar fascia), is continued into the fascia of the ulnar side of the forearm.

Nerve-supply.—By a branch from the musculocutaneous nerve for each head. These branches may be bound in a common trunk for some distance. They enter the deep surface of the muscle in the proximal part of the middle third of each belly often by several rami. Usually there is a distinct intramuscular fissure for the reception of the branches to each head and the blood-vessels which accompany them. The nerve fibers come from the fifth and sixth cervical nerves.

Action.—It is a flexor of the arm at the elbow and is the strongest supinator of the forearm. This last action is most marked when the forearm is flexed and pronated. Both heads are flexors and medial rotators of the arm at the shoulder. The long head is an abductor and so also is the short head when the arm is greatly abducted, otherwise the short head is an adductor.

Relations.—The tendons of origin are concealed by the pectoralis major and deltoid muscles. Beyond this the muscle is covered by the fascia brachii. In the lower part of the arm it lies upon the brachialis muscle. Upon the medial margin lie the coracobrachialis muscle, the brachial vessels, and the median nerve.

Variations.—Variations are frequent (cf. fig. 223). The whole muscle or either head may be missing, but such cases are rare. The long head may extend only to the bicipital groove. Frequently the muscle is partially divided into the four primitive portions mentioned above. The two heads may be separate from origin to insertion. There may be an accessory head (1 in 10 subjects—Le Double) which arises from the coracoid process, the capsule of the joint, the tendon of the pectoralis major, or the shaft of the humerus near the insertion of the coracobrachialis. In most instances the origin takes place above the origin of the brachialis from the humerus. Sometimes several accessory heads are seen. Marked variation of insertion is less frequent, but occasionally a supernumerary slip may go to the medial intermuscular septum or the medial epicondyle. The fusion of the biceps with neighboring muscles (pectoralis major and minor, coracobrachialis, brachialis, palmaris longus, pronator teres, brachioradialis) by means of tendinous or muscular slips has been frequently reported.

The **brachialis** (fig. 427).—*Origin.*—(1) From the distal three-fifths of the front of the humerus, (2) from the medial intermuscular septum, and (3) from the lateral intermuscular septum proximal to the heads of the brachioradialis and extensor carpi radialis longus. Proximally it sends up a pointed process on the lateral side of the insertion of the deltoid and another between the insertions of the deltoid and the coracobrachialis. Distally the area of origin stops a little above the capitulum and the trochlea.

Structure and Insertion.—The fiber-bundles arise directly from this area of origin, except near the insertion of the deltoid and on the medial margin, where tendinous bands are developed. The fiber-bundles descend, the middle vertically, the medial obliquely lateralward, the lateral still more obliquely medialward. The tendon of insertion appears on the dorsal side of the lateral edge of the muscle in its lower fourth. Continuous with this stronger lateral portion of the tendon more distally a thinner band appears upon the ventral surface of the muscle above the joint. The tendon becomes thick as it passes distally, is closely united to the capsule of the elbow-joint, and is attached to the ulnar tuberosity. In addition to the main tendon, some of the deeper fiber-bundles of the muscle and some of these coming from the lateral intermuscular septum are attached by short tendinous bands to the coronoid process.

Nerve-supply.—From the musculocutaneous nerve by a branch which enters the ventral surface of the muscle near the junction of the upper and middle thirds of the medial border. In addition the radial (musculospiral) nerve usually sends a small branch into the distal lateral portion of the muscle. A branch from the median nerve frequently supplies the medial side of the muscle near the elbow-joint (Frohse).

Action.—To flex the forearm.

Relations.—It lies behind the biceps, on each side of which it projects. The distal lateral portion of the muscle is grooved by the brachioradialis, which here is closely applied to it. The radial (musculospiral) nerve runs between these two muscles. On the medial side run the brachial vessels and median nerve.

Variations.—It may be divided into two distinct heads continuous with the projections on each side of the deltoid tuberosity. A great number of supernumerary slips have been recorded. These may be attached to the radius, ulna, fascia of the forearm, capsule of the joint, brachioradialis, and extensor carpi radialis muscles. It may be partially fused with neighboring muscles. It has also been reported absent.

Bursæ

B. m. coracobrachialis.—Between the subscapularis muscle, the tendon of the coracobrachialis, and the coracoid process. Frequent.

B. bicipitoradialis.—Between the ventral half of the radial tuberosity and the tendon of the biceps. Constant.

B. cubitalis interossea.—Between the tendon of the biceps and the ulna and the neighboring muscles. Frequent.

D. MUSCULATURE OF THE FOREARM AND HAND

(Figs. 428–443)

The muscles of the forearm arise in part from the humerus, in part from the radius and ulna. Their bellies lie chiefly in the proximal half of the forearm. They are divisible into two groups:—a radiodorsal, composed of extensors of the hand and fingers and supinators of the forearm; and an ulnovolar, composed of flexors of the hand and fingers and pronators of the forearm. The brachioradialis, which belongs morphologically with the former group, is physiologically a flexor of the forearm.

The two groups are separated on the medial side of the back of the forearm by the dorsal margin of the ulna (figs. 428, 432). Ventrally they are separated by the insertions of the biceps and brachialis and by an intermuscular septum (figs. 428, 433).

In the **hand,** in addition to the tendons of the muscles of the forearm mentioned above (fig. 440), there are several sets of intrinsic muscles. About the metacarpal of the thumb (figs. 439–441) is grouped a set of muscles which arise from the carpus and metacarpus and are inserted into the metacarpal and first phalanx of the thumb. A similar set of muscles is grouped about the metacarpal of the little finger (figs. 439, 440.) These sets of muscles give rise respectively to the thenar and hypothenar eminences. Between the metacarpals lies a series of dorsal and palmar interosseous muscles (figs. 441–443) which are inserted into the first row of phalanges and into the extensor tendons. From the tendons of the deep flexor of the fingers a series of lumbrical muscles passes to the radial side of the extensor tendons (figs. 436, 439). These various muscles abduct, adduct, flex, and extend the digits. In addition to these deeper skeletal muscles of the hand there is a subcutaneous muscle over the hypothenar eminence (fig. 439). Of the muscles of the hand, all are supplied by the ulnar nerve except most of those of the thumb and the two more radial lumbricals, which are supplied by the median nerve.

An arrangement of the muscles of the forearm in which the dorsal extensor-supinator musculture extends proximally on the radial side of the arm to the distal extremity of the humerus and the volar flexor-pronator musculature similarly on the ulnar side, is chararteristic of all limbed vertebrates and is associated with the pronate position of the forelimb characteristic of quadrupeds. In amphibia and reptiles the musculature terminates distally on the carpus and in the aponeuroses of the hand. In the higher forms special tendons are differentiated for those muscles of the forearm which act on the fingers. On the back of the hand in many vertebrates short extensor muscles are found running from the carpus to the phalanges. On the volar surface a complex musculature is found in all forms which have freely movable fingers. In animals which walk on the ends of the fingers, especially in the hoofed animals, the intrinsic musculature of the hand is greatly reduced. The phylogenetic development of the muscles of the forearm and hand is too complex a subject to be briefly summarized. The phylogeny of the forearm flexors and the palmar musculature has been studied by McMurrich. In his papers a summary of the literature on the subject may be found.

FASCIÆ

The **fasciæ** and the general relations of the musculature of the forearm and hand may be followed in the cross-sections, fig. 428.

The **tela subcutanea** contains a moderate amount of fat in the upper part of the forearm. This grows less in amount as the wrist is approached. On the back of the hand it contains little fat. In the palm and on the volar surface of the fingers a moderate amount of fat is embedded between dense vertical bundles of fibers which unite the skin to the fascia. Except on the volar surface of the hand and on the backs of the terminal phalanges, the tela is but loosely united to the underlying fascia.

The **bursa subcutanea olecrani** lies over the dorsal surface of the olecranon. Subcutaneous bursæ are also frequently found over the knuckles (**b. subcutaneæ metacarpophalangeæ dorsales**) and the proximal joints of the fingers (**b. subcutaneæ digitorum dorsales**).

The **antibrachial fascia** encloses the muscles of the forearm in a cylindrical sheath, composed in the main of circular fiber-bundles, but strengthened by longitudinal and oblique bundles extending in from the epicondyles of the humerus, the olecranon, the lacertus fibrosus of the biceps, and the tendon of the triceps. The fascia of the forearm is attached to the dorsal surface of the olecranon and to the subcutaneous margin of the ulna. Above, it is continued into the fascia of the arm; below, into the fascia of the hand. From the antibrachial fascia in the upper half of the forearm a fibrous septum extends between the radiodorsal and the ulnovolar muscle group to the radius. In the radial septum below the elbow a branch of communication extends between the superficial and deep veins of the arm. That part of the fascia overlying the radiodorsal group of muscles is much denser than that covering the volar group, except where the latter is strengthened by the lacertus fibrosus. In addition to the main radial septum other septa descend between the underlying muscles from the antibrachial fascia. These septa are best marked near the attachment of the muscles to the humerus. Here the fascia is firmly fused to the muscles.

Dorsally the antibrachial fascia is strengthened at the wrist by transverse fibers which extend from the radius to the styloid process of the ulna, the triquetrum (cuneiform), and

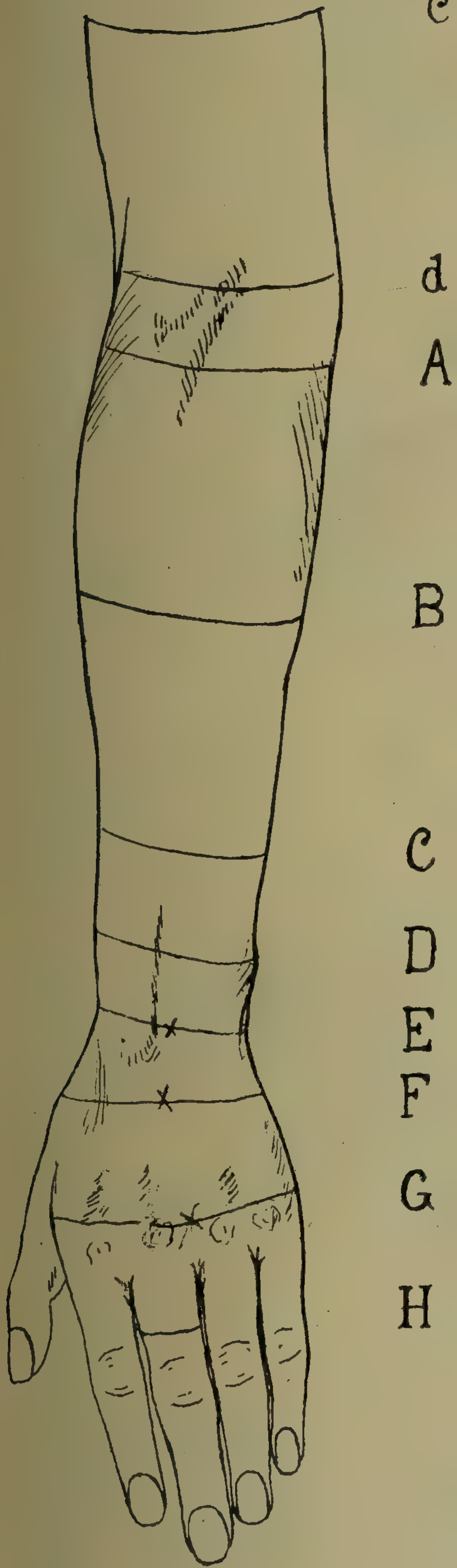
---

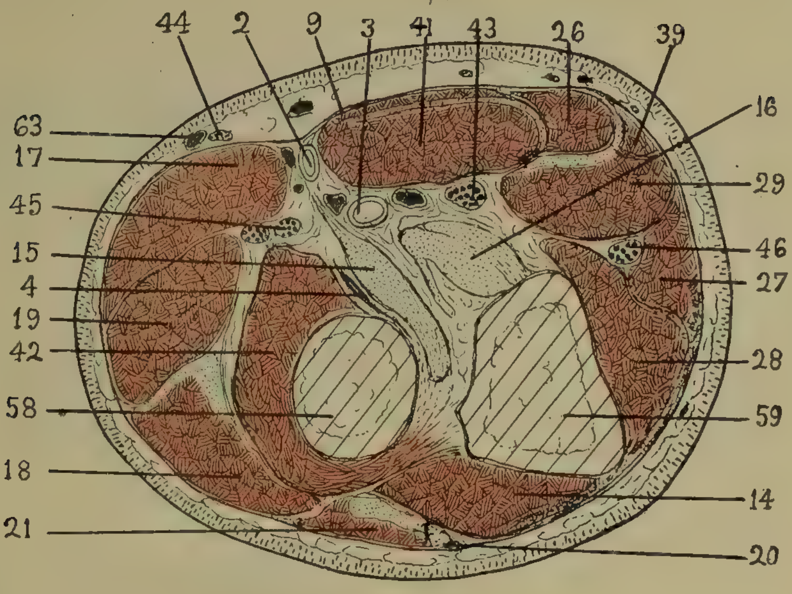
Fig. 428, A–H.—Transverse Sections through the Left Forearm and Hand.

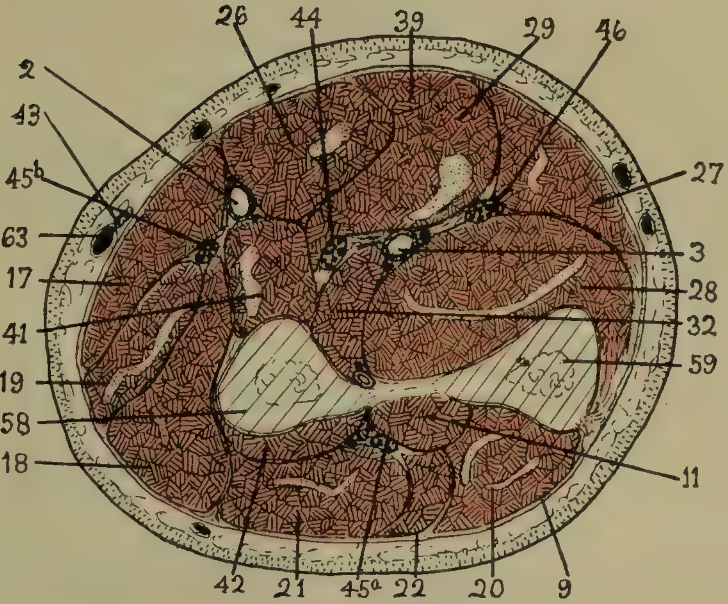
H. Transverse section through the first phalanx of the middle finger, diagrammatic, with the cavity of the synovial sheath of the flexor tendons distended.

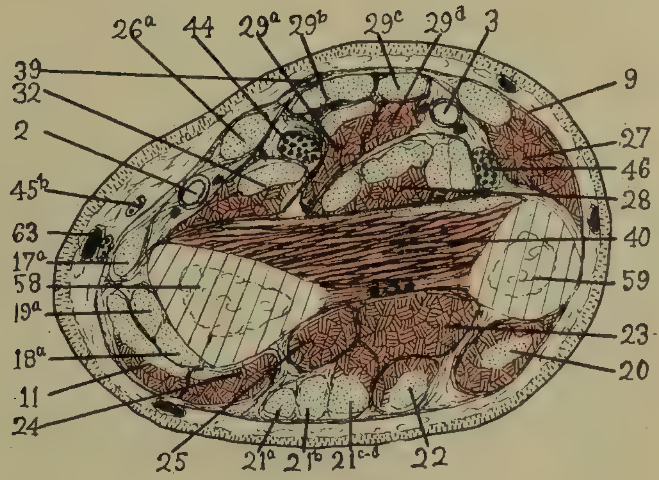
The regions through which these sections pass are indicated in the diagram. *c* and *d* in the diagram show the regions through which pass sections C and D, fig. 424.

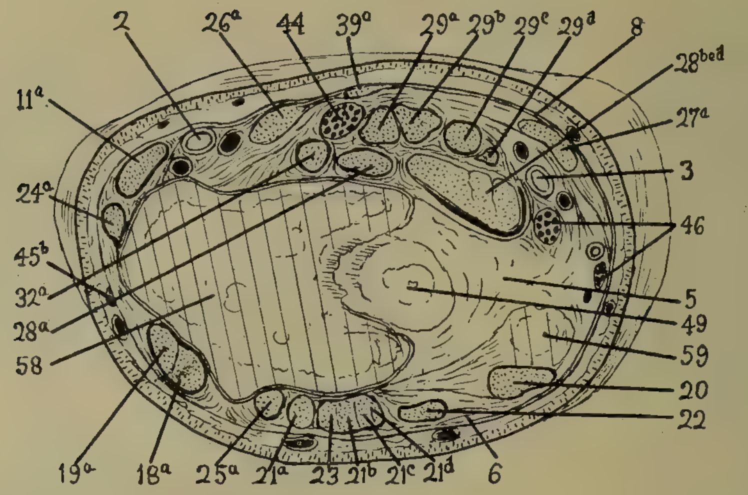
1. Aponeurosis palmaris. 2. Arteria radialis. 3. A. ulnaris. 4. Bursa bicipitoradialis. 5. Discus articularis. 6. Ligamentum carpale dorsale. 7. L. carpi transversum. 8. L. carpi volare. 9. Fascia antibrachii. 10. Musculus abductor pollicis brevis. 11. M. abductor pollicis longus—a, tendon. 12. M. abductor digiti quinti. 13. M. adductor pollicis. 14. M. anconeus. 15. M. biceps, tendon. 16. M. brachialis, tendon. 17. M. brachioradialis—a, tendon. 18. M. extensor carpi radialis brevis—a, tendon. 19. M. extensor carpi radialis longus—a, tendon. 20. M. extensor carpi ulnaris. 21. M. extensor digitorum communis—a, tendon for second finger; b, tendon for the third finger; c, tendon for fourth finger; d, tendon for fifth finger; e, digital aponeurosis. 22. M. extensor digiti quinti proprius. 23. M. extensor indicis proprius. 24. M. extensor pollicis brevis —a, tendon. 25. M. extensor pollicis longus—a, tendon. 26. M. flexor carpi radialis—a, tendon. 27. M. flexor carpi ulnaris—a, tendon. 28. M. flexor digitorum profundus—a, tendon for second finger; b, tendon for third finger; c, tendon for fourth finger; d, tendon for fifth finger. 29. M. flexor digitorum sublimis—a, tendon for second finger; b, tendon for third finger; c, tendon for fourth finger; d, tendon for fifth finger. 30. M. flexor digiti quinti brevis. 31. M. flexor pollicis brevis. 32. M. flexor pollicis longus a, tendon. 33. M. interossei dorsales. 34. M. interossei volares. 35. M, lumbricales. 36. M. opponens pollicis. 37. M. opponens digiti quinti. 38. M. palmaris brevis. 39. M. palmaris longus—a, tendon. 40. M. pronator quadratus. 41. M. pronator teres. 42. M. supinator. 43. N. cutaneus antibrachii lateralis. 44. N. medianus. 45. N. radialis—a, deep radial nerve; b, superficial radial nerve. 46. N. ulnaris. 47. Os capitatum (magnum). 48. Os hamatum (unciform). 49. Os lunatum (semilunar). 50. Os metacarpale, I. 51. Os metacarpale, II. 52. Os metacarpale, III. 53. Os metacarpale, IV. 54, Os metacarpale, V. 55. Os multangulum majus (trapezium). 56. Os naviculare. 57. Ossa sesamoidea of fifth digit. 58. Radius. 59. Ulna. 60. Vagina fibrosa (tendon-sheath) of the long digital flexors. 61. Vagina fibrosa (tendon-sheath) of the flexor pollicis longus. 62. Vagina fibrosa (tendon-sheath in digit). 63. Vena cephalica.


c
d
A
B
C
D
E
F
G
H


44 2 9 3 41 43 26 39
16
63
17
29
45
46
15
4
27
19
42
28
58
59
18
14
21
20
A

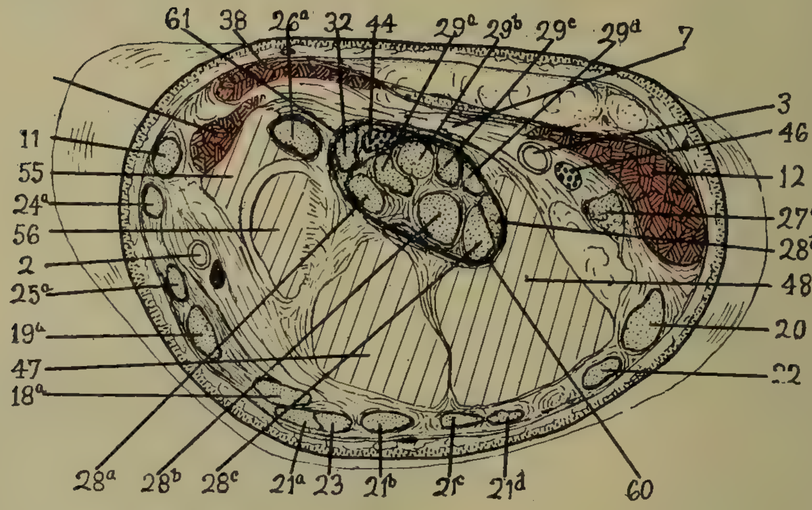

26 44 39 29 46
2
43
27
45b
63
3
17
28
41
32
59
19
58
18
11
42 21 45a 22 20 9
B


26a 44 29a 29b 29c 29d 3
39
9
32
27
2
46
45b
28
63
40
17a
58
59
19a
23
18a
20
11
24
25 21a 21b 21c-d 22
C



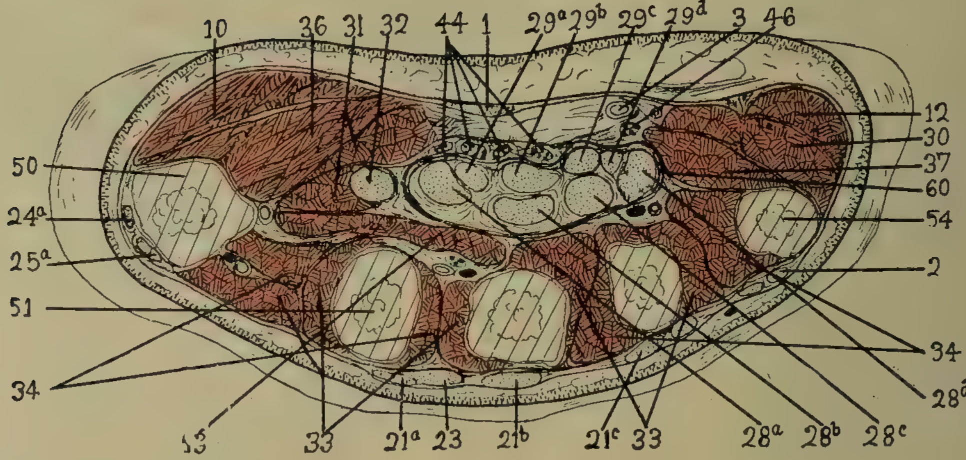
2
26^{a}
44
39^{a}
29^{a}
29^{b}
29^{c}
29^{d}
8
28^{bcd}
27^{a}
3
46
5
49
59
20
22
11^{a}
24^{a}
45^{b}
32^{a}
28^{a}
58
19^{a}
18^{a}
25^{a}
21^{a}
23
21^{b}
21^{c}
21^{d}
6

D



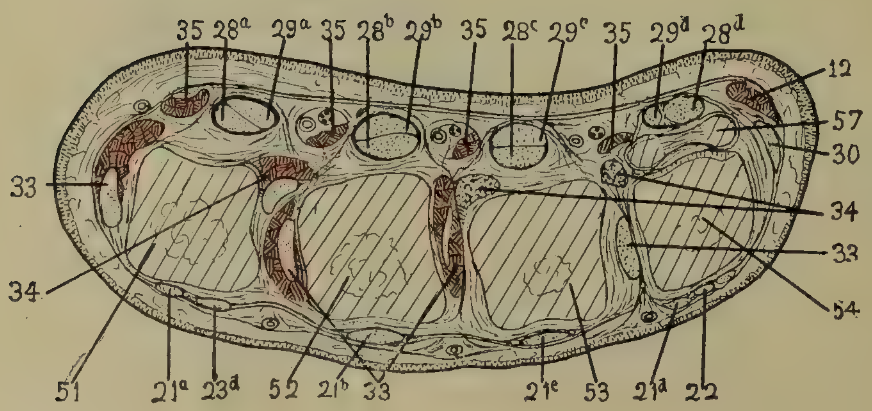
61
38
26^{a}
32
44
29^{a}
29^{b}
29^{c}
29^{d}
7
3
46
12
27^{a}
28^{d}
48
20
22
11
55
24^{a}
56
2
25^{a}
19^{a}
47
18^{a}
28^{a}
28^{b}
28^{c}
21^{a}
23
21^{b}
21^{c}
21^{d}
60

E



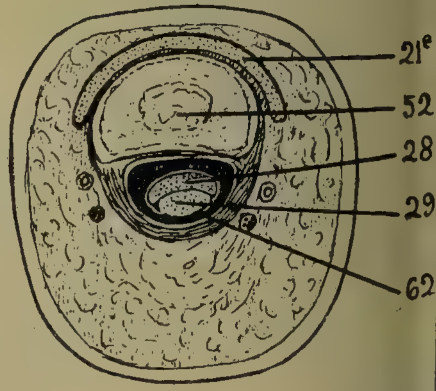
10
36
31
32
44
1
29^{a}
29^{b}
29^{c}
29^{d}
3
46
12
30
37
60
54
2
34
28^{d}
50
24^{a}
25^{a}
51
34
53
33
21^{a}
23
21^{b}
21^{c}
33
28^{a}
28^{b}
28^{c}

F



35
28^{a}
29^{a}
35
28^{b}
29^{b}
35
28^{c}
29^{c}
35
29^{d}
28^{d}
12
57
30
34
33
54
33
34
51
21^{a}
23^{d}
52
21^{b}
33
21^{e}
53
21^{d}
22

G



21^{e}
52
28
29
62

H

pisiform, and give rise to the **dorsal ligament of the carpus** (posterior annular ligament). From this ligament septa descend to the radius and ulna and convert the grooves in these bones into osteofibrous canals which lodge the tendons of the various muscles extending to the wrist and hand.

On the **back of the hand** there is spread a fascia composed of two thin fascial sheets between which the extensor tendons are contained. Between the tendons these sheets are more or less fused. On the backs of the fingers the fascia blends with the extensor tendons and the associated aponeurotic expansions from the interosseous and lumbrical muscles. Between the fingers it is continued into the transverse fasciculi of the palmar aponeurosis. At the sides of the hand the fascia is continued into the thenar and hypothenar fasciæ. Each dorsal interosseous muscle is covered by a special fascial membrane which is separated by loose tissue from the fascia investing the extensor tendons.

On the **volar side of the forearm** for some distance above the wrist the tendons of the flexor carpi radialis, the palmaris longus, and the flexor carpi ulnaris run between two layers of the fascia. The fascia is much strengthened at the wrist by transverse fibers which give rise to the **volar ligament of the carpus.** Beneath it lies the **transverse ligament of the carpus** (anterior annular ligament). This dense band is broader than the volar ligament but like it extends from the pisiform bone and the hamulus of the hamatum (unciform) to the tuberosity of the navicular and the tuberosity of the greater multangular (trapezium). It serves to complete an osteofibrous canal through which pass the flexor tendons of the fingers. Between the two ligaments which are partially fused with one another run the ulnar artery and nerve.

On the **palm of the hand** the ensheathing fascia presents three distinct areas—a central, a lateral, and a medial.

The central portion, the **palmar aponeurosis,** is composed chiefly of bundles of fibrous tissue which radiate superficially toward the fingers from the tendon of the palmaris longus or from a corresponding region of the forearm fascia when this muscle is absent. Between these bundles are others which arise from the transverse ligament. The deep surface of the fascia is composed of a thin incomplete layer of transverse fibers which continue the transverse fibers of the forearm fascia. Near the capitula of the metacarpals this layer becomes much stronger and constitutes a ligamentous band (**superficial transverse ligament** of Poirier). Near the bases of the digits bundles of transverse fibers (**fasciculi transversi**) lie in the webs of the fingers and constitute an incomplete transverse ligament separated by a distinct interval from the superficialtr ansverse ligament. Dupuytren's contraction of the palmar fascia causes flexion of the fingers.

From the palmar aponeurosis processes are sent in toward the deeper structures. Of these, the most important are those continued into a fibrous sheath which surrounds the space containing the long flexor tendons and the lumbrical muscle. This dense fibrous sheath is united by fibrous processes to the third, fourth, and fifth metacarpals. As the flexor tendons diverge and the ends of the metacarpals are approached, numerous processes descend from the palmar aponeurosis to the transverse capitular ligament. These hold the tendons in place. On the volar surface of the fingers the fascia serves to complete osteofibrous canals for the long flexor tendons. The ventral surface of the first and second phalanges of each finger is slightly grooved. The fascia is firmly united on each side to the margin of the groove, and over the groove forms a semicylindrical, strong, fibrous sheath, the **vaginal ligament** of the finger. This sheath is strengthened by transverse bands over the bases of the first and second phalanges (**annular ligaments**) and by cruciate bands over the shafts of the phalanges (**cruciate ligaments**). Over the interphalangeal joints the sheath is thin, but is strengthened by crucial bands which permit of freedom of motion.

The **thenar fascia** is a thin membrane covering the short muscles of the thumb. It is continued above into the fascia of the forearm, medially is fused with the tendon of the palmaris longus and the palmar aponeurosis, and extends as a septum to be attached to the third metacarpal. Laterally it is attached to the first metacarpal and is continued into the dorsal fascia of the hand. It is fused with an aponeurosis from the tendon of the abductor pollicis longus. Distally it is continued into the vaginal ligament of the long flexor of the thumb. Superficially it is closely adherent to the skin.

The **hypothenar fascia** invests the palmar muscles of the little fingers. It is continued from the ulnar margin of the fifth metacarpal over the muscles of the little finger to the palmar aponeurosis, and, by means of a septum, to the radial side of the fifth metacarpal. Proximally, it is attached to the hamatum (unciform) and extends into the fascia of the forearm, distally, it extends into the vaginal ligament of the tendon of the fifth digit.

A deeply seated suprametacarpal fascial layer, or **deep palmar fascia,** covers the interosseous muscles and is attached to the volar surface of the metacarpal bones.

In addition to the fasciæ mentioned, intermuscular septa serve to separate more or less completely the various intrinsic muscles of the hand.

Clinical relations.—Suppuration in the hand owes much of its gravity to the possibility of infection of the synovial tendon sheaths and consequent sloughing of the tendons. At the same time it is now recognized that unless these sheaths are primarily infected pus collects at first in certain potential spaces, more or less well defined, in the looser connective tissue of the hand. One of these known as the middle pālmar space (Kanavel: Infections of the Hand, 1921) is situated on the front of the metacarpals of the middle and ring fingers, and lies deeply between the flexor tendons and the interosseous muscles. Continuations of this potential space extend downward along the lumbrical muscles on the radial side of the three medial fingers and may lead pus from the palm to the subcutaneous tissue of these fingers or vice versa. A second potential compartment, the thenar space (Kanavel) lies in front of the index metacarpal, between the flexors of the index-finger and the adductor transversus pollicis. As in the former space, the corresponding lumbrical muscle prolongs it down to the radial side of the index-finger. (See fig. 429.)

Distention of the middle palmar space with pus leads to obliteration of the hollow of the palm and a variable extension of the swelling along the radial side of the three medial fingers.

Distention of the thenar space follows the thenar eminence, obliterates the adduction crease of the thumb and may extend down the radial side of the index-finger. It must be remembered also that infection of the above fascial spaces may take place secondarily, by the bursting into them of pus from the synovial tendon sheaths.

MUSCLES

1. Radiodorsal Division

The muscles of this group lie in two chief layers, a superficial and a deep.

a. Superficial Layer

(Figs. 430, 433, 434)

The muscles of this layer, closely associated at their origins, extend from the radial side of the distal end of the humerus to the distal extremity of the radius, the carpus and the fingers. They are divisible into a radial, an intermediate, and an ulnar set.

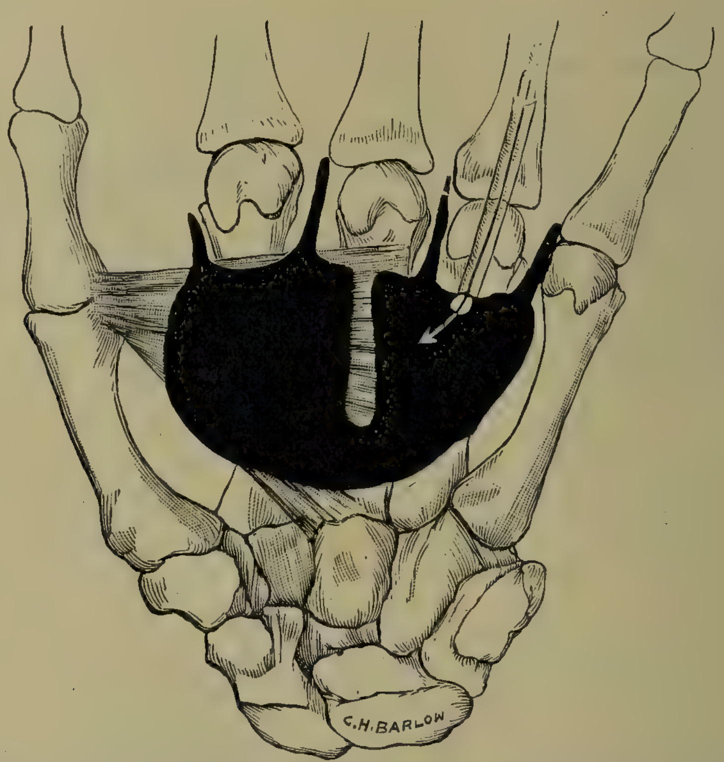


Fig. 429.—Schematic Drawing Made from a Dissection of a Hand in which the Injection Was Made Along the Tendon Sheath of the Ring Finger Under Great Force. The Mass Filled the Middle Palmar and Thenar Spaces, with Extension Along All Lumbrical Muscles. (From Kanavel's 'Infections of the Hand,' Lea & Febiger.)

Radial set.—To this belong three muscles, the brachioradialis, extensor carpi radialis longus and brevis. The **brachioradialis** (fig. 433), a forearm flexor, is a superficial fusiform muscle which arises from the lateral epicondylar ridge of the humerus and is inserted into the base of the styloid process of the radius. The **extensor carpi radialis longus** (fig. 434) is a narrow, fusiform muscle which extends along the radial margin of the forearm, partly under cover of the brachioradialis It arises from the lateral epicondylar ridge of the humerus, and is inserted into the second metacarpal bone. The **extensor carpi radialis brevis** (fig. 430) is a band-like muscle more dorsally placed than the last at the radial side of the arm. It arises from the lateral epicondyle and is inserted into the bases of the second and third metacarpals. These muscles are supplied by branches of the radial nerve which arise proximal to the passage of the deep radial (posterior interosseous) through the supinator muscle. Distally this set of muscles is separated from the intermediate set by the long abductor and the extensors of the thumb, which pass from an origin under the latter set over the tendons of the radial extensors to the thumb.

The **intermediate set.**—This consists of the thick, flattened **extensor digitorum communis** and the slender **extensor digiti quinti proprius** (fig. 430). They arise from the lateral epicondyle, and are inserted into the backs of the fingers.

The **ulnar set** consists of one muscle, the fusiform **extensor carpi ulnaris** (fig. 430), which arises from the lateral epicondyle of the humerus and is inserted into the back of the base of the fifth metacarpal.

The intermediate and ulnar sets of muscles are supplied by branches from the ramus profundus of the radial nerve after this has passed through the supinator muscle.

In the leg the lateral set of the superficial layer is represented by the tibialis anterior. The intermediate set is represented by the long extensors of the toes. The single muscle which constitutes the medial set is represented by the peroneal muscles.

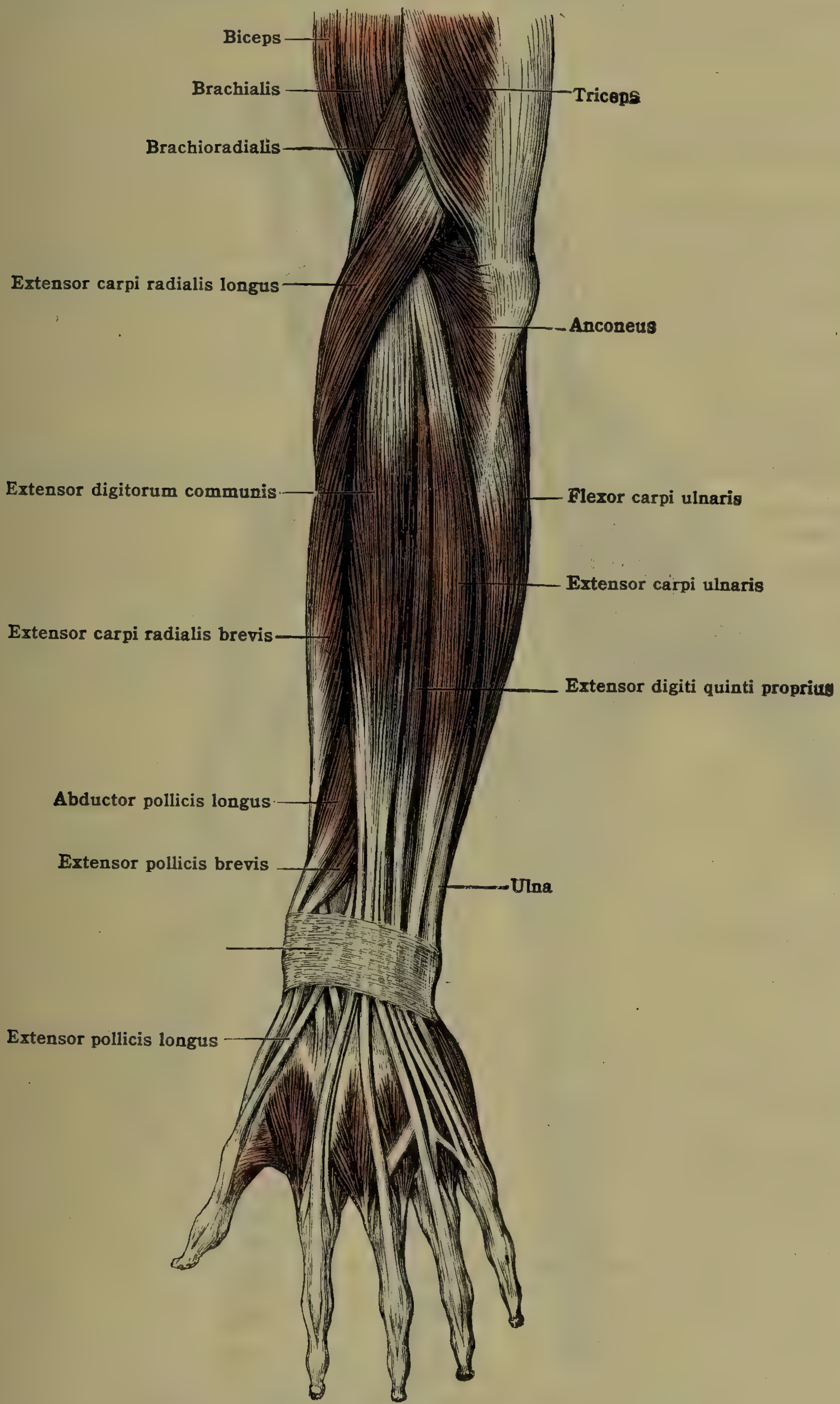


Fig. 430.—Muscles of the Radial Side and the Back of the Forearm.

The brachioradialis (supinator radii longus) (figs. 430, 433).—*Origin.*—From the upper two-thirds of the lateral epicondylar ridge of the humerus and from the front of the lateral intermuscular septum.

Insertion.—Into the lateral side of the base of the styloid process of the radius.

Structure.—The constituent fiber-bundles arise directly from the septum and by short tendinous bands from the epicondylar ridge, extend downward and ventrally, and terminate in a penniform manner on a tendon which extends high on the deep surface of the muscle.

This tendon becomes free about the middle of the forearm as a broad, flat band. This becomes narrow as the tendon winds about the radius from the volar to the lateral surface. Before its insertion it expands laterally and is connected with neighboring ligaments. The free surface of the muscle faces laterally at its origin, but, owing to the torsion, ventrally in the forearm. The tendon, however, is turned again so that at the insertion it faces laterally once more.

Nerve-supply.—From a branch of the radial nerve (musculospiral) which enters the proximal third of the muscle on its deep surface. The nerve fibers arise from the fifth and sixth cervical nerves.

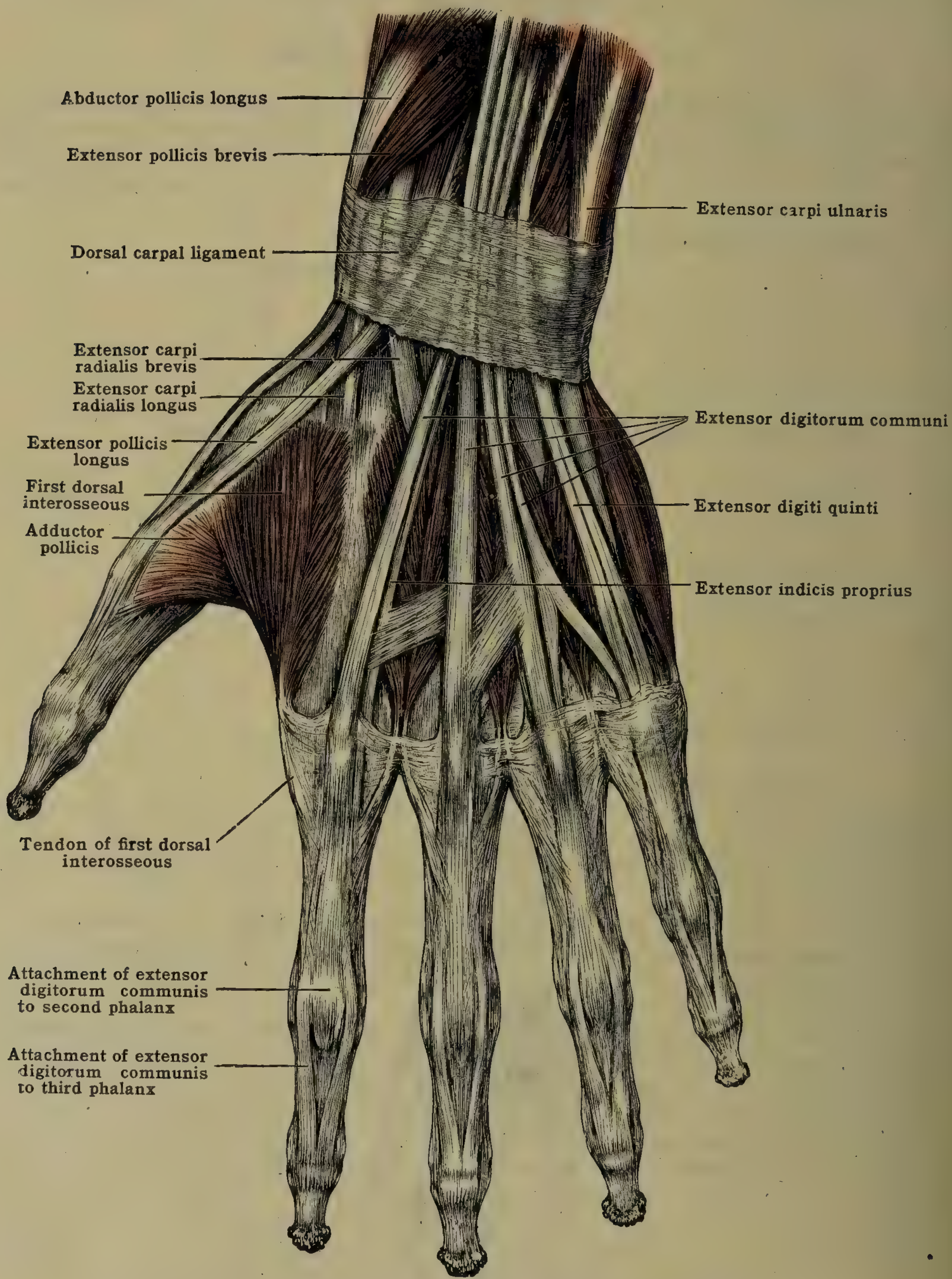


Fig. 431.—Tendons upon the Dorsum of the Hand.

Action.—To flex the forearm. This action is strongest when the forearm is pronated. It acts as a supinator only when the arm is extended and pronated. It then serves to put the arm in a state of semipronation. When the forearm is flexed and supinated, it acts as a pronator.

Relations.—The muscle is superficially placed on the ventrolateral surface of the forearm. Its tendon of insertion, however, is covered by the long abductor and the short extensor of the thumb. Near its origin (fig. 430) it lies lateral to the brachialis. In the intervening tissue run the radial nerve and the terminal branch of the profunda brachii artery. Dorsally and laterally

lies the medial head of the triceps. More distally the muscle overlies the extensor carpi radialis longus. It crosses the supinator, pronator teres, and flexor pollicis longus muscles. Beneath its medial edge lie the radial vessels and nerve.

Variations.—The humeral origin may extend half-way up the shaft. The radial insertion may be as high as the middle of the shaft or descend to the lesser multangular, navicular, or third metacarpal. In about 7 per cent. of bodies (Le Double) the tendon of insertion divides into two or three slips which are inserted on the styloid process of the radius. Occasionally the radial nerve passes between these slips. An accessory slip may pass to the fascia of the forearm. The muscle may be doubled throughout its length and it may be missing. It may be connected by accessory slips with neighboring muscles, the deltoid, brachialis, long abductor of the thumb, or long radial carpal extensor. The slip most frequently found goes to the brachialis.

The extensor carpi radialis longus (figs. 430, 431, 434).—*Origin.*—From the lower third of the lateral epicondylar ridge, the lateral intermuscular septum, and from the front of the tendons of the extensor carpi radialis brevis and the extensor communis digitorum which arise from the lateral epicondyle.

Structure and insertion.—The fiber-bundles are inserted in a penniform manner on both surfaces of a tendon which first appears on the lateral border of the deep surface of the muscle, becomes free above the middle of the forearm, and descends, closely applied to the tendon of the short radial carpal extensor, to the second compartment beneath the dorsal carpal ligament, through which it passes to its insertion into the base of the second metacarpal near the radial border. The outer surface of the muscle faces at first laterally, then ventrally.

Nerve-supply.—By one or two branches which arise from the radial (musculospiral) nerve as it passes between the brachialis and brachioradialis. The nerve enters the deep surface of the muscle in the proximal third. The nerve fibers arise from the (fifth), sixth and seventh cervical nerves.

Action.—To extend and abduct the hand. It steadies the wrist when the flexors act on the fingers. It is a flexor of the forearm; a supinator when the forearm is extended and pronated, a pronator when it is flexed and supinated.

Relations.—It is covered by the brachioradialis near the elbow. Below it becomes superficial except where crossed by the tendons of the muscles of the thumb. (For the relations to the short radial carpal extensor see below.)

Variations.—The humeral attachment may be more extensive than that indicated above. The tendon of insertion may send a band to the third or to the fourth metacarpal or to the multangulum majus (trapezium). The muscle may be fused, partly or completely, with the short radial extensor. It may send a slip to the abductor pollicis longus or to some of the interossei.

The extensor carpi radialis brevis (figs. 430, 431).—*Origin.*—From a band which descends on its deep surface from the common extensor tendon attached to the lateral epicondyle, from the intermuscular septa surrounding its head, and from the radial collateral ligament of the elbow-joint.

Structure and insertion.—The fiber-bundles converge obliquely toward a tendon which appears high up on the dorsolateral surface of the muscle. Toward the lower third of the forearm this tendon becomes a free, strong band closely applied to the under surface of the tendon of the long radial extensor, and with this passes through the second compartment beneath the dorsal ligament of the carpus, diverging as it does so toward its insertion into the back of the bases of the second and third metacarpal bones.

Nerve-supply.—A branch is supplied to the muscle from the deep radial (posterior interosseous) nerve before this enters the supinator (brevis). The branch enters the middle third of the medial margin of the muscle by several rami. The nerve fibers arise from the (fifth), sixth and seventh cervical nerves.

Action.—To extend the hand radialward and, to a slight extent, to flex the forearm.

Relations.—In its proximal portion the muscle is placed with a medial surface toward the common extensor, a deep toward the supinator (brevis) and pronator teres, and a dorsolateral toward the long radial extensor. More distally the muscle and its tendon become flattened about the radius and partly covered by the long radial extensor and its tendon.

In the distal quarter of the forearm the tendons of these two muscles are crossed by the long abductor and the short extensor of the thumb. Beneath the dorsal carpal ligament the tendon of the short radial extensor is crossed by the tendon of the long extensor of the thumb.

Variations.—The tendon often sends no slip to the second metacarpal. Fusion of the two radial extensors is frequent. The fused muscle may have from one to four tendons. The **extensor carpi radialis intermedius** of Wood is a muscle which arises, rarely directly from the humerus, but not infrequently as a slip from one or both radial extensors. It is inserted into the second or third metacarpal bone or into both. The **extensor carpi radialis accessorius** is a muscle which has an origin like the extensor intermedius, but which terminates on the base of the metacarpal or first phalanx of the thumb, the short abductor of the thumb, or some neighboring structure.

The extensor digitorum communis (figs. 430, 431).—*Origin.*—From a tendon attached to the lateral epicondyle, and from intermuscular septa which lie between the head of the muscle and the short radial extensor, the extensor of the little finger, and the supinator muscle.

Insertion.—By four tendons into the bases of the phalanges of the fingers.

Structure.—The fiber-bundles arise from the interior of the pyramidal case formed by the tendon, the fascia, and intermuscular septa, and pass distally to converge on four tendons which begin in the middle of the forearm, become free a little above the wrist, pass under the dorsal carpal ligament in a groove common to them and the tendon of the extensor indicis proprius, and diverge to the backs of the fingers. Opposite the metacarpophalangeal joint each tendon gives rise on its under surface to a band which becomes attached to the base of the first phalanx of its respective digit. The tendon is also closely bound to the joint by fibrous bands connected with the palmar fascia. On the dorsum of the first phalanx the tendon expands and is bound

to an aponeurotic extension from the interosseous and lumbrical muscles. The tendon divides into three bands. The middle band passes to the base of the second phalanx, the lateral bands pass laterally around the joint to be inserted into the back of the base of the third phalanx. The lateral bands are bound to the second joint by a thin layer of transverse and oblique fibers.

An obliquely transverse band usually passes from the tendon of the index to that of the middle finger above the heads of the metacarpals. The tendon to the index finger is united to the tendon of the extensor indicis proprius opposite the metacarpophalangeal articulation. The tendon to the ring finger usually sends a slip to join the tendon of the middle finger. The fourth tendon lies near that of the ring finger and divides into two slips, one of which joins the tendon of the ring finger and one goes to the little finger to join the tendon of the extensor digiti quinti proprius.

Nerve-supply.—From a branch which arises from the deep radial (posterior interosseous) nerve as it emerges from the supinator (brevis) muscle. From this several twigs enter the deep surface of the middle third of the belly. Often the nerve is bound up with the nerve to the extensor of the little finger and the ulnar extensor. On the other hand, there may be several separate branches to the muscle. The nerve fibers arise from the sixth, seventh, and eighth cervical nerves.

Action.—The muscle extends the two terminal phalanges on the basal, the basal on the metacarpus, and the hand at the wrist. The extensor action is strongest on the first phalanx. The cross-bands between the tendons hinder the independent extension of the middle and ring fingers, while the special extensors of the index and little fingers makes the movements of these fingers freer. When the hand is abducted toward the radial side, the extensor muscles tend to draw the fingers ulnarward. When the hand is abducted toward the ulnar side, the muscles tend to draw the fingers toward the thumb. When the hand is in the mid-position the ring finger and little finger are abducted and the index-finger is adducted. (Frohse.)

Relations.—It is superficially placed. Under it lie the deep muscles of the back of the forearm, the interosseous vessels, and the deep radial (posterior interosseous) nerve. It lies between the short radial carpal extensor and the extensor of the little finger.

Variations.—There is considerable variation in the extent of isolation of the parts going to the various fingers. That to the index-finger is the one most frequently isolated. At times the tendon to the index or little finger may be wanting. More frequently one or more of the tendons subdivides to be attached to two or more fingers or to the thumb. The connections between the tendons on the back of the hand vary greatly.

The **extensor digiti quinti proprius** (extensor minimi digiti) (figs. 430, 431).—*Origin.*—Chiefly from the septum between it and the common extensor, but also in part from the septum between it and the extensor ulnaris and from the overlying fascia.

Structure and insertion.—The fiber-bundles descend in a narrow band which begins near the neck of the radius. They are inserted into the side of a tendon which begins high on the ulnar margin of the muscle. The most distal fiber-bundles extend nearly to the wrist-joint. The tendon passes through the fifth compartment beneath the dorsal carpal ligament, and extends on the back of the fifth metacarpal to the base of the first phalanx of the little finger, where it is joined by a slip from the fourth tendon of the common extensor. The insertion of the tendons is like that of the tendons of the common extensor.

Nerve-supply.—By a branch or branches from the deep radial (posterior interosseous) nerve. The nerve filaments enter the middle third of the fleshy portion of the muscle on its deep surface. The innervation of this muscle is intimately related to that of the preceding.

Action.—It acts as a portion of the common extensor, but, owing to its separation, independent movement of the little finger is possible.

Relations.—It lies between the common extensor and the ulnar extensor and upon the deep muscles of the back of the forearm.

Variations.—Absence is not very frequent; blending with the common extensor is frequent Its tendon often divides into two or more slips. The belly may also be doubled. It may have a supplementary origin from the ulna. A tendon slip to the ring-finger is frequently found.

The **extensor carpi ulnaris** (figs. 430, 431).—*Origin.*—By two heads: one from the inferior dorsal portion of the epicondyle by an aponeurotic band attached below the tendon of the common extensor, from the enveloping fascia, and from the septa between it and the extensor digiti quinti, anconeus, and supinator (brevis); the other from the proximal three-fourths of the dorsal border of the ulna.

Structure and insertion.—The fiber-bundles descend in an osteofascial compartment bounded by the dorsal surface of the ulna, the fascia of the forearm, the dense fascia overlying the ulnar origin of the muscles of the thumb, and the origin of the extensor indicis. The tendon commences high in the muscle and appears on the radial border of the middle third of the back of its belly. The fiber-bundles are inserted in a penniform manner on the ulnar border and deep surface of the tendon as far as the wrist. Here the tendon enters the sixth osteo-fibrous canal beneath the dorsal carpal ligament in a special groove on the outer side of the styloid process of the ulna. It is inserted into the base of the fifth metacarpal.

Nerve-supply.—By a branch which arises from the deep radial (posterior interosseous) nerve as this emerges from the supinator (brevis) muscle. Several filaments enter the deep surface of the muscle in the middle third. The nerve fibers arise from the sixth, seventh and eighth cervical nerves.

Action.—To extend and abduct the hand ulnarward. It also abducts and extends the fifth metacarpal.

Relations.—It occupies a superficial position on the ulnar side of the extensors of the forearm. Beneath it lie the deep muscles of the back of the forearm and the posterior surface of the ulna.

Variations.—It may receive a slip from the triceps or be fused with the anconeus or with the extensor of the little finger. More frequently it is doubled, partially or completely. An accessory tendon may go to the first phalanx of the little finger, to the head of the fifth meta-

carpal, to the fourth metacarpal, to the extensor tendon of the little finger, or to the fascia over the opponens digiti quinti. The muscle may be reduced to a fibrous band. The **ulnaris digiti quinti** is a rare muscle arising from the dorsal surface of the ulna and inserted into the base of the first phalanx of the little finger. It may be represented by a fasciculus or an extra tendon from the ulnar extensor.

b. Deep Layer

(Fig. 432)

The muscles of this group extend from the ulna to the radius, thumb, and index-finger. They are the supinator, abductor pollicis longus, extensor pollicis longus and brevis, and extensor indicis proprius. The **supinator** is a rhomboid muscle which arises from the lateral epicondyle of the humerus and the supinator crest of the ulna, winds laterally around the radius and is inserted into its volar surface. The **abductor pollicis longus** is a fusiform muscle which arises from the middle third of the ulna, the interosseous membrane, and the radius, and is inserted into the base of the first metacarpal. The **extensor pollicis brevis** arises from the radius distal to the preceding muscle, and is inserted into the base of the first phalanx of the thumb. The **extensor pollicis longus** is a narrow muscle which arises from the middle third of the dorsal surface of the ulna and is inserted into the base of the second phalanx of the thumb. The **extensor indicis proprius** is a narrow, fusiform muscle arising from the shaft of the ulna and inserted into the dorsal aponeurosis of the index-finger. These muscles are supplied from branches of the deep radial (posterior interosseous) nerve while this is passing through or after its exit from the supinator.

The extensor pollicis longus is represented by the extensor hallucis longus of the leg. The abductor pollicis longus and extensor pollicis brevis are represented by the abnormal abductor hallucis longus and extensor primi internodii hallucis muscles, the rudiments of which are perhaps normally present in the tibialis anterior. The supinator and the extensor indicis muscles are not represented in the leg. On the other hand, the extensor digitorum brevis, normal in the foot, is only occasionally found on the back of the hand.

The supinator (brevis) (figs. 428, 432, 435).—*Origin.*—From (1) the inferior dorsal portion of the lateral epicondyle by a tendinous band which is adherent to the deep surface of the tendons of origin of the radial and common extensors and to the radial collateral ligament of the joint; and (2) the ulna by a superficial aponeurosis and by fiber-bundles attached directly to the depression below the radial notch and to the supinator crest.

Insertion.—The lateral and volar surfaces of the radius from the tuberosity to the attachment of the pronator teres.

Structure.—From their origin the fiber-bundles descend spirally in a muscular sheet which enwraps the radius (fig. 428). The attachment extends to the oblique line. The muscle is divided into a superficial and a deep plane by a septum in which the deep radial (posterior interosseous) nerve runs. The radial attachments of these two portions are separated by an osseous area into which no fiber-bundles are inserted. The fiber-bundles of the superficial layer have a much more vertical course and are longer than those of the deep layer.

Nerve-supply.—By branches which arise from the deep radial (posterior interosseous) nerve before it passes between the two layers of the supinator muscle. The nerve fibers arise from the fifth, sixth, and seventh cervical nerves.

Action.—To supinate the forearm.

Relations.—The supinator is covered by the superficial group of extensor muscles above described and by the anconeus.

Variations.—The extent of separation of the muscles into two portions varies. Accessory fasciculi of origin are not uncommon. These may spring from the annular ligament, **tensor ligamenti annularis anterior** (5 per cent. or more of bodies—Le Double), the lateral epicondyle, the tendon of the biceps, the tuberosity of the radius, etc. A sesamoid bone may lie in the tendon of origin. The **tensor ligamenti annularis posterior** is a slip generally present and often independent of the supinator. It runs from the ulna behind the radial notch to the annular ligament of the radioulnar joint.

The abductor pollicis longus (extensor ossis metacarpi pollicis) (fig. 432).—*Origin.*—From (1) the lateral margin of the dorsal surface of the ulna in the proximal portion of the middle third, and the adjacent interosseous membrane, (2) the dorsal surface of the radius distal and medial to the attachment of the supinator, and (3) at times, from the septa lying between it and the supinator, extensor carpi ulnaris, and extensor pollicis longus.

Structure and insertion.—The fiber-bundles from this extensive area of origin converge in a bipenniform manner upon a tendon which appears as an aponeurosis on the deep surface of the muscle about the middle of the forearm. The tendon as it descends becomes rounded. The insertion of fiber-bundles continues nearly to the wrist. Here, together with the tendon of the short extensor, it enters the first osteofibrous canal beneath the dorsal carpal ligament upon the lateral surface of the distal extremity of the radius. Upon leaving this canal the tendon extends to be inserted on the radial side of the base of the first metacarpal bone.

Nerve-supply.—By one or more branches from the deep radial (posterior interosseous) nerve after it has emerged from the supinator. The branches enter the muscle on the superficial surface in the proximal third. The nerve fibers come from the sixth, seventh (and eighth) cervical nerves.

Action.—It abducts the first metacarpal. At the height of its contraction it flexes and abducts the hand at the wrist.

Relations.—Near its origin the muscle is covered by the superficial extensors of the forearm More distally, accompanied by the short extensor, it passes radially, becomes superficial, and crosses the tendons of the two radial carpal extensors. On the lateral side of the dorsum of the wrist, proximal to the thumb, is the so-called **'snuff-box space'** (*tabatière anatomique* of Cloquet), a triangular depression, bounded toward the radius by the tendons of the long abductor and short extensor of the thumb, and toward the ulna by the long extensor. The navicular and greater multangular, with their dorsal ligaments, form the floor. In the roof lie the radial vein and branches of the radial nerve. More deeply is the radial artery, following a line from the apex of the styloid process to the back of the interosseous space.

Variations.—The muscle or its tendon may be doubled. An accessory tendon may be applied to the multangulum majus (trapezium), the transverse ligament of the carpus, the superficial muscles of the thenar eminence, or the first metacarpal. Of these, the attachment to the short abductor and short flexor is the most frequent (7 out of 36 bodies—Wood). There may be three or more tendons. The muscle may be fused with the short extensor.

The extensor pollicis brevis (fig. 432).—*Origin.*—From the distal part of the middle third of the medial portion of the dorsal surface of the radius and from the neighboring portion of the interosseous membrane. Rarely its origin extends to the ulna.

Structure and insertion.—The fiber-bundles converge on a tendon which appears on the radial border. The fibers are inserted as far as the dorsal carpal (posterior annular) ligament. The tendon lies parallel to the ulnar side of that of the abductor pollicis longus, and, in close connection with it, passes through the first compartment beneath the dorsal carpal ligament, and crosses the metacarpophalangeal joint on the radial side of the long extensor tendon. It is inserted on the base of the first phalanx of the thumb or into the capsule of the metacarpophalangeal joint.

Nerve-supply.—From a branch derived from the deep radial (posterior interosseous) nerve; this branch is usually given off in common with or near the nerve to the abductor pollicis longus, and may traverse that muscle to reach the extensor pollicis brevis, which it enters in the proximal third of its radial border. The nerve fibers come from the sixth, seventh (and eighth) cervical nerves.

Action.—To extend the thumb at the metacarpophalangeal joint and to abduct the first metacarpal. It is a radial abductor of the hand at the wrist-joint.

Relations.—It lies between the abductor pollicis longus and the extensor pollicis longus, by which its origin is partly overlapped. In company with the former muscle it passes medially from beneath the common extensor of the fingers and over the tendons of the radial carpal extensors to reach its osteofibrous canal under the dorsal carpal ligament.

Variations.—The head of the muscle may be fused with the long abductor. Its tendon of insertion may give rise to a slip inserted on the first metacarpal (in 2 out of 85 bodies—Le Double) or into the terminal phalanx. Its tendon is often united with that of the long extensor. It may be fused with the long abductor of the thumb and has been found missing. It may be doubled.

The extensor pollicis longus (fig. 432).—*Origin.*—From the middle third of the lateral part of the dorsal surface of the ulna; from the neighboring part of the interosseous membrane; and from the septa between it and the extensor indicis proprius and the extensor carpi ulnaris.

Structure and insertion.—The fiber-bundles converge in a bipenniform manner on the two sides of a tendon which appears high on the dorsal surface of the muscle. They extend as far as the dorsal carpal (posterior annular) ligament. The fusiform body of the muscle descends somewhat obliquely on the dorsal surface of the forearm. The tendon enters the third osteofibrous canal beneath the dorsal carpal (posterior annular) ligament. On emerging from the canal it passes very obliquely across the dorsal surface of the carpus, over the tendons of the radial extensors, to the ulnar side of the first metacarpal. It passes along this and, on the dorsal surface of the first phalanx, expands to be inserted into the base of the second phalanx. The aponeurosis of insertion receives tendinous slips from the short muscles of the volar surface of the thumb.

Nerve-supply.—By a twig from the deep radial (posterior interosseous) nerve. The branch gives rise to twigs which enter the proximal third of the radial border of the muscle. The fibers arise from the sixth, seventh, and eighth cervical nerves.

Action.—To extend the second phalanx on the first, and this on the metacarpal. It also draws the whole thumb when extended toward the second metacarpal. It is a radial abductor of the hand at the wrist-joint.

Relations.—The head of the muscle is partly overlapped by the long abductor of the thumb. It lies between this and the extensor pollicis brevis on one side, and the extensor indicis proprius on the other. Over it lie the extensors of the fingers and the ulnar carpal extensor.

Variations.—The tendon may give a slip to the base of the first phalanx of the thumb to the dorsal carpal ligament, or to the index finger. It may receive an accessory slip from the common extensor of the fingers or the short extensor of the thumb. It is frequently doubled. An additional extensor is found in about 6 per cent. of bodies between the extensor of the index finger and that of the thumb. It has a double tendon and insertion into both digits (**extensor communis pollicis et indicis**).

The extensor indicis proprius (fig. 432).—*Origin.*—From the proximal part of the distal third of the posterior surface of the ulna, medial and distal to that of the preceding muscle, from the adjacent interosseous membrane, and from the septum between it and the extensor pollicis longus.

Structure and insertion.—The fiber-bundles are inserted on a tendon which first appears on the radial border of the muscle. The insertion of fiber-bundles extends nearly to the dorsal carpal (posterior annular) ligament. Here the tendon passes beneath that of the extensor of the little finger and enters the fourth osteofibrous canal beneath the lateral tendons of the common extensor. It passes across the wrist beneath the tendon from the extensor communis

to the index finger, and is inserted on the ulnar side of this into the dorsal aponeurosis of the index finger opposite the base of the first phalanx.

Nerve-supply.—By a twig from the deep radial (posterior interosseous) nerve. This twig enters the proximal third of the radial border of the muscle. It frequently arises from a branch to the extensor pollicis longus. The nerve fibers come from the sixth, seventh, eighth cervical nerves.

Action.—To extend the first phalanx on the metacarpal. Like the common extensor it has a limited action on the two terminal phalanges. (It also adducts the index finger.)

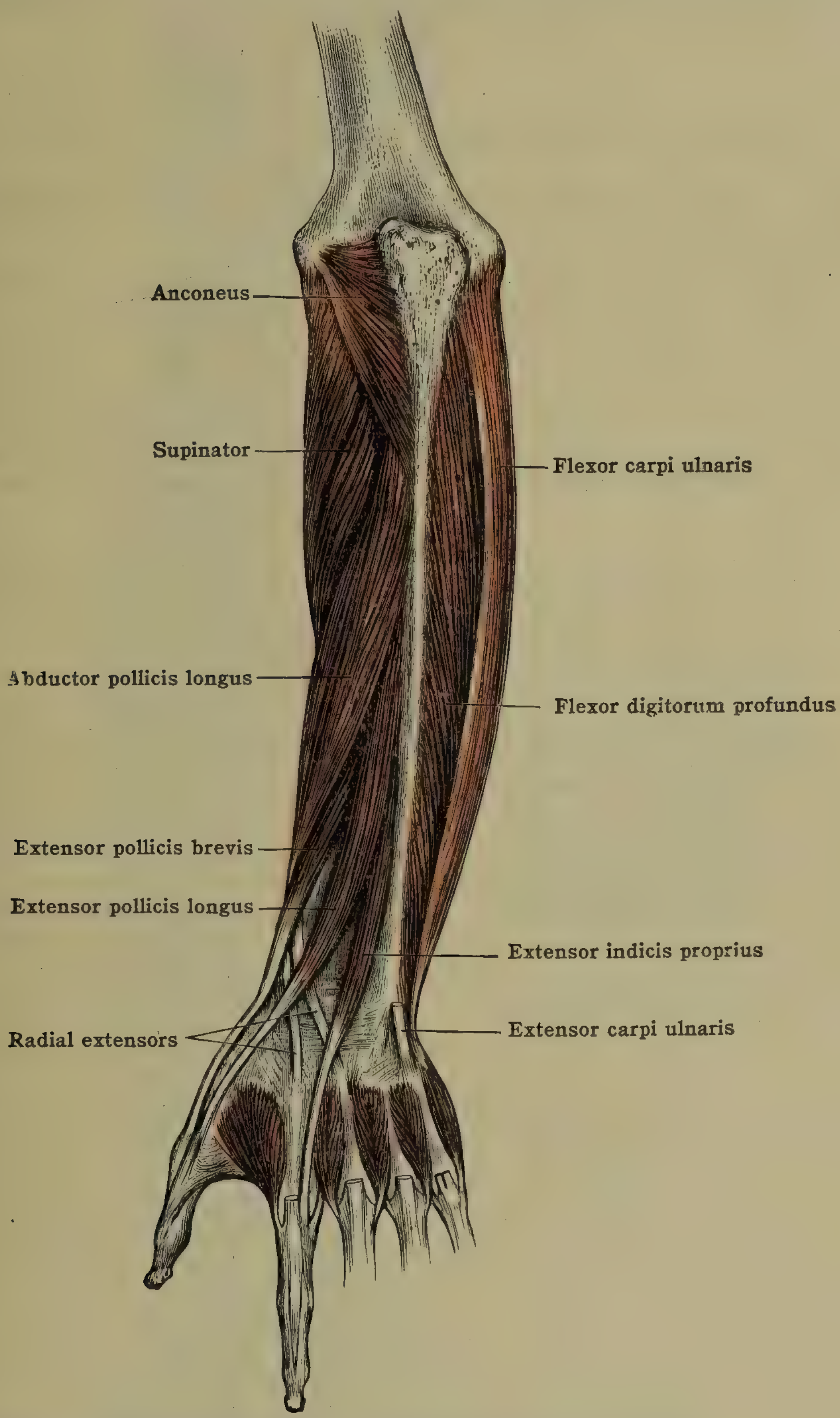


Fig. 432.—The Deep Muscles of the Back of the Forearm.

Relations.—It is covered by the superficial extensor group.

Variations.—These are frequent. It may be absent. There may be two heads, or the muscle may be completely doubled. It may receive an accessory slip from the ulna or the carpus. The tendon may give accessory slips to the middle finger, the ring finger, or the thumb, The accessory tendon to the middle finger is the most frequent. The tendon to the index finger may be inserted on the metacarpus.

Abnormal Muscles of the Back of the Wrist and Hand

The **extensor medii digiti** is a small muscle which arises from the ulna beneath the extensor of the index finger, with which it is more or less fused. It sends a tendon to the extensor aponeurosis of the middle finger or slips both to this finger and the index finger. It is present in about 10 per cent. of bodies (Le Double).

The **extensor digiti annularis** is a muscle similar to the extensor medii digiti, but much rarer.

The **extensor digitorum brevis**, which resembles the muscle of corresponding name on the dorsum of the foot, may have from one to four fasciculi, but most frequently one. The most common fasciculus is one which sends a tendon to the extensor tendon of the index finger. One for the middle finger is nearly as frequent. Others are rare. A fasciculus for the thumb has not been reported. (Le Double.) The fasciculi usually arise from the bones of the ulnar half of the carpus—lunatum (semilunar), triquetrum (cuneiform), hamatum (unciform), and capitatum (magnum), and from the dorsal ligaments uniting these bones. The tendons are inserted either into the corresponding extensor tendons or into the metacarpals. The muscle is found in about 10 per cent. of bodies (Wood).

Bursæ

B. m. extensoris carpi radialis brevis.—Between the tendon and the base of the third metacarpal.

B. m. abductoris pollicis longi.—Between the tendons of the long and short radial extensors and the tendons of the abductor pollicis longus and extensor pollicis brevis. Another bursa lies beneath the tendon of insertion of the abductor.

B. intermetacarpophalangeæ.—Between the lateral surfaces of the heads of the metacarpal bones of neighboring fingers dorsal to the transverse capitular ligament.

B. tendinum m. extensoris digitorum communis.—Small bursæ are sometimes found beneath the tendons to the index and little fingers near where they begin to diverge from the common tendon.

B. m. extensoris carpi ulnaris.—A small bursa may be found under the tendon of origin of this muscle.

B. m. supinatoris.—Between the supinator and the tendon of the extensor muscles.

B. m. extensoris pollicis longi.—Between the tendon and the first metacarpal.

2. Ulnovolar Division

The muscles on the volar side of the forearm lie in four layers.

a. First Layer
(Fig. 433)

Of the four muscles of associated ulnar epicondylar origin which constitute this layer the **pronator teres** is a strong, band-like muscle which is inserted into the lateral surface of the middle third of the shaft of the radius; the fusiform **flexor carpi radialis** sends a tendon to the base of the second metacarpal; the slender **palmaris longus** is inserted into the palmar fascia; and the medially situated, fusiform **flexor carpi ulnaris** into the pisiform bone and the palmar fascia. The pronator teres is the most powerful pronator of the forearm. When the hand is slightly flexed the ulnar carpal flexor abducts ulnarward. When the hand is greatly flexed lateral movement is difficult. The ulnar flexor is supplied by the ulnar nerve, the other muscles by the median.

The pronator teres probably corresponds with the popliteus of the leg. The flexor carpi radialis and flexor carpi ulnaris probably represent in the main the two heads of the gastrocnemius; and the palmaris longus, the plantaris.

Anterior cubital region.—The **cubital fossa** lies just below the elbow and is triangular in form. It is bounded above by a line joining the two humeral epicondyles, medially by the pronator teres, and laterally by the brachioradialis (fig. 433). In the center of the fossa lies the tendon of the biceps, giving off the lacertus fibrosus medially to the antibrachial fascia. Under the medial side of the tendon lies the brachial artery, usually dividing into the radial and ulnar opposite the neck of the radius. For a short distance, the median nerve here lies parallel with the brachial artery. The radial (musculospiral) nerve is outside the fossa.

Over this region the delicacy of the skin must always be kept in mind in the application of splints. The median basilic vein here is usually chosen for venesection, and for intravenous injections, owing to its larger size and firm support by the subjacent bicipital fascia (lacertus fibrosus) which separates it from the brachial artery; but the median cephalic vein is the safer. The median basilic is crossed by branches of the medial antibrachial (internal) cutaneous nerve, while those of the musculocutaneous lie under the median cephalic. The M-like arrangement of the superficial veins is by no means constant (see p. 739).

The pronator teres (fig. 433).—*Origin.*—By two heads:—(1) the *humeral* or chief head arises by a tendon from the superior half of the ventral surface of the medial epicondyle and directly from the overlying fascia and from the intermuscular septa between it and the medial head of the triceps and the flexor carpi radialis. (2) The *ulnar*, deep or accessory, head arises by an aponeurotic band attached to the inner border of the coronoid process medial to the tendon of the brachialis. Between the humeral and ulnar heads is a fibrous arch beneath which the median nerve passes.

Structure and insertion.—The fiber-bundles of the humeral head are inserted in a penniform manner on a tendon which begins near the middle of the belly of the muscle on the superficial surface along the radial border. The tendon gradually becomes broader, winds about the volar surface of the radius, and is inserted into the middle third of its lateral surface. The attach-

ment of fiber-bundles continues nearly to this insertion. The fiber-bundles of the ulnar head form a slender fasciculus which is inserted into the radial side of the deep surface of the humeral head.

Nerve-supply.—By a branch derived from the median nerve before it passes between the two heads of the muscle. The nerve enters the proximal part of the middle third of the main belly of the muscle on its deep surface near the radial border. The branch to the ulnar head usually enters this portion of the muscle somewhat proximal to its fusion with the humeral head. The nerve fibers arise from the sixth and seventh cervical nerves.

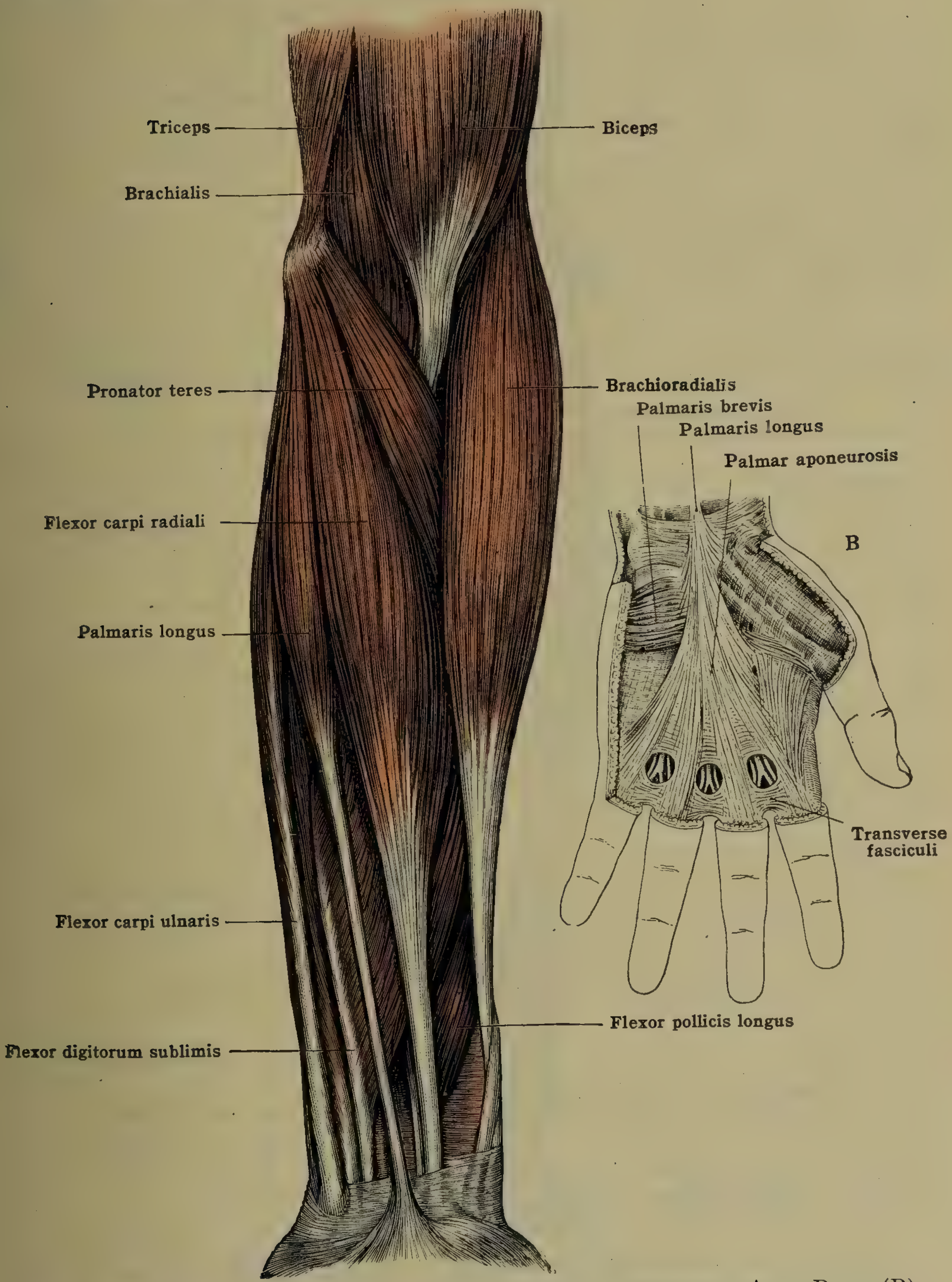


Fig. 433.—Front of the Forearm: First Layer of Muscles. Also Palm (B).

Action.—To pronate and flex the forearm.

Relations.—The muscle is superficially placed. Near its origin it is covered by the lacertus fibrosus of the biceps, and near its insertion by the radial vessels and nerve and the brachioradialis and radial extensor muscles. It is the most radial of the group of muscles under consideration. The radial border helps to bound an angular space, the cubital fossa, in which lie the brachial vessels, median nerve, and the tendon of the biceps. The median nerve passes between its humeral and ulnar heads. The muscle overlies the supinator, the brachialis, and the radial origin of the flexor digitorum sublimis muscles and the ulnar artery.

Variations.—Supplementary fasciculi may arise from the humerus, the medial intermuscular septum of the arm, the flexor carpi radialis, the flexor sublimis, or the brachialis muscles. The

two portions of the muscle may be distinct from origin to insertion. Either part of the muscle may be doubled. The ulnar head may be absent. The radial insertion may be extensive. Fasciculi may extend to the long flexor of the thumb. There may be a sesamoid bone in the tendon of origin from the humerus.

The flexor carpi radialis (fig. 433).—*Origin.*—From (1) the common tendon attached to the medial epicondyle; and (2) the septa between its head and the pronator teres, the flexor sublimis, and the palmaris longus.

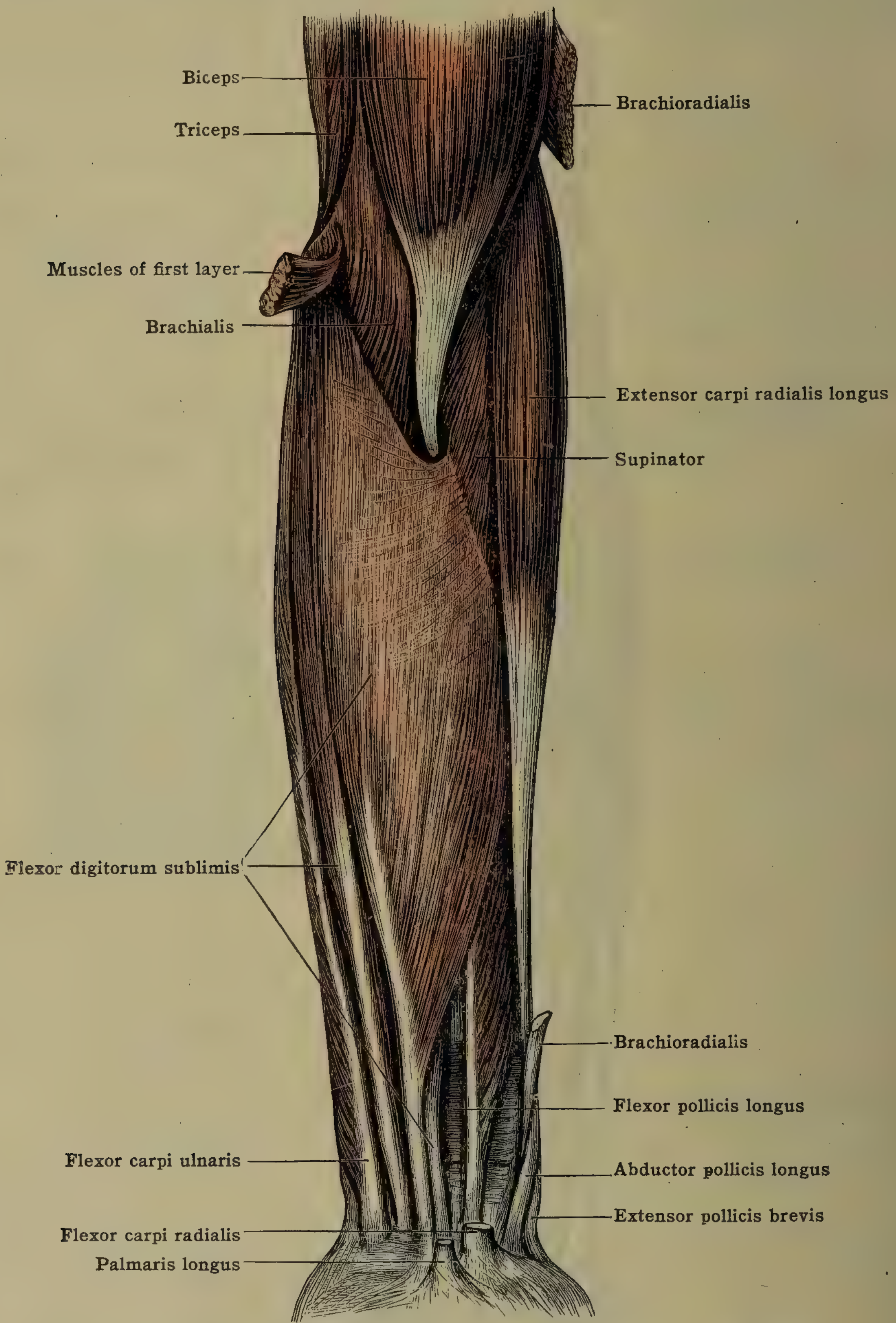


Fig. 434.—Front of the Forearm: Second Layer of Muscles.

Structure and insertion.—The fiber-bundles descend to converge upon a tendon at first intramuscular, but which in the middle of the arm appears on the volar surface of the muscle and soon becomes free from the attachment of fiber-bundles. The fiber bundles from the epicondyle descend nearly vertically to the front and sides of the tendon, while those from the intermuscular septa take an oblique course to the deep surface of the tendon. The tendon is at first flat, but soon becomes cylindrical, bound to the superficial muscle fascia, and enters the hand through a special osteofibrous canal formed mainly by the groove in the os multangulum majus (trapezium) and the transverse carpal (anterior annular) ligament. It is inserted into the base of the second metacarpal. It usually also sends a tendon slip to the third.

Nerve-supply.—By a branch from the median nerve which divides into several twigs that enter the muscle near the junction of its proximal and middle thirds on the deep surface. The

nerve usually arises near the elbow. The nerve fibers arise from the sixth, seventh (and eighth) cervical nerves.

Action.—To flex the hand at the wrist. To a slight extent it may also act as a pronator of the forearm and a flexor of the forearm on the arm.

Relations.—It is superficial except near its insertion. The belly of the muscle lies between the pronator teres and the palmaris longus and upon the flexor digitorum sublimis. The tendon of the muscle passes over the flexor pollicis longus, and near the wrist is a guide to the radial artery, which here lies lateral to it. In the hand the tendon lies beneath the thenar muscles and is crossed by the tendon of the long flexor of the thumb.

Variations.—It may receive a fasciculus from the brachialis or biceps muscles or from the radius or ulna. It may send tendon slips to the multangulum majus (trapezium), navicular, the transverse carpal (anterior annular) ligament, or the fourth metacarpal. The insertion may take place variously into these structures.

The palmaris longus (fig. 433).—*Origin.*—From the common tendon attached to the medial epicondyle and from the surrounding intermuscular septa.

Structure and insertion.—The fiber-bundles take a nearly parallel course to a tendon which appears high in the middle third of the forearm on the volar surface of the muscle. In the middle of the forearm the attachment of fiber-bundles usually ceases, the tendon becomes bound to the overlying fascia, and descends parallel with that of the radial flexor. Near the proximal border of the transverse carpal (anterior annular) ligament the tendon expands into radiating bundles of fibers of which the medial and lateral are attached to the fascia over the intrinsic muscles of the thumb and little finger, while the middle, much more developed, constitute the chief portion of the palmar aponeurosis.

Nerve-supply.—From a branch which usually arises in company with the nerve to the proximal part of the flexor sublimis. It frequently traverses the superficial fibers of the flexor sublimis. The nerve enters the middle third of the muscle.

Action.—To flex the hand. It is also a weak flexor and pronator of the forearm.

Relations.—It is placed between the radial and ulnar flexors over the flexor sublimis. In the distal part of the forearm the tendon lies over the median nerve.

Variations.—It is absent in 11.2 per cent. of all cases (Le Double). It may be highly developed or reduced to a tendinous band. The belly of the muscle may lie in the distal instead of in the proximal part of the forearm. It may be digastric. It may be fused with neighboring muscles. It may arise from the medial intermuscular septum of the arm or from the lacertus fibrosus, from the radius, from the coronoid process, from the radial or ulnar flexor, or from the flexor sublimis muscles. The tendon may terminate in the fascia of the forearm, the thenar eminence, the carpus, or the abductor of the thumb. The muscle may be partly or wholly doubled.

The flexor carpi ulnaris (fig. 433).—*Origin.*—By two heads:—(1) the **humeral head** arises from the common flexor tendon attached to the lower ventral part of the medial epicondyle. Fiber-bundles of this head are also attached to the surrounding intermuscular septa and the deep fascia of the forearm. (2) The **ulnar head** arises by short tendinous fibers from the medial side of the olecranon and by an aponeurotic band common to it and the flexor digitorum profundus from the upper two-thirds of the dorsal border of the ulna. Proximally the two heads of the muscle are united by a fibrous arch extending from the olecranon to the medial epicondyle. Beneath this band pass the ulnar nerve and the dorsal recurrent ulnar artery. (See Epitrochleo-olecranonis, p. 469.)

Structure and insertion.—The fiber-bundles of the humeral head descend nearly vertically, those of the ulnar head obliquely distally in a radial direction. They are inserted in a penniform manner on a tendon which appears in the proximal part of the middle third of the belly of the muscle on the radial margin of the deep surface, and in the distal third of the forearm forms the radial border of the muscle. On the ulnar side the insertion of fiber-bundles continues nearly to the pisiform bone. The insertion of the tendon takes place chiefly into the pisiform bone, but from it tendinous bundles extend to the palmar aponeurosis, volar ligament of the carpus, to the pisohamate (pisounciform), ligament, and to the bases of the fifth, fourth, and third metacarpals.

Nerve-supply.—From two or three branches of the ulnar nerve, the most proximal of which arises near the elbow-joint. These branches, which may arise by a single trunk, enter the deep surface of the proximal third of the muscle and send long twigs distally across the middle third of the constituent fiber-bundles. The nerve fibers arises from the seventh and eighth cervical and first thoracic nerves.

Action.—To flex the hand and to abduct the hand ulnarward.

Relations.—It is superfically placed. Its aponeurotic origin is adherent to the fascia of the forearm. It lies medial to the palmaris longus and flexor sublimis and upon the flexor profundus. Beneath the muscle lies the ulnar nerve. The ulnar artery extends along the radial border of the tendon near the wrist.

Variations.—These are rare. Slips from the tendon may pass to the metacarpophalangeal articulation of the little finger. (See, however, Abnormal Muscles, p. 469.)

b. Second Layer

This is composed of one muscle, the **flexor digitorum sublimis**, which, although in part covered by the muscles of the preceding layer, is in part superficial. It arises from the medial epicondyle of the humerus, and from the radius and the ulna, and sends tendons to the second row of phalanges of the fingers. It corresponds probably to the soleus and the tendons of the flexor digitorum brevis in the leg and foot. The nerve supply is from the median nerve.

The flexor digitorum sublimis (figs. 434, 436, 439).—*Origin.*—By two heads: the **ulnar or chief head** arises (1) by the tendon common to it and the superficial group of muscles from the medial epicondyle, and by short tendinous bands from the ventral surface of the epicondyle; (2) from the ulnar collateral ligament of the elbow, the ulnar tuberosity, the medial border of the coronoid process, and the inferior extremity of the tendon of the brachialis; and (3) from the intermuscular septum between the flexor sublimis and the overlying muscles. The **radial head** arises from an oblique line on the volar surface of the radius, and from the middle third of the anterior border.

Insertion.—Into the sides of the volar surface of the shafts of the second row of phalanges of the fingers.

Structure.—The fiber-bundles of the ulnar head and the upper part of the radial head converge, the ulnar fiber-bundles nearly vertically, the radial obliquely, to form a common belly the deep surface of which on the ulnar side is backed by a dense tendinous band. On the radial side of this a less dense membrane covers over an oval canal which passes distally along the line of junction of the two heads and lodges the ulnar artery and the median nerve.

The fiber-bundles of the ulnar head form a superficial and a deep group. The superficial portion near the middle of the forearm divides into a lateral and a medial division, the former being inserted on a tendon that goes to the middle and the latter on one that goes to the ring finger. The fiber-bundles of the radial head join with the lateral division of the superficial layer of the ulnar head and are inserted on the tendon of the middle finger nearly as far as the wrist. A small muscle fasciculus of the superficial portion of the ulnar head is usually united by a tendon to the long flexor of the thumb.

The deep portion of the ulnar head about the middle of the forearm terminates in large part on the volar surface of the dense tendinous band above mentioned. From this in turn two muscle bellies arise. One of these is inserted in a bipenniform manner to a tendon going to the index finger, the other on a tendon going to the little finger. A muscle fasciculus also usually passes from the region of the tendon band to that portion of the superficial fasciculus which terminates on the tendon of the ring finger.

The four tendons pass together through the carpal canal under the transverse carpal (anterior annular) ligament, those to the middle and ring fingers lying at first superficial to the other two. The tendons then diverge, and each tendon, together with and above a tendon of the flexor profundus, passes over the metacarpophalangeal joint into an osteofibrous canal on the palmar surface of the first phalanx of the finger for which it is destined. Here the tendon becomes flattened about the round tendon of the flexor profundus. Opposite the middle of the phalanx the tendon divides into two slips, between which the tendon of the flexor profundus passes. The divided halves of the sublimis tendon fold about the profundus tendon so that their lateral edges come to meet in the mid-line beneath this tendon opposite the phalangeal joint (figs. 439, 440). They then again separate, extend distally, and are attached one on each side into a ridge at the middle of the lateral border of the second phalanx. The tendons are also attached by **vincula tendinum, a ligamentum breve**, between the tendon and the head of the first phalanx and the joint, and a **ligamentum longum**, between the tendon and the volar surface of the first phalanx. The tendency of the dense osteofibrous tunnels of the tendons to gape widely after section is to be remembered in amputations through infected parts.

Nerve-supply.—Before the median nerve passes between the two heads of the pronator teres a branch arises which accompanies the nerve through the pronator and sends several branches into the proximal third of the ulnar head of the muscle. As the median nerve passes beneath the muscle, one or more branches are given to the radial head, and a long branch is given to the fasciculus of the second and from this one to that of the fifth digit. Occasionally, the median nerve in the distal third of the forearm gives rise to branches for these fasciculi. The nerve fibers arise from the seventh and eighth cervical and first thoracic nerves.

Action.—Chiefly to flex the second phalanx of each finger on the first; secondarily, to flex the fingers on the hand and the hand on the forearm.

Relations.—The belly of the muscle is covered by the pronator teres, flexor carpi radialis, and palmaris longus, but is superficial along a narrow strip between the flexor carpi ulnaris and the palmaris longus, and on each side of the tendon of the flexor carpi radialis. The muscle rests on the flexor pollicis longus and flexor digitorum profundus, the median nerve (see description given above) and ulnar vessels. The median nerve emerges from beneath the radial border of the muscle in the lower third of the forearm. In the palm the tendons lie beneath the palmar aponeurosis, the superficial palmar arch, and the branches of the median nerve, while they lie in front of the tendons of the flexor profundus, with which they are closely associated into a common bundle by loose fibrous tissue. The digital relations of the tendons are described above.

Variations.—The whole muscle may be rendered digastric by a transverse tendon. A fasciculus of the flexor sublimis may replace the palmaris longus or the two may coexist. A fasciculus may terminate in the fascia of the forearm or in the transverse carpal ligament, the palmar aponeurosis, etc. Various parts of the muscle may be absent or more independent than usual. The extent of the radial attachment varies greatly and may be missing. A special fasciculus may be received from the coronoid process of the ulna. A fasciculus may be sent to the flexor profundus or to other muscles. There may be some fusion with neighboring muscles.

c. Third Layer

(Figs. 435–440)

The two muscles which constitute this layer may be looked upon as differentiated from a single deep flexor muscle. The **flexor digitorum profundus** is a strong, broad muscle which arises from the upper three-fourths of the volar surface of the ulna and gives rise to tendons which are inserted into the bases of the third

row of phalanges of the fingers. The **flexor pollicis longus,** likewise broad and flat, arises from the volar surface of the radius and is inserted into the base of the second phalanx of the thumb. Both muscles are supplied by the median nerve and the flexor profundus is also supplied by the ulnar nerve.

These muscles correspond to the flexor digitorum longus and the flexor hallucis longus of the leg.

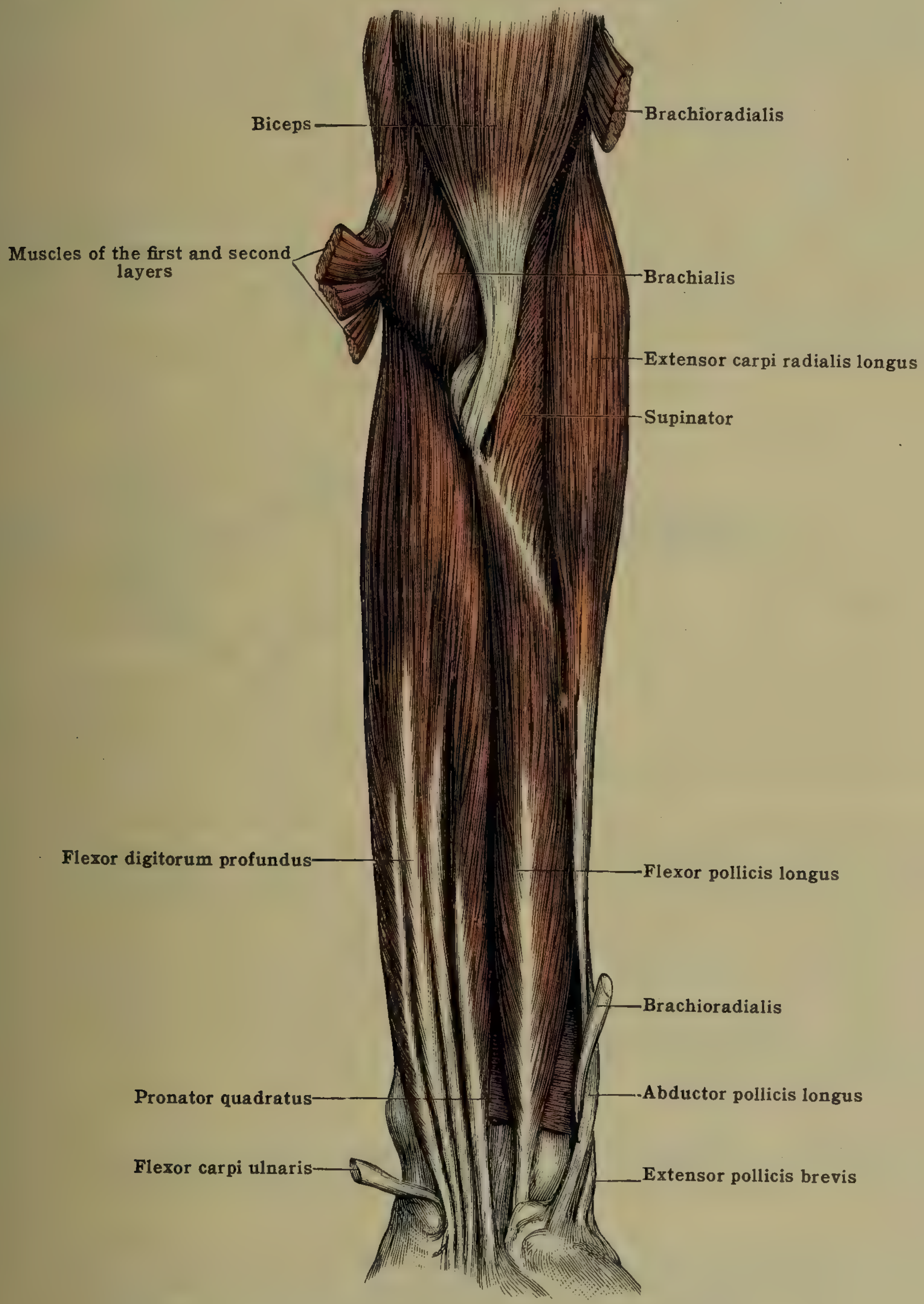


FIG. 435.—FRONT OF THE FOREARM: THIRD LAYER OF MUSCLES.

The flexor digitorum profundus (figs. 435–440).—*Origin.*—(1) Through an aponeurotic septum between it and the flexor carpi ulnaris from the dorsal border of the ulna; (2) directly from the proximal two-thirds of the medial surface and the proximal three-fourths of the volar surface of the ulna and from the adjacent interosseous membrane; and (3) inconstantly, from a small area on the radius below the bicipital tuberosity.

Structure and insertion.—The fiber-bundles descend nearly vertically and give rise to a common belly which soon divides into four portions, each of which is attached about midway down the forearm in a semipenniform manner to the dorsal surface of a tendon. The attachment of fiber-bundles continues nearly to the wrist. The digital divisions of the muscle vary in the height to which they extend. That belonging to the index finger is usually the one most extensively isolated, and that to the little finger is the next most so. The tendons pass side by side under the transverse carpal (anterior annular) ligament, and then diverge to the bases of the

fingers. At the metacarpophalangeal joints, they enter the osteofibrous canals described above (p. 466). On the volar surface of the first phalanx each tendon passes through the slit in the sublimis tendon. The tendon then is continued over the second phalanx to the base of the third. **Vincula tendinum** are described passing to the capsule of the second interphalangeal joint (**ligamentum breve**) and to the tendon of the flexor sublimis (**ligamentum longum**). The lumbrical muscles arise from the tendons while they are in the palm.

Nerve-supply.—The interosseous branch of the median nerve arises usually before the nerve passes through the pronator teres and accompanies the main trunk. This branch as it passes beneath the flexor sublimis gives off a branch (or two) from which several twigs spring. These twigs enter the muscle near the radial border and pass in across the middle third of the constituent fiber bundles of the fasciculi to the index and middle fingers. The ulnar nerve near the elbow gives rise to a branch which enters the volar surface of the muscle near the junction of the proximal and middle thirds of that portion of the belly, giving tendons to the ring and little fingers. There is some variation in the extent of the innervations by the branches of the ulnar and those of the median nerve. To a greater or less extent through anastomosis their territories overlap. The nerve fibers arise from the seventh and eighth cervical and first thoracic nerves.

Action.—To flex the terminal phalanx of each finger on the second and the second on the first, while that of the superficial flexor is to flex the second phalanx on the first. The action of the two flexors on the first phalanx is somewhat more limited. The interosseous muscles, aided by the lumbricals, are the chief flexors of the first row of phalanges. The flexor profundus acts, though not powerfully, as a flexor of the wrist.

Relations.—The flexor profundus muscle lies beneath the flexor sublimis and the flexor carpi ulnaris muscles, the median nerve, and the ulnar vessels and nerve. Under the muscle lie the ulna the interosseous membrane, and the pronator quadratus muscle. Under the transverse

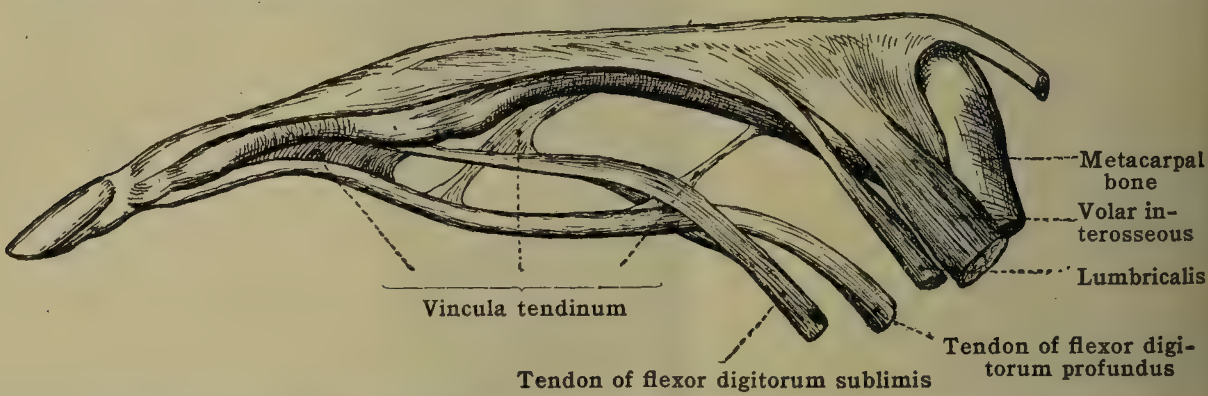


Fig. 436.—Insertions of the Tendons of the Muscles which act on the Finger. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

carpal (anterior annular) ligament the tendons lie beneath those of the flexor sublimis in the same synovial sac. In the palm the tendons with the associated lumbrical muscles lie upon the interosseous muscles, the adductor of the thumb, and the deep palmar arch, and beneath the flexor sublimis tendons. For the relations to the synovial bursæ see p. 471.

Variations.—There is considerable variation in the extent of the radial origin and in the extent of the independence and fusion of the different fasciculi. In the prosimians a common tendon extends as far as the hand. The division in the higher forms is associated with refinement of movements of the fingers. One or more special fasciculi not infrequently join the muscle from the flexor sublimis, the flexor pollicis longus, the medial epicondyle, or the ulna. The **accessorius ad flexorem digitorum profundum** is a fasciculus which arises from the coronoid process of the ulna and sends a tendon to join the tendon of one of the fingers, most frequently the middle or index. It is found in 20 per cent. of bodies.

The flexor pollicis longus (fig. 435).—*Origin.*—The attachment extends along the oblique line and the ventral border of the radius from slightly below the bicipital tuberosity to within 5 cm. of the wrist. Medially it is continued into the interosseous membrane. Proximally the tendon frequently extends to the distal radial margin of the coronoid process of the ulna and gives rise to fiber-bundles connected with the muscle, as well as to a fasciculus of the flexor profundus.

Structure and insertion.—The fiber-bundles descend obliquely to be inserted in a penniform manner on a tendon which begins high up on the volar surface near the ulnar border of the muscle, and descends as a broad band which near the wrist becomes cylindroid. The insertion of fibers continues nearly to the point where the tendon passes under the transverse carpal ligament. Here the tendon enters the carpal canal radial to the tendons of the flexor profundus, and passes beneath the superficial head of the short flexor of the thumb, then between the thumb sesamoids into the osteofibrous canal of the thumb, in which it is continued to the base of the terminal phalanx.

Nerve-supply.—Usually from two branches of the volar interosseous ramus of the median nerve. These enter the proximal half of the ulnar margin of the muscle. The nerve fibers arise from the sixth, seventh (and eighth) cervical nerves.

Action.—It is a strong flexor of the second phalanx on the first and has less powerful action on the metacarpophalangeal joint and on the wrist. It adducts and flexes at the carpometacarpal joint.

Relations.—It lies beneath the flexor sublimis, the flexor carpi radialis and brachioradialis muscles, and the radial artery. Near the wrist it crosses over the insertion of the pronator quadratus. In the hand the tendon runs beneath the opponens pollicis and the superficial head of the flexor brevis, and across the deep head of the latter.

Variations.—It may be fused or united by fasciculi with the flexor profundus the flexor sublimis, or the pronator teres. It may be partially doubled, giving rise to an accessory tendon which extends to the index finger. The origin may extend to the medial epicondyle of the humerus (epitrochlear bundle).

d. Fourth Layer

This layer consists of a single quadrilateral muscle, the pronator quadratus, which passes transversely across the lower part of the forearm from the ulna to the radius. In the leg there is no corresponding muscle. The nerve supply is from the volar interosseous branch of the median nerve.

The pronator quadratus (fig. 441).—*Origin.*—Medial side of the volar surface of the lower fourth of the ulna.

Structure and insertion.—From the ulna a strong aponeurosis extends a third of the way across the volar surface of the muscle. From this membrane and from the bone fiber-bundles extend transversely to be inserted on the distal quarter of the volar surface of the radius and on the triangular area above the ulnar notch. The deeper fiber-bundles which arise directly from the ulna are inserted into the radius by means of an aponeurosis. The superficial and deep portions of the muscle are often separated. The muscle is thicker distally than proximally.

Nerve-supply.—The volar interosseous nerve descends along the interosseous membrane, passes behind the middle of the proximal margin of the muscle, and sends branches into its deep surface. The nerve fibers arise from the (sixth), seventh and eighth cervical and first thoracic nerves.

Action.—To pronate the forearm.

Relations.—The muscle lies immediately beneath the muscles of the third layer and upon the radius and ulna, the interosseous membrane, and radioulnar joint. The radial artery and ulnar nerve pass in front of it, the volar interosseous artery behind it.

Variations.—It may be missing or may extend further up the forearm than usual or down upon the carpus. It may be triangular or divided into parts the fiber-bundles of which take different directions. It may send fasciculi to the carpus or metacarpus or be fused with the flexor carpi radialis brevis (see below).

Abnormal Muscles of the Volar Side of the Forearm and Wrist

The epitrochleo-olecranonis (anconeus internus).—A muscle fasciculus, distinct from the distal margin of the triceps, which runs from the medial epicondyle to the olecranon over the groove for the ulnar nerve, by a branch of which it is supplied. It takes the place of the fibrous arch normally extending between the epicondylar and ulnar heads of the flexor carpi ulnaris. It occurs in about 25 per cent. of bodies (Testut), and represents an adductor of the olecranon of the lower mammals. Occasionally the medial head of the triceps may descend over the ulnar groove, but this forms another type of muscle variation.

The flexor carpi ulnaris brevis (ulnocarpeus).—An abnormal muscle which arises from the distal quarter of the volar surface of the ulna and is inserted in the hamatum (unciform) the pisiform, the abductor of the little finger, or the superior extremity of the fifth metacarpal.

The uncipisiformis.—A short, thick band of muscle which runs from the pisiform to the tip of the hamulus of the os hamatum (unciform) parallel with the pisohamate (pisounciform) ligament. It is innervated by the ulnar nerve.

The flexor carpi radialis brevis (radiocarpeus). An abnormal muscle found in about 5 per cent. of bodies (Le Double). It arises from the lateral or the volar surface of the distal half of the radius. Some of the fiber-bundles may spring from the pronator quadratus, the fasciæ of the forearm, or the ulna. It is inserted into the carpus or metacarpus, and occasionally even into the first phalanx of the index finger, etc. It is supplied by a branch of the volar interosseous nerve. It serves to flex the wrist. It is said to represent the tibialis posterior of the leg.

Bursæ

B. m. flexoris carpi ulnaris.—Between the tendon of this muscle and the pisiform bone.

B. m. flexoris carpi radialis.—Between the tendon of this muscle and the tubercle of the navicular bone.

A bursa is often found between the tendon of the deep flexor of the index finger and the carpus. This bursa is frequently in communication with the radial and ulnar tendon-sheaths.

A bursa is also often found between the deep and superficial tendons of the index finger.

Clinical relations.—Owing to the frequency of wounds here, the relation of the structures in front of the wrist is most important. The radial artery lies between the tendon of the brachioradialis and flexor carpi radialis. Next to this tendon is the palmaris longus, when present. At the midpoint of the front of the wrist and usually under the palmaris longus is the median nerve. To the medial side of the palmaris longus is the flexor sublimis, the tendons for the middle and ring-finger being in front. The tendon of the flexor carpi ulnaris is most medial and between this and the superficial flexor of the finger the ulnar nerve and vessels become superficial.

Synovial Tendon Sheaths

(Figs. 401, 428, 437, 438)

The synovial tendon sheaths of the hand and wrist merit special attention because of their relationship to infections of the hand. Their arrangement is somewhat variable; the most typical will be described.

On the volar surface of the wrist, there are two sheaths: a smaller radial and a larger ulnar (fig. 437). The radial sheath surrounds the tendon of the flexor pollicis longus from a point just proximal to the transverse carpal ligament to the distal phalanx of the thumb. The ulnar sheath surrounds the flexor tendons of the second to the fifth digit. It begins just proximal to the transverse carpal ligament and extends to about the mid-transverse line of the palm. The tendon sheaths of the digits proper begin at the heads of the second to the fifth metacarpals and extend to the distal phalanges. The sheath of the fifth digit usually communicates with the ulnar sheath at the wrist, the sheaths of the second to the fourth digits do not, their distal extremities being separated from the ulnar sheath by an interval of one half to one inch.

On the dorsal surface (fig. 438) there are usually six tendon sheaths which surround the extensor tendons and the tendon of the abductor pollicis longus.

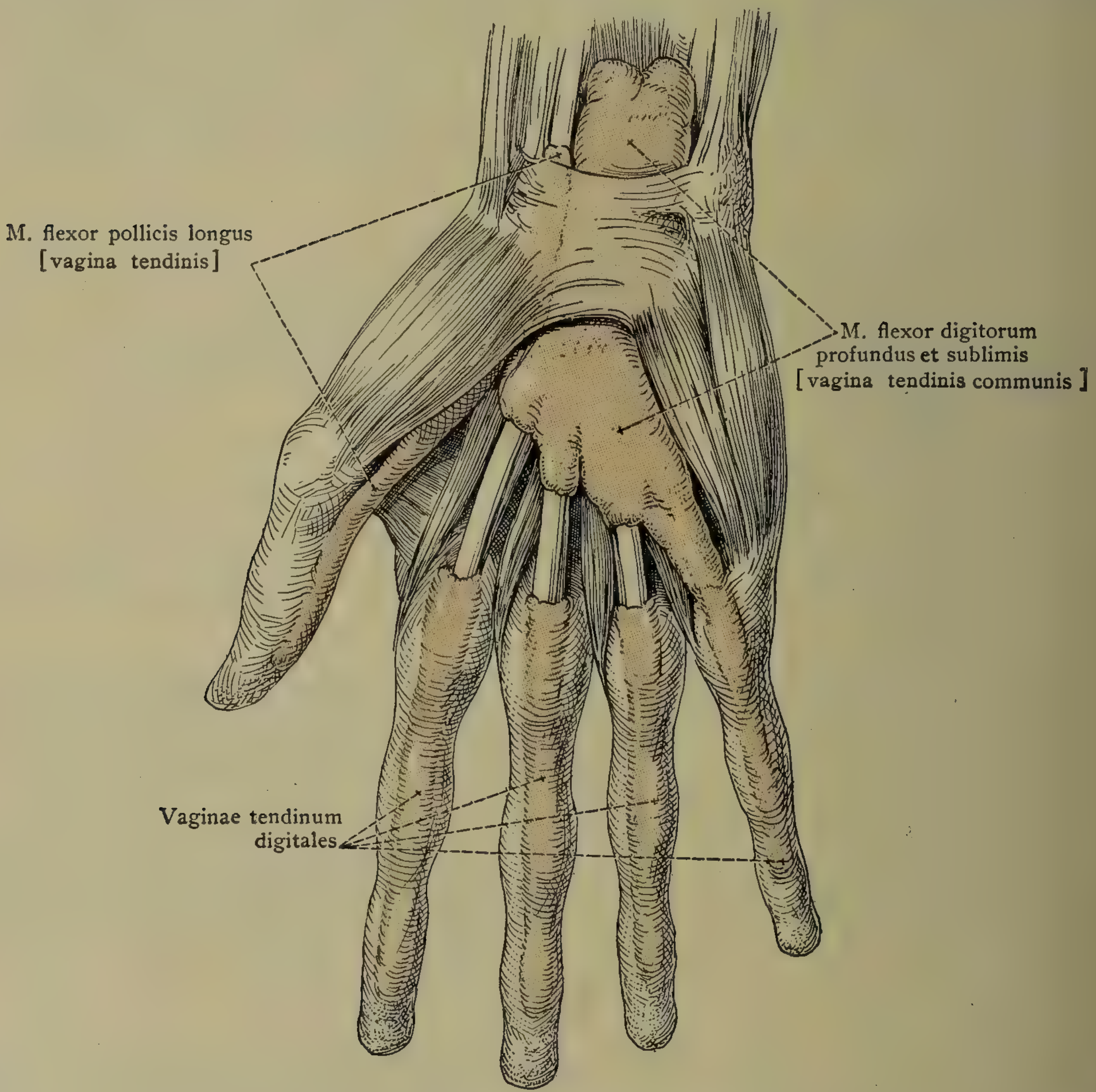


Fig. 437.—Tendon Sheaths of the Palmar Surface of the Right Hand. (From Eycleshymer-Jones 'Hand-Atlas of Clinical Anatomy,' Lea & Febiger.)

In general they ensheath the tendons where they pass under the dorsal carpal ligament, beginning at a point just proximal to this ligament and extending a few centimeters beyond its distal border. Separate sheaths usually enclose the extensor carpi radialis longus and brevis; the extensor digitorum communis and extensor indicis proprius; the extensor digiti quinti; the extensor carpi ulnaris; the abductor pollicis longus and extensor pollicis brevis; and the extensor pollicis longus. There may be communications between the various separate sheaths.

There is no synovial sheath beneath the pulp of the fingers or thumb, this part lying on the periosteum of the last phalanx. This has an important bearing on **whitlow.** Infection here may be merely *subcutaneous,* or deeper, in the latter case from the connection of the skin with the periosteum here existing the bone is soon affected, and necrosis keeps up a tedious ulcer. As the two centers of the phalanx do not unite till about the twentieth year, the distal one only requires removal; as the flexor sheath only reaches to the insertion of the flexor, i. e., into the proximal, part of the bone, both sheath and tendon may escape implication. Higher up

along the fingers whitlow may be *cellulocutaneous* or *synovial*. While the continuity of the synovial sheath in the little finger and thumb renders infection here more dangerous, the short gap between the digital and the palmar sacs is readily traversed by acute infection, with all the grave results of synovial suppuration. (See also p. 453 and fig. 429.)

Vagina tendinis m. flexoris carpi radialis.—About the tendon as it passes beneath the transverse carpal ligament.

Vaginæ tendinum mm. flexorum digitorum.—The osteofibrous canals of the digits are lined by a synovial membrane which is reflected by means of a fold (cul-de-sac) to the tendons at each end and over the vincula tendinum, in which blood-vessels and nerves for the tendons are contained. The synovial cavity of the first and usually that of the fifth digit communicate with those of the palm.

In the wrist and palm two large synovial sacs may usually be recognized, although the number may be raised to five or reduced to one.

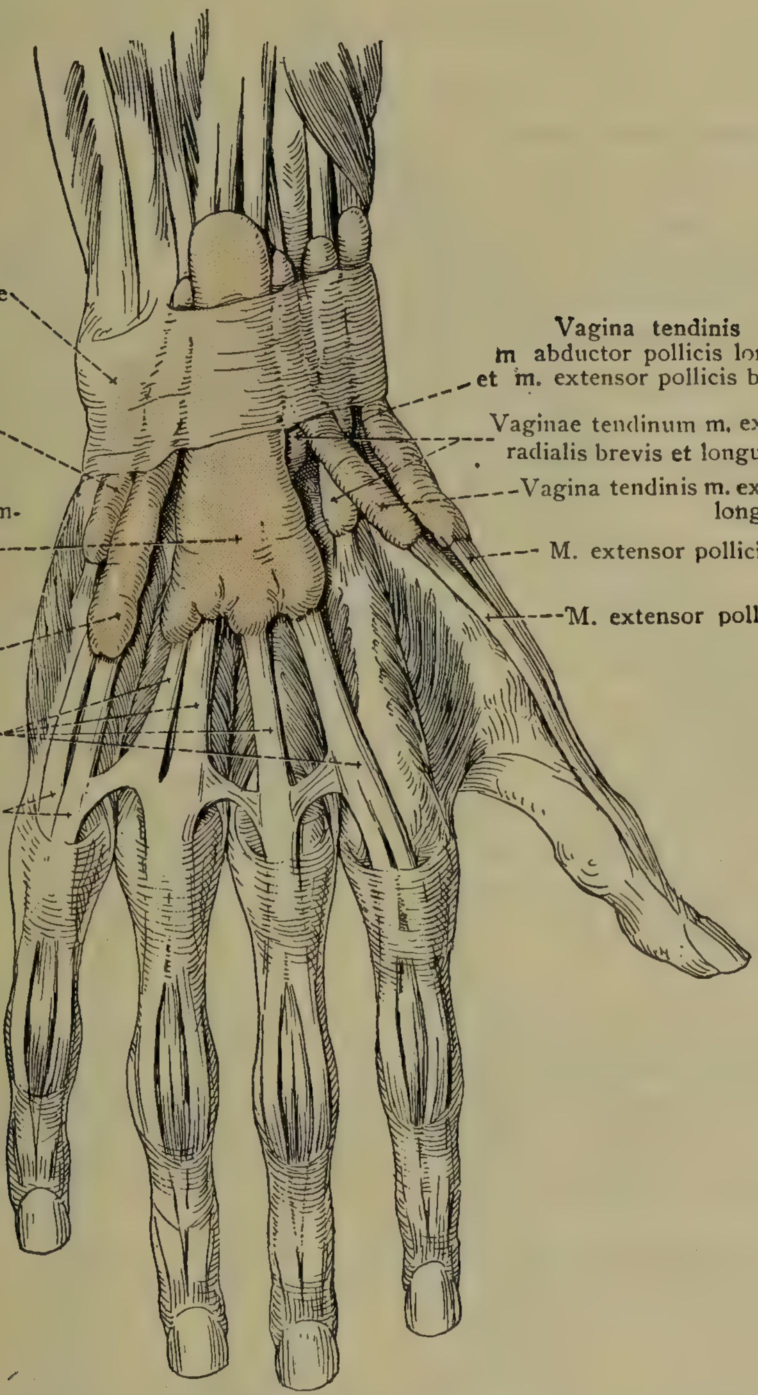


Fig. 438.—Tendon Sheaths of the Dorsal Surface of the Right Hand. (From Eycleshymer-Jones 'Hand-Atlas of Clinical Anatomy,' Lea & Febiger.)

The radial sac, **vagina tendinis m. flexoris pollicis longi,** surrounds the long flexor tendon of the thumb in the wrist and palm and usually communicates with that of the thumb. In the palm a well marked mesotendon usually extends to the deep ulnar side of the tendon from the parietal layer of the sheath.

The ulnar sac, **vagina tendinum mm. flexorum communium,** surrounds the tendons of the long flexors of the fingers. It begins proximal to the transverse carpal ligaments and extends nearly or quite to the synovial sheath of the little finger on the ulnar side and on the radial side to the center of the palm.

Vagina tendinum mm. extensorum carpi radialium.—Synovial sheaths cover the tendons of the two radial carpal extensors as they pass beneath the dorsal carpal (posterior annular) ligament. In the adult these sheaths usually are more or less fused and communicate with the sheath of the extensor pollicis longus where this crosses them.

Vagina tendinum mm. extensoris digitorum communis et extensoris indicis.—A synovia sheath surrounds the tendons of these muscles as they pass beneath the dorsal carpal (posterio annular) ligament. This sheath extends for some distance on the tendons as they diverge

Vagina tendinis m. extensoris digiti quinti.—A synovial sheath extends on the tendon o this muscle from above the dorsal carpal (posterior annular) ligament to the base of the meta carpal.

Vagina tendinis m. extensoris carpi ulnaris.—This sheath commences above the carpa (posterior annular) ligament and extends to the insertion of the tendon.

Vagina tendinum mm. abductoris pollicis longi et extensoris pollicis brevis.—The sheath which surround these two tendons beneath the dorsal carpal (posterior annular) ligamen usually communicate freely.

Vagina tendinis m. extensoris pollicis longi.—A long synovial sheath surrounds this tendon Where it crosses the tendons of the radial extensors, a communication is found with the sheat of the latter.

3. Musculature of the Hand

(Figs. 428, 431, 439–443)

The intrinsic muscles of the hand are taken up in the following groups:—

a The subcutaneous muscle of the palm.
b The muscles of the little finger.
c The muscles of the thumb.
d The lumbrical muscles.
e The interosseous muscles.

The ulnar nerve supplies the muscles of the little finger, the interossei, the medial lumbrical muscles, and two of the muscles of the thumb; the median nerve supplies most of the muscles of the thenar region and the lateral lumbrical muscles.

(*a*) *Subcutaneous Muscle*

(Figs. 433, 439)

The **palmaris brevis** is a small, trapezoid sheet situated between the hypothenar fascia and the skin. It arises at the lateral edge of the palmar aponeurosis from tendinous slips which may be traced through the aponeurosis to the navicular and greater multangular. It is composed of nearly parallel fiber-bundles, and extends into the deep surface of the skin along the ulnar border of the palm. It is generally taken to be a subcutaneous muscle like the superficial muscles of the head and neck. It has, however, been suggested that it represents the remnants of a short flexor of the digits corresponding with the flexor digitorum brevis of the foot.

Nerve supply.—The superficial branch of the palmar division of the ulnar nerve gives rise to a twig which enters the deep surface of the muscle. The fibers come from the (seventh and) eighth cervical and first thoracic nerves.

Action.—The action of the muscle is to draw the skin of the ulnar side of the hand toward the center ot the palm. It is said that it thus helps to from a cup-shaped hollow when the hand conveys fluid to the mouth. The contraction of the muscle by raising a ridge over the ulnar nerve and artery when an object is grasped hard serves according to Henle, to protect these structures.

Variations.—It varies in size. In about 2 per cent. of bodies it is absent (Le Double). It may send tendinous slips to the pisiform bone. (For a thenar subcutaneous muscle, see variations of the abductor pollicis brevis.)

(*b*) *Muscles of the Little Finger*

(Figs. 439–441)

In the hypothenar eminence are three muscles, the abductor, the flexor brevis, and the opponens digiti quinti. The **abductor digiti quinti** is a flat, fusiform muscle which arises from the pisiform and is inserted into the ulnar border of the first phalanx and into the dorsal aponeurosis through which it helps to flex the first and extend the second and third phalanges of the little finger. The fusiform **flexor brevis** arises from the hamatum (unciform) and adjacent part of the transverse carpal (anterior annular) ligament and is inserted into the ulnar side of the base of the first phalanx. The triangular **opponens** likewise arises from the hamatum (unciform) and the transverse (anterior annular) ligament. It is inserted into the ulnar border and the head of the fifth metacarpal. These muscles are supplied by the ulnar nerve.

The abductor of the little finger corresponds with that of the little toe. A part of the opponens beneath the ulnar nerve corresponds with that of the little toe, while the more superficial portion is unrepresented in the foot. The flexor brevis of the little toe corresponds with a part of the deep portion of the opponens of the little finger. The flexor brevis of the little finger is unrepresented in the foot. (Cunningham.)

The abductor digiti quinti (figs. 439, 440).—*Origin.*—From the distal half of the pisiform, the ligaments between this and the hamatum, the tendon of the flexor carpi ulnaris, and often from the transverse carpal (anterior annular) ligament.

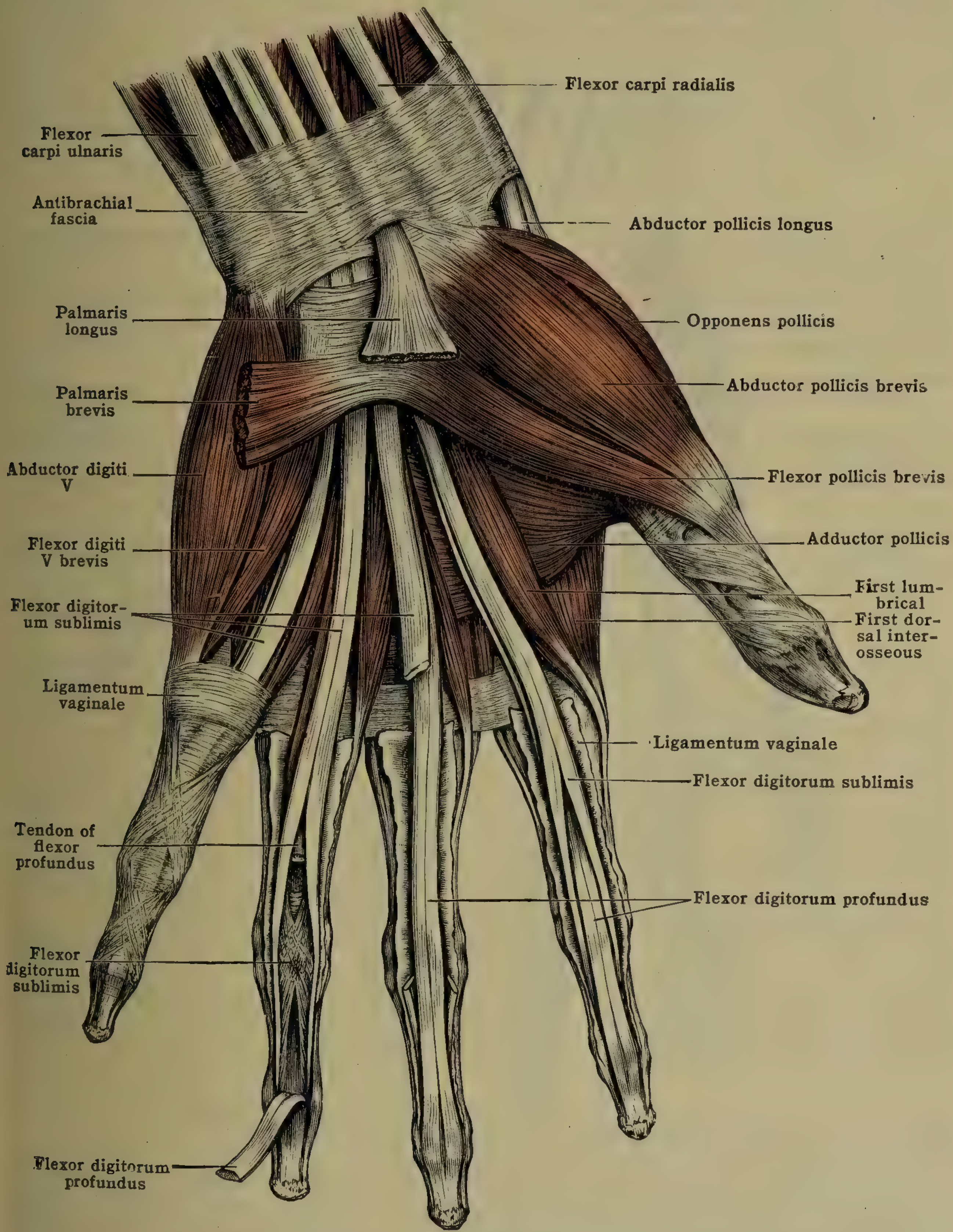


Fig. 439.—The Superficial Muscles of the Palm of the Hand.

Structure and insertion.—The fiber-bundles descend vertically, at first increasing in number and then concentrated, toward two short tendons one of which is inserted into the ulnar border of the first phalanx of the little finger and the other into the aponeurosis of the extensor tendon of the little finger.

Nerve-supply.—From the deep palmar division of the ulnar nerve before it passes through the opponens or from the superficial palmar branch arise one or more twigs which enter the radial side of the muscle on its deep surface in the proximal third. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To abduct the little finger, flex the first phalanx, and extend the last two.

Relations.—It overlies the opponens and flexor brevis. Superficially it is covered by fascia and the palmaris brevis muscle. Along the proximal part of its radial margin run the deep palmar branches of the ulnar artery and nerve.

Variations.—It may be missing or doubled. It may be fused with the short flexor or receive fasciculi from the palmaris longus, the ulnar flexor, the fascia of the forearm, etc.

The flexor digiti quinti brevis (figs. 440, 441).—*Origin.*—By a short tendon from the hook of the hamatum (unciform) and from the adjacent parts of the transverse carpal (anterior annular) ligament.

Structure and insertion.—The fiber-bundles take a nearly parallel course and are inserted by a short tendon which is fused with that of the abductor and is inserted into the ulnar side of the base of the first phalanx of the little finger. A sesamoid bone may lie in the tendon.

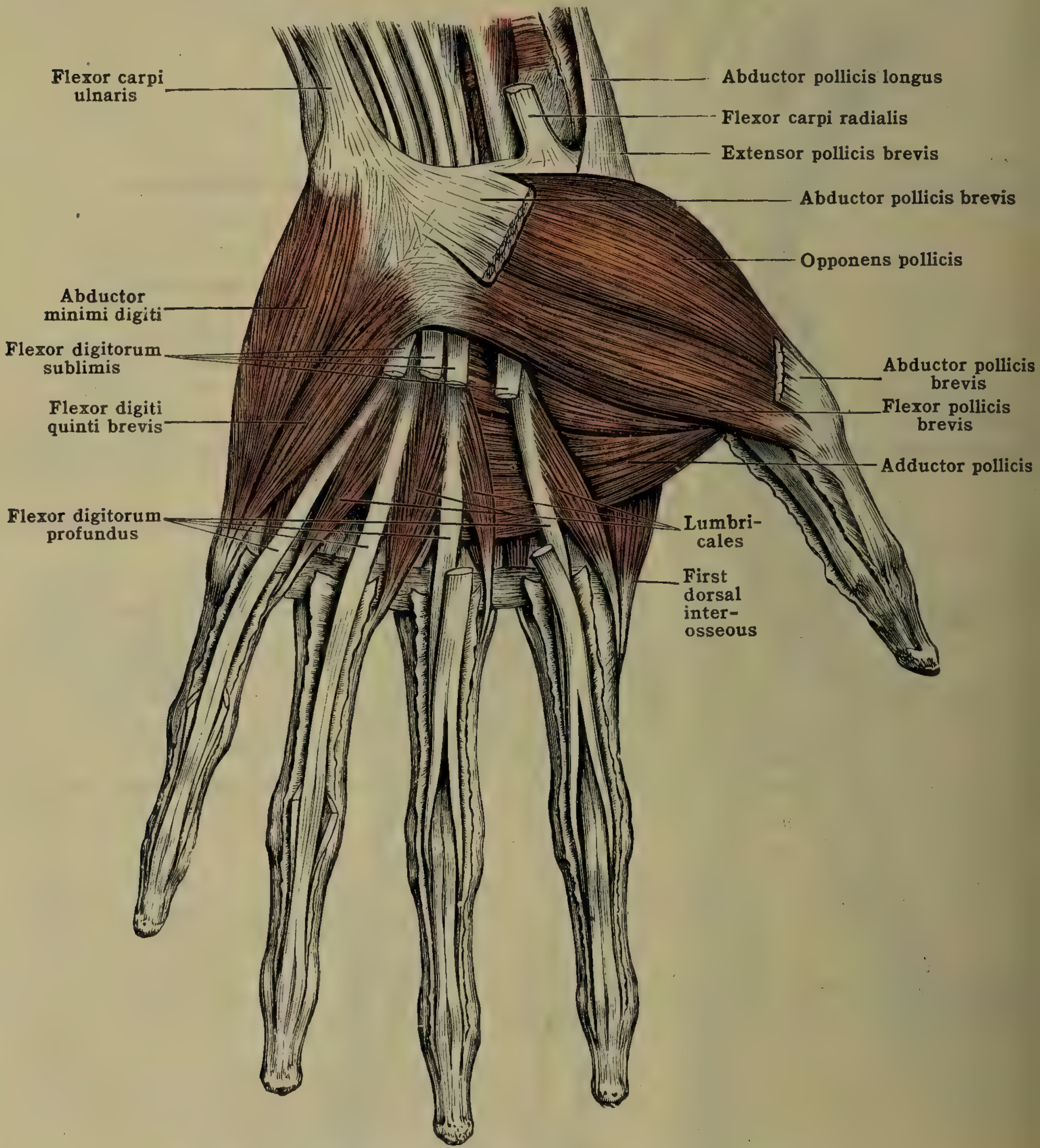


Fig. 440.—The Deeper Muscles of the Palm of the Hand.

Nerve-supply.—A branch from the superficial or deep palmar division of the ulnar nerve enters the deep surface of the muscle in its proximal half. The nerves to the abductor and flexor may arise in common from the ulnar. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To flex the first phalanx of the little finger. When it sends a tendon slip to the aponeurosis of the extensor of the finger it helps to extend the two terminal phalanges.

Relations.—The muscle closely adjoins and is partly covered by the abductor. The palmaris brevis and the lateral volar digital artery to the fifth finger lie superficial to it. Under it lies the opponens.

Variations.—The muscle may be wanting or may be closely fused with the abductor or the opponens. It may receive an accessory slip from the forearm fascia. It may give a tendon slip to the extensor aponeurosis or to the head of the fifth metacarpal.

The opponens digiti quinti (fig. 441).—*Origin.*—Partly tendinous, from the distal ulnar border of the hook of the hamatum (unciform) and from the adjacent transverse carpal (anterior annular) ligament.

Structure and insertion.—The fiber-bundles diverge, the proximal short and horizontal, the distal long and oblique, and are inserted on the whole of the ulnar border and on a part of the head of the fifth metacarpal. Often the muscle is divisible into two portions between which the ulnar nerve runs.

Nerve-supply.—Before the deep palmar branch passes through the muscle it gives rise to a twig which enters its volar surface in the middle third near the ulnar margin. The nerve fibers arise from the (seventh and) eighth cervical and first thoracic nerves.

Action.—To flex, adduct, and slightly rotate the fifth metacarpal; as, for example, in 'cupping' the hand to drink from it.

Relations.—The opponens lies beneath the abductor and flexor brevis muscles. The deep branches of the ulnar nerve and artery pass through the opponens near its carpal origin and then under it extend into the palm.

Variations.—It may be fused with neighboring muscles or receive accessory slips.

The **tensor capsularis articulationis metacarpophalangei digiti quinti** is a slender muscle which arises from the ligaments which unite the pisiform to the hamatum, and is inserted into the volar surface of the metacarpophalangeal joint of the little finger.

(c) *Muscles of the Thumb* (Figs. 439–441)

In the thenar region there are four muscles. Of these, the abductor pollicis brevis is the most superficial. Then come the opponens pollicis and the short flexor, and beneath the last the adductor pollicis. All are triangular in form. The **abductor pollicis brevis** arises from the radial side of the volar surface of the carpus and is inserted into the radial side of the base of the first phalanx of the thumb. The **opponens** is a thick muscle extending from the transverse carpal (anterior annular) ligament to the radial side of the first metacarpal. The **flexor pollicis brevis** arises by two heads, a deep and a superficial, from the carpus and is inserted into the radial side of the base of the first phalanx. The **adductor pollicis** arises from the carpus and the second and third metacarpals and is inserted into the ulnar side of the first phalanx of the thumb. From the tendons of insertion of the abductor and flexor brevis slips are continued into the dorsal aponeurosis of the thumb so that they aid in extending the second phalanx. The median nerve supplies all of these muscles except the adductor which is supplied by the ulnar. The ulnar nerve may supply the flexor brevis.

In the foot an opponens hallucis occurs as an abnormal muscle. The abductor, flexor brevis and adductor of the thumb are represented by the corresponding muscles of the big toe, although the last two muscles are not perfectly homologous in the hand and foot.

The abductor pollicis brevis (fig. 439).—*Origin.*—From the volar surface of the transverse carpal (anterior annular) ligament, and from the greater multangular bone (trapezium). Also often from the navicular bone and from a tendon slip of the long abductor.

Structure and insertion.—The fiber-bundles converge upon a flat tendon with two lamellæ, the deeper of which is inserted into the radial side of the base of the first phalanx of the thumb and the superficial into the aponeurosis of the extensor pollicis longus.

Nerve-supply.—By a branch of the first volar digital ramus of the median nerve. This branch passes over or through the flexor brevis and enters the muscle on the volar surface in the middle third near its ulnar border.

Action.—To abduct the thumb, flex the first phalanx, and extend the terminal phalanx.

Relations.—It lies beneath the thenar fascia lateral to the superficial head of the flexor brevis and over the opponens. The superficial volar artery usually perforates the muscle.

Variations.—It may be wanting or may be divided into two divisions. The origin may extend to the fascia of the forearm or styloid process of the radius It may receive an accessory slip from the long radial extensor, the opponens, or the short extensor of the thumb. A *thenar subcutaneous muscle* is occasionally present. It is narrow, is closely associated with the short abductor of the thumb, and extends from the radial side of the base of the first metacarpal into the skin of the thenar eminence.

The opponens pollicis (fig. 441).—*Origin.*—From the volar surface of the transverse carpal (anterior annular) ligament and from the tubercle of the greater multangular bone (trapezium).

Structure and insertion.—The fiber-bundles extend obliquely in a nearly parallel direction to their insertion along the whole lateral border of the volar surface of the shaft and the head of the first metacarpal.

Nerve-supply.—By a branch of the first volar digital ramus of the median nerve. This branch passes over or through the superficial division of the flexor brevis near the origin of the muscle. One or two twigs enter the deep surface of the proximal third of the oppponens near its ulnar border. The nerve fibers arise from the sixth and seventh cervical nerves.

Action.—To flex, adduct, and rotate medialward the first metacarpal bone. The volar surface of the thumb is thus brought to face the volar surface of the other digits.

Relations.—It lies beneath the thenar fascia and the abductor brevis. The flexor brevis overlies its ulnar border.

Variations.—It may be absent or it may be divided into two heads. It is usually more or less fused with the short flexor.

The flexor pollicis brevis (figs. 440, 441).—The muscle is divided by the tendon of the long flexor into a superficial and a deep portion. The **superficial head** arises from the greater multangular bone (trapezium), the adjacent part of the transverse carpal (anterior annular)

ligament, and the tendon sheath of the flexor carpi radials. The fiber-bundles descend closely applied to the opponens, and terminate by a tendon which is attached to the lateral side of the front of the base of the first phalanx. Over the joint a sesamoid bone lies in the tendon. The **deep head** has a tendinous origin from the os multangulum minus (trapezoid) and the os capitatum (magnum). The fiber-bundles take an oblique course, to be inserted into the tendon of the superficial part. A muscle fasciculus which arises from the ulnar side of the base of the first metacarpal and the neighboring carpal ligaments and is inserted on the ulnar side of the base of the first phalanx, is sometimes considered to be the deep head of the flexor brevis. It is closely bound up with the carpal head of the adductor pollicis and they have a common tendon. Some fibers of the medial division of the tendon may be traced into the aponeurosis of the extensor tendon. It is probable that this portion of the muscle represents a first volar interosseous, and it is so described later with the interosseous muscles. There is much dispute as to what fasciculi should be included in the flexor brevis.

Nerve-supply.—The muscle is usually supplied by twigs derived from a branch from the first volar digital ramus of the median nerve as this branch passes through its substance, and by twigs from the deep branch of the ulnar. Brookes found this supply in 19 out of 29 instances, in 5 by the median alone, and in 5 by the ulnar alone. The nerve fibers come from the sixth and seventh cervical nerves

Action.—To flex, adduct, and rotate medialward the metacarpal of the thumb; flex the first phalanx; and extend the second phalanx.

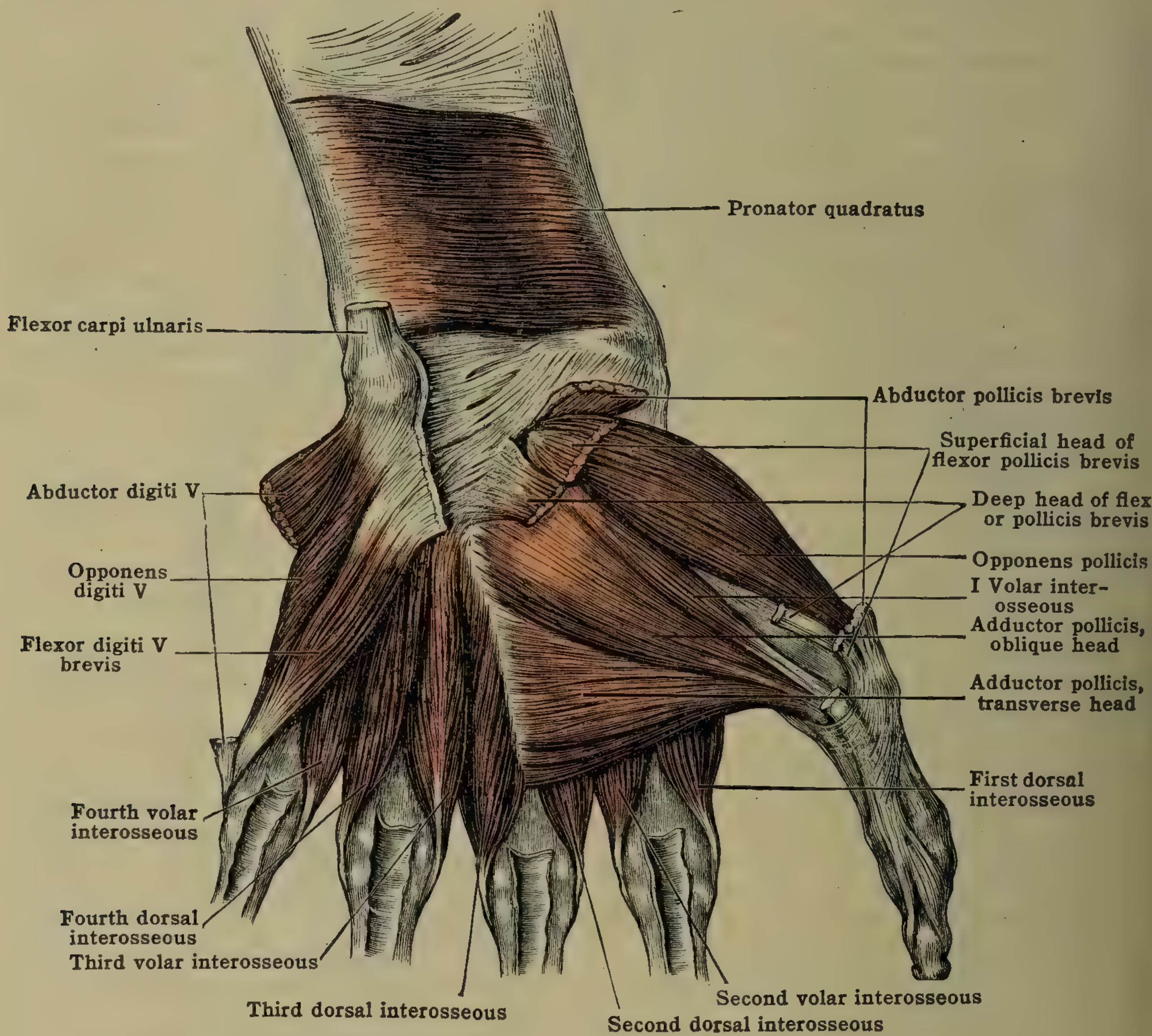


Fig. 441.—The Pronator Quadratus and Deep Muscles of the Palm.

Relations.—Proximally the short flexor is grooved for the tendon of the long flexor, beneath which more distally the deep head of the muscle passes laterally. The superficial portion of the muscle lies beneath the skin The ulnar border of the deep head is fused proximally with the adductor.

Variations.—The deep head may be absent. Either or both heads may be double The superficial head may be fused with the abductor brevis, and is usually more or less fused with the opponens.

The adductor pollicis (fig. 441).—*Origin*—By two heads. The **carpal or oblique head** arises from the deep carpal ligaments, the capitatum and the bases of the second and third metacarpals; the **metacarpal or transverse head**, from the crest of the third metacarpal, from the suprametacarpal fascia of the third interspace, and sometimes also from that of the fourth interspace and from the capsules of the second, third, and fourth metacarpo-phalangeal articulations.

Structure and insertion.—The fiber-bundles converge toward a tendon which is inserted into the ulnar side of the front of the base of the first phalanx of the thumb. A sesamoid bone lies in the tendon over the joint.

Nerve-supply.—One or more twigs from the deep palmar branch of the ulnar enter the middle third of the muscle on its deep surface. There may also be an anastomosing branch from the median nerve. The nerve fibers come from the sixth seventh and eighth cervical and first thoracic nerves.

Action.—To adduct and flex the first metacarpal and flex the first phalanx of the thumb. When the thumb is in an extreme position of apposition it acts as an abductor.

Relations.—Superficial to the muscle lie some of the tendons of the deep flexor of the fingers and the first two lumbrical muscles. It extends over the two more lateral intermetacarpal spaces, and is in part subcutaneous on the dorsal surface. The deep volar arch extends between the two heads and beneath the oblique head. The oblique head of the muscle is closely united to the first volar interosseous so that the latter by some is considered a part of the adductor.

Variations.—The extent of the attachments of origin of the muscle vary considerably. The two heads of the muscle may be more or less completely separated from one another. Each may be divided into separate fasciculi.

(*d*) *Lumbrical Muscles*

From the deep flexor tendons in the palm of the hand arise the lumbrical muscles, four in number, which are attached by small tendons to the radial side of the extensor tendons (figs. 436, 440, 441). These lumbrical muscles have homologues in the sole of the foot. The nerve supply is from the median and ulnar nerves.

The **lumbricales** (figs 439, 440).—*Origin.*—The two lateral arise from the radial side of the volar aspect of the first and second tendons of the flexor digitorum profundus; the two medial arise from the adjacent sides of the second and third and third and fourth tendons.

Structure and insertion.—The fiber-bundles of each muscle arise directly from the flexor tendons near the distal border of the transverse carpal (anterior annular) ligament. They converge as far as the metacarpophalangeal joint, upon a small tendon which begins about the middle of the muscle. The tendon passes out between the palmar aponeurosis and the transverse capitular ligament, winds about the metacarpophalangeal joint, expands, and is attached along the side of the first phalanx to the radial border of the tendon of the extensor digitorum communis.

Nerve-supply.—Branches from the median nerve enter the middle third of the radial border of the first two or three lumbrical muscles. The last one or two are supplied by branches from the deep volar branch of the ulnar nerve, which enter the middle third of the deep surface. The third lumbrical and sometimes one or more of the others may receive a branch from both nerves. The nerve fibers come from the eighth cervical and first thoracic nerves.

Action.—Together with the interosseous muscles they flex the basal phalanges on the metacarpal bones and extend the terminal and middle phalanges. They also adduct the fingers toward the thumb.

Relations.—The muscles run between the tendons of the flexor profundus and beneath the palmar aponeurosis. They lie upon the fascia covering the interosseous muscles, the capitular ligaments, and the septum over the adductor and deep head of the flexor pollicis brevis.

Variations.—These are very frequent, especially in case of the third and fourth. Each may be doubled or missing. They may arise from the tendons of the flexor sublimis or from the belly of the deep flexor. The first lumbrical may come from the tendon of the long flexor, from the opponens, or the metacarpal of the thumb. The tendon of insertion may go to the ulnar side of the base of the digit opposite that to which the tendon is usually attached, or the tendon may divide and go to the adjacent sides of two fingers. Kopsch has found that in 110 bodies all four lumbricals were inserted on the radial side of their respective digits in 39 per cent. In 35 per cent. the first, second, and fourth were so inserted, while the third sent slips to the adjacent sides of the middle and ring fingers. An accessory fasciculus has been found to arise from the tendon of the flexor pollicis longus and go to the base of the index finger.

(*e*) *Interosseous Muscles* (Figs. 441–443)

These muscles lie between the metacarpal bones and are covered dorsally and ventrally by fasciæ attached to the metacarpals. In each interspace are two muscles, a dorsal and a volar (palmar). The volar interossei are inserted into all the fingers except the middle finger, and are adductors toward an axis passing through the middle finger; the dorsal interossei are inserted into both sides of the middle finger and into the radial side of the second and the ulnar side of the fourth finger, and are abductors. All also serve as flexors of the first row of phalanges and extensors of the second and third. In the foot the axis to and from which the interosseous muscles adduct and abduct the toes passes through the second toe. The nerve supply is from the ulnar nerve.

The **interossei volares** arise from the sides toward the middle finger and the front of the shafts of the first, second, fourth, and fifth metacarpals. The first arises from near the base the others from three-fourths of the shaft. The fiber-bundles of each muscle converge in a penniform manner upon a tendon which is inserted into the aponeurosis of the digital extensor tendon

and the base of the first phalanx on the middle finger side of the corresponding digit (see fig. 436) The first volar interosseous is often described as a division of the flexor pollicis brevis or of the adductor pollicis.

The **interossei dorsales** arise from the adjacent sides of the metacarpal bones in each interspace. On the sides nearest the middle finger they cover three-fourths of the bone, on the opposite sides much less. The fiber-bundles converge in a bipenniform manner upon a tendon which begins high in the muscle and is inserted into the aponeurosis of the extensor muscles and the base of the first phalanx on each side of the middle finger, on the thumb side of the index finger, and the ulnar side of the ring finger. The interosseous muscle in the first interspace is thick and strong and forms with the adductor pollicis the fleshy web between the base of the thumb and the palm.

Nerve-supply.—By branches of the deep volar division of the ulnar nerve. As a rule, a branch to each volar interosseous enters the proximal third of the muscle. To each dorsal interosseous a branch is given which enters between the two heads. These branches may be variously combined before entering the interosseous muscles. The nerve fibers arise from the eighth cervical and first thoracic nerves.

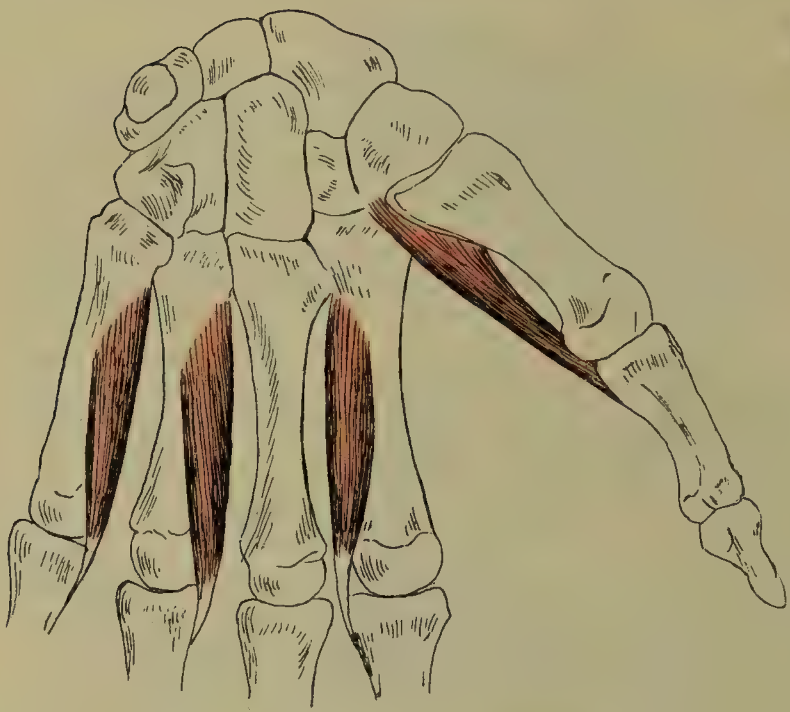


Fig. 442.—The Volar Interossei.

Fig. 443.—The Dorsal Interossei.

Action.—To move the fingers toward the radial and ulnar sides, to flex the first phalanx and extend the second and third. The volar interossei move the fingers toward the median axis of the middle finger in repose, the dorsal from this axis.

Relations.—The volar interossei lie volarward from the dorsal interossei. The two sets of muscles are bound in place by the dorsal and volar metacarpal fasciæ. The tendons pass out on the dorsal side of the transverse capitular ligament and are closely applied to the metacarpo-phalangeal joints. The muscles of the first two interspaces lie immediately dorsal to the adductor of the thumb; the others dorsal to the flexor tendons.

Variations.—The tendon-slip from an interosseous muscle to the base of the first phalanx of a digit may be missing. This is more frequent in case of the volar than in that of the dorsal interossei, and in the medial than the lateral muscles. Either a volar or a dorsal interosseous muscle may be double or missing. Rarely the insertions of the interosseous muscles characteristic of the foot (see p. 567) may be found in the hand.

III. SPINAL MUSCULATURE

(Figs. 444–447)

The spinal (vertebral) column is of special interest as the segmented longitudinal axial support of the body which has given rise to the term 'vertebrates' as applied to the group of animals of which man is the highest form. The segmentation in fishes permits the lateral movements of the body which are their chief means of propulsion. In the land-vertebrates, with the exception of snakes, the limbs are developed as the chief organs of propulsion but flexibility of the column

is retained for the sake of freedom of movement. In man the spinal column, with the exception of the sacral region, may be readily extended (bent backward) and flexed (bent forward), abducted (bent to the side) and rotated. Freedom of movement is greatest in the cervical and lumbar region and is restricted by the thorax in the thoracic region. The cervical region allows considerable flexion, extension and rotation, but a more limited abduction. In the thoracic region rotation and abduction are freer than flexion and extension. The lumbar region is that in which the chief flexion and extension of the trunk takes place, but abduction and rotation are limited, especially the latter. In the isolated articulated spinal column freedom of movement of the various parts depends chiefly upon the thickness and elasticity of the intervertebral disks, upon the conformation of the articular processes, and upon the elasticity or arrangement of the various ligaments uniting the vertebræ. In the living body freedom of movement is further restricted by the musculature and skeletal apparatus attached to the column. There is much individual variation in the flexibility of the vertebral column.

The various movements of the column are produced partly by muscles which act directly on it and partly by muscles which act on it through the head, thorax or pelvis. Most of the muscles which act on it directly belong to the intrinsic dorsal musculature; that is, to musculature which is derived from the dorsal divisions of the myotomes and is innervated by the dorsal divisions of the spinal nerves. This musculature extends from the sacrum to the skull and is closely applied on each side of the middorsal line of the body to the backs of the vertebræ and the back of the thorax (fig. 445). Its chief function is to extend the spinal column and head, hence the old term applied to the superficial portion of this musculature 'erector spinæ.' During the development of the body, muscles belonging to the ventrolateral thoracic musculature and to the upper extremity come to overlie in part the intrinsic dorsal musculature. The trapezius and rhomboid muscles which cover it in the cervical and thoracic regions, and the latissimus dorsi which covers it in the thoracic and lumbar regions belong to the shoulder girdle and arm and have already been described, p. 414. The serratus posterior superior, which overlaps it in the upper thoracic region, and the serratus posterior inferior, which overlaps it at the junction of the thoracic and lumbar regions, are derived from the intercostal musculature which is described later, p. 490 (fig. 444). All of these muscles are innervated by the ventrolateral divisions of the spinal nerves. The levatores costarum (fig. 447), which extend from the transverse process of the thoracic vertebræ to the ribs, and which, in spite of their name, act chiefly on the spinal column, are derived from the external intercostal musculature and are innervated by the intercostal nerves.

Ventral to the spinal column and closely applied to it there are a few muscles, the chief function of which is to flex the column. All are supplied by branches from the ventrolateral divisions of the spinal nerves. Of these the *longus colli* and *longus capitis* and *scalene* muscles have been described in connection with the muscles of the neck, p. 420. In the thoracic region there are no muscles of this type. In the lumbar region there are four muscles on each side, the pillars of the *diaphragm*, the *psoas minor*, the *psoas major* and the *quadratus lumborum* (figs. 455, 470). All of these muscles are flexors of the spine, except the quadratus, which is an extensor. The psoas major muscle is also a flexor of the thigh. Even more powerful flexors of the column than those above mentioned are some of those which work indirectly upon it through the leverage offered by the skull (sternocleidomastoid described above, p. 414), and the thorax (the ventrolateral abdominal musculature).

Abduction and rotation of the spine are produced by contraction of muscles on one side while the corresponding muscles on the other side are relaxed. See Table, p. 572.

In the present section we shall confine our attention to the intrinsic dorsal musculature, leaving for consideration elsewhere the other musculature which acts on the vertebral column.

The **intrinsic dorsal musculature** is attached to the sacrum, to the ilium, to the spines, transverse, and articular processes and laminæ of the lumbar, thoracic, and cervical vertebræ, to the backs of the ribs and to the base of the skull. Two great longitudinal subdivisions may be recognized, a **lateral,** supplied by lateral branches of the posterior divisions of the spinal nerves, and a **medial,** supplied by medial branches. The lateral portion is further divisible into a **superficial division,** in-

cluding the splenius iliocostalis and longissimus consisting chiefly of systems of muscles extending laterally from the spines of the vertebræ upward toward the transverse processes of the vertebræ, the ribs, and the mastoid process of the skull; and a **deep division,** the dorsal intertransverse muscles, extending between succes-

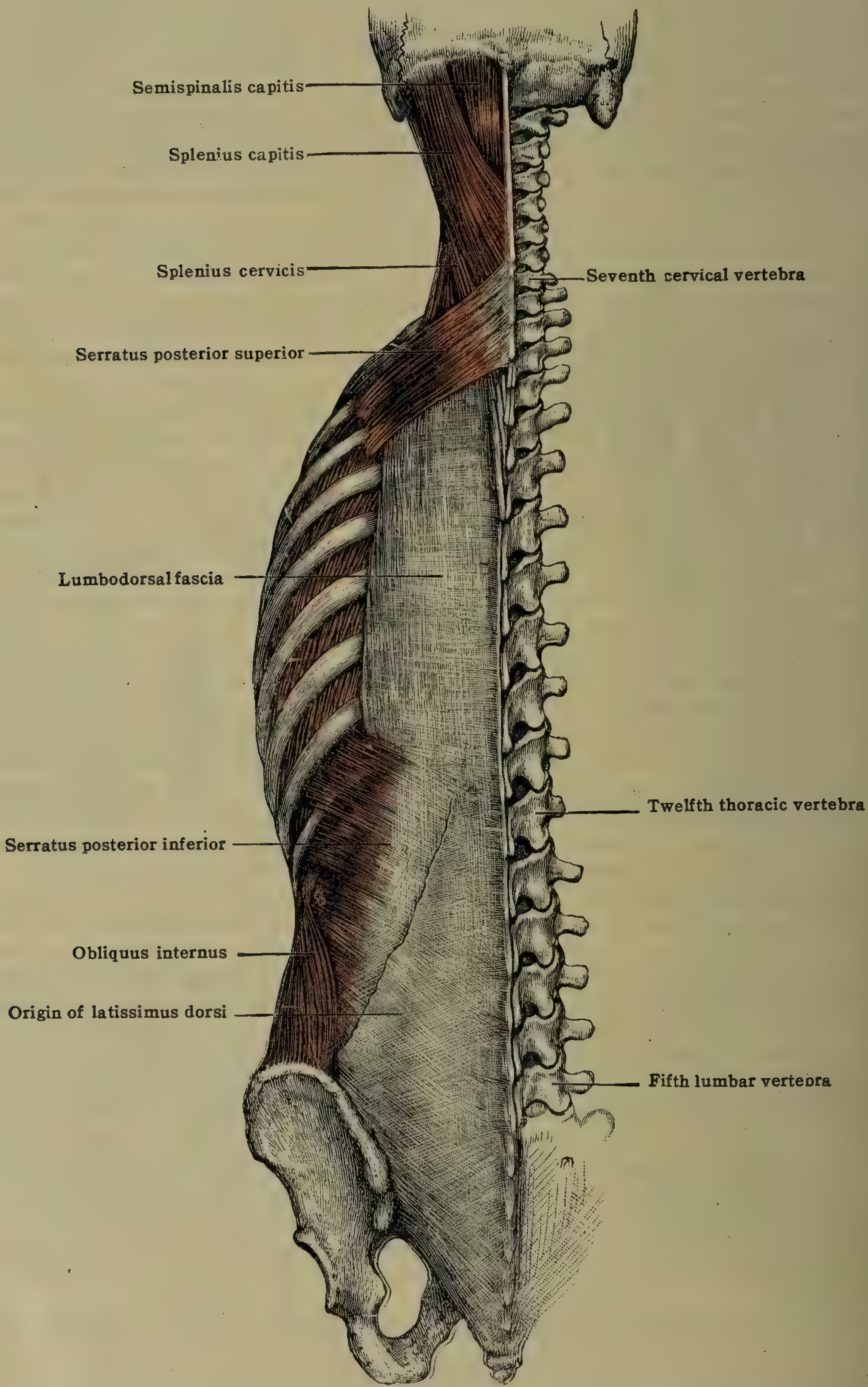


Fig. 444.—The Deep Muscles of the Back, with Lumbodorsal Fascia.

sive transverse processes. The medial portion likewise consists of two parts: a **superficial medial** (spinalis dorsi and cervicis) composed of fasciculi extending from inferior to superior spines, best developed in the dorsal region; and a **deep portion** (semispinalis capitis, transversospinal and interspinal), consisting mainly

of muscle fasciculi which pass from the transverse processes upward toward the spines of vertebræ situated more cranially. In the neck the more superficial extend to the base of the skull.

Between the base of the skull and the first two vertebræ there are several specialized muscles. There is also frequently present the rudimentary *sacro-coccygeus posterior* described on p. 514, which represents an extension into the caudal region of the intrinsic dorsal musculature.

The primitive condition of the dorsal musculature is one of metameric segmentation. This is characteristic of fishes, many amphibia, and of the embryos of all higher vertebrates. In the tailless amphibia, however, a partial differentiation of the dorsal musculature takes place during embryonic development, and in all higher forms a differentiation takes place which corresponds in many ways to that described above for man. According to Favaro, the splenius is differentiated from the medial dorsal system, but its innervation should place it with the lateral system. In the human embryo the dorsal segmental musculature extends into the tail region, but afterward here undergoes retrograde metamorphosis.

The **fasciæ** and the general relations of the muscles of the back may be followed in the cross-sections shown in figs. 409, 413, 420, 448, and 471.

The **tela subcutanea** of the upper dorsal region has been described in connection with the muscles of the shoulder girdle (p. 414). It is thick, fibrous, and adherent. In the lower dorsal region it is somewhat less compact, but is thicker and contains more fat. It is usually divisible into two layers, of which the deeper is adherent to the lumbodorsal fascia.

The splenius (fig. 444) is enveloped in a thin, adherent fascial covering. The sacrospinalis is covered by a fascia, the **fascia lumbodorsalis** (fig. 444), which inferiorly is attached to the iliac crest, the distal and lateral margins of the sacrum, and the sacral spines. In the lumbar and thoracic regions it is attached medially to the vertebral spines. Laterally, in the lumbar region, it is reflected around the muscle to its ventral surface, where a 'ventral' or 'deep' layer forms an intermuscular septum (fig. 448) between the quadratus lumborum and the sacrospinalis. This ventral layer (fig. 447) extends from the twelfth rib to the iliac crest and the iliolumbar ligament, and is attached medially to the transverse processes of the lumbar vertebræ, from which fiber-bands extend laterally into it. It is strengthened above by fiber-bundles which pass from the first and second lumbar vertebræ to the twelfth rib (lumbocostal ligament).

In the thoracic region (fig. 448) the lumbodorsal fascia is attached to the ribs lateral to the iliocostal muscle. In the cervical region (fig. 413) the fascia is continued into the intermuscular septa which surround the muscles of this group in the neck.

The *transversospinal muscles* are covered throughout their extent by a fascial membrane which serves to separate them from the longissimus in the sacral, lumbar, and thoracic regions.

In the dorsal region of the neck (figs. 409, 413, 419) the muscles are covered on each surface by adherent fascial sheets, **fascia nuchæ**, and are arranged in several concentric layers, each of which is separated from its neighbors by dense fatty areolar tissue. The deepest of the layers is formed by the muscles of the transversospinal group. This is covered by a dense membrane, and is separated from the semispinalis capitis (complexus) by a thick layer of areolar tissue containing the chief blood-vessels and nerves of the neck. The semispinalis capitis (complexus) is covered on each surface by a more delicate adherent membrane, and is separated from the splenius by loose tissue. The splenius has a somewhat denser adherent fascial covering into which the fascia of the levator scapulæ is continued. Separated from this by areolar tissue lies the trapezius. The cervical and thoracic portions of the semispinalis are separated by delicate membranous septa from the semispinalis capitis (complexus), the levator scapulæ, and the splenius. The muscles of each side are separated in the dorsal median plane by the dense **ligamentum nuchæ** (septum nuchae NK), into which the various cervical septa and fasciæ extend. The suboccipital muscles are covered by fascial sheaths which are so fused as to constitute a special fascia for these muscles. Distally this is continued into the fascia of the transversospinal muscles.

MUSCLES

A. Superficial Lateral Dorsal System

The splenius (fig. 447).—The two parts of which this muscle is composed may be separately considered.

The splenius cervicis.—*Origin.*—By a narrow aponeurotic band from the spinous processes and the supraspinous ligament of the third to the sixth thoracic vertebræ.

Structure and insertion.—The fiber-bundles extend upward and laterally and give rise to a flat muscle sheet from which fasciculi arise that are inserted by short tendinous processes on the posterior tubercles of the transverse processes of the first two or three cervical vertebræ. The processes are often united with those of the levator scapulæ and the longissimus cervicis.

The splenius capitis.—*Origin.*—From the ligamentum nuchæ in the region of the third to the seventh cervical vertebræ and from the spinous processes and the supraspinous ligament of the first two to five thoracic vertebræ.

Structure and insertion.—The fiber-bundles form a sheet which continues cranialward that of the splenius cervicis. The fiber-bundles converge somewhat and are inserted by a short, broad, thick tendon into—(1) the back, the side, and the tip of the mastoid process below the sternocleidomastoid muscle, and (2) into the neighboring part of the occipital bone.

Relations.—The splenius lies dorsal to the semispinalis capitis (complexus) and to the cervical (transversalis cervicis) and the cranial (trachelomastoid) portions of the longissimus

and the cervical portion (cervicalis ascendens) of the iliocostalis and to the levator scapulæ, and is partly covered by the trapezius, sternocleidomastoid, serratus posterior superior, and the rhomboids. In the triangle bounded by the trapezius, sternocleidomastoid, and the levator scapulæ it is subcutaneous.

Nerve-supply.—The lateral branches of the posterior divisions of the second, third and fourth (sometimes also of the first, the fifth and the sixth) cervical nerves give off rami which enter the deep surface of the muscle.

Action.—To incline and rotate the head and neck toward the side on which the muscle is placed. When both muscles act, the head and neck are extended.

Variations.—The extent of separation and of fusion of the two muscles varies. Absence of either muscle is rare. The splenius capitis may be divided into mastoid and occipital portions. The attachment of the muscle also varies somewhat. Occasionally the spinal origin of the splenius may extend to the cranial end of the ligamentum nuchæ. The origin may extend laterally over the fascia covering the deeper dorsal muscles. An accessory slip, the **splenius cervicis accessorius**, separated from the main muscle by the tendon of the serratus posterior superior, is frequently (8 per cent. of instances, Le Double) found to run from the lower cervical or upper thoracic vertebræ to the transverse process of the atlas.

The sacrospinalis (erector spinæ), (figs. 445, 446).—*Origin.*—(1) From a strong aponeurosis attached to the spines of the lumbar, and the sacral vertebræ, to the ligament passing from the sacrum to the coccyx, to the lateral sacral crest, the sacrotuberous ligament, the long posterior sacroiliac ligament, and to the dorsal fifth of the iliac crest; (2) directly from the iliac crest in front of and lateral to the attachment of the aponeurosis; and (3) from the short posterior sacroiliac ligaments. The aponeurosis covers the muscles of the sacral region and is there united to the overlying fascia by more or less dense areolar tissue. Opposite the iliac crest fiber-bundles begin to take origin from the lateral margin of the dorsal surface as well as from the deep or ventral surface of the aponeurosis of origin, and gradually the line of dorsal attachment extends medially until, in the lower thoracic region, the tendon becomes completely embedded in the muscle fasciculi which take their origin from it. The aponeurosis, which is the strongest in the lower lumbar region, is composed chiefly of fibers which take a direction upward and somewhat lateralward.

In the lower lumbar region the sacrospinalis (erector spinæ) muscle begins to show a distinct division into its two chief component parts, the iliocostalis and the longissimus. The parts of which the iliocostalis and longissimus are composed will be taken up separately.

The iliocostalis lumborum (figs. 445, 446).—*Origin.*—(1) Chiefly from the back of the sacrospinal aponeurosis, medial to and cranialward from the iliac crest, and (2) from the iliac crest directly. The deep medial surface of the muscle is closely united in the lumbar region to the longissimus.

Structure and insertion.—From the mass of fiber-bundles which compose the muscle, fasciculi are given off which are attached chiefly by tendinous slips to—(1) the tips of the transverse processes of the lumbar vertebræ; (2) the fibrous processes which extend lateralward from the tips of the transverse processes of the upper lumbar vertebræ into the anterior layer of the lumbodorsal fascia; (3) the inferior margin of the last six or seven ribs near the angles. The insertions into the lumbodorsal fascia and the twelfth rib are usually fleshy. The portions attached to the lumbar vertebræ are by some considered to belong to the longissimus (Eisler).

Relations.—The muscle lies on the lateral margin of the longissimus and upon the ribs and the external intercostal and levatores costarum muscles, and under the axioappendicular muscles described above.

The iliocostalis dorsi (accessorius).—*Origin.*—By fleshy fasciculi from the superior borders of the lower seven ribs medial to the angles.

Structure and insertion.—The slips of origin lie beneath the preceding portion of the muscle, pass medial to and partly fuse with it, and give rise to a belly from which tendinous slips extend to be inserted into the upper seven ribs near their angles and to the transverse process of the seventh cervical vertebra.

Relations.—The muscle lies upon the ribs and the external intercostal muscles lateral to the longissimus.

The iliocostalis cervicis (cervicalis ascendens).—*Origin.*—By fleshy slips from the upper borders near the angles of the seventh to the third (sometimes to the second or first) ribs.

Structure and insertion.—The slips of origin are covered by the slips of insertion of the dorsal portion (accessorius). They emerge medial to them and give rise to a fleshy belly from which tendons pass to the backs of the transverse processes of the sixth to the fourth cervical vertebræ.

Relations.—The scalenus posterior lies in front, the levator scapulæ at the side, and the splenius and longissimus (transversalis) cervicis medial to this muscle.

A *bursa* is frequently found between the muscle and the tubercle of the first rib.

The longissimus dorsi (figs. 445, 446).—*Origin.*—(1) From the deep surface of the sacrospinal aponeurosis; (2) from the short posterior sacroiliac ligaments; and (3) through accessory slips which arise from the transverse processes of the first two lumbar and the last five or six thoracic vertebræ. In the lumbar region it is fused dorsolaterally with the iliocostalis.

Structure and insertion.—From the muscle mass arise fasciculi which are inserted partly directly, partly by means of tendons, into—(1) the lower border of the back of the transverse processes of the lumbar vertebræ and the inferior margins of the ribs lateral to the tubercles; and (2) the accessory tubercles of the lumbar and the tips and inferior margins of the transverse processes of the thoracic vertebræ. The attachment to the first rib is usually wanting. The attachment to the first five ribs may fail. The medial attachments seldom extend to the first vertebra.

Relations.—The lateral margin of the muscle is covered by the iliocostalis. Medially it overlies the transversospinal muscles. The lateral branches of the dorsal veins, arteries, and nerves pass mainly in the fibrous tissue which separates the longissimus from the iliocostalis, the medial branches chiefly between the longissimus and the transversospinal muscles. The relations to the axioappendicular muscles and to the dorsal fascia have been pointed out above.

Ventrally it lies upon the intertransverse muscles, the external intercostals, and the levatores costarum.

The longissimus cervicis (transversalis cervicis).—*Origin.*—By tendinous slips from the transverse processes of the first four to six thoracic vertebræ.

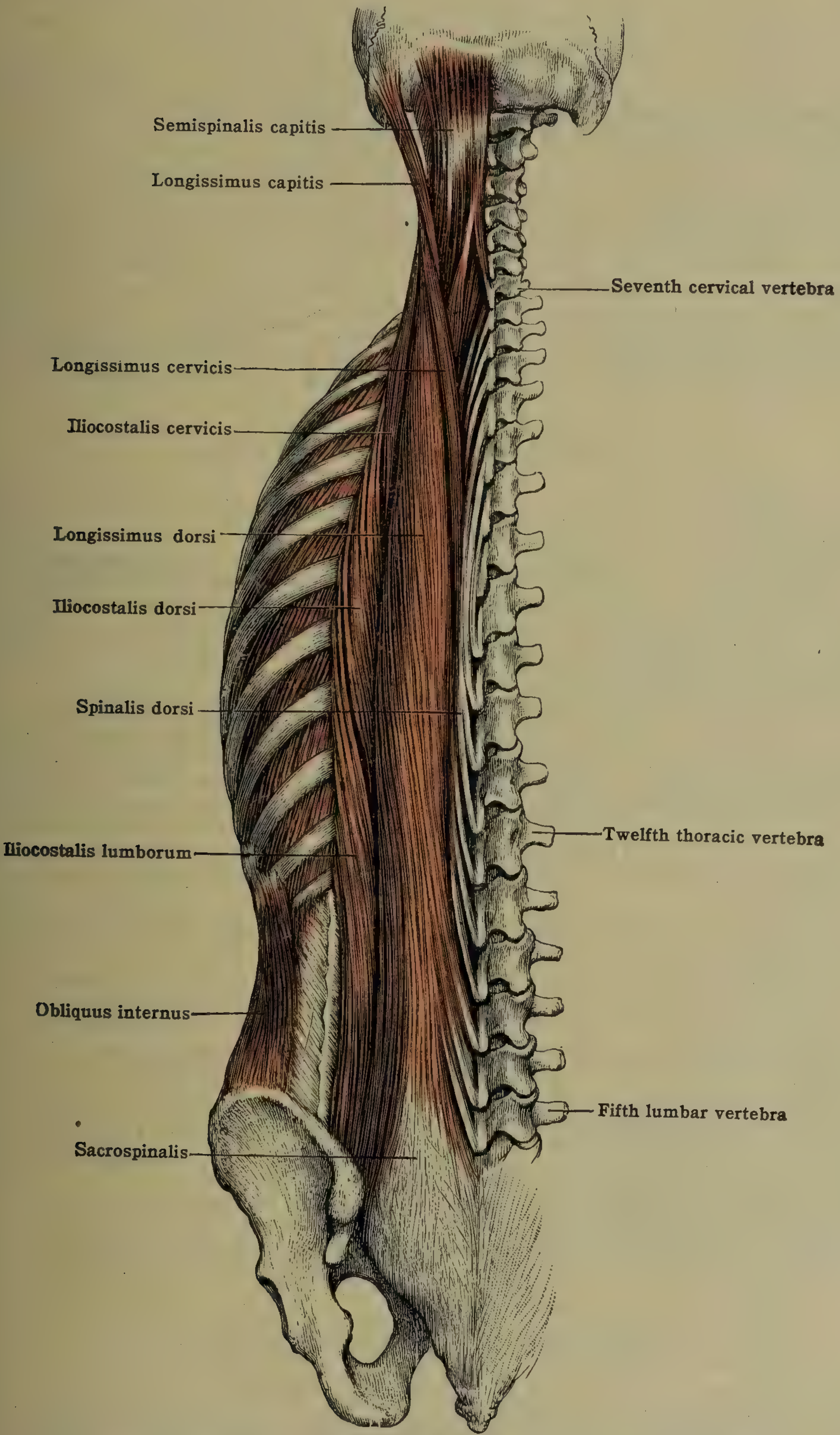


FIG. 445.—THE DEEP MUSCLES OF THE BACK (FASCIA REMOVED).

Structure and insertion.—The fasciculi which arise from these slips give rise to a muscle belly from which tendons of insertion extend to the posterior tubercles of the transverse processes of the mid-cervical (second to sixth) vertebræ.

Relations.—This muscle lies between the longissimus dorsi and capitis with which it is to some extent fused and the iliocostalis dorsi (accessorius) and cervicis (cervicalis ascendens) muscles.

The longissimus capitis (trachelomastoid).—*Origin.*—By tendinous slips from the transverse processes of the first three or four thoracic vertebræ and the articular processes of the last four cervical.

Structure and insertion.—The muscle fasciculi arising from these tendons form a belly which is united to the mastoid process by a short tendon. A tendinous inscription often crosses the muscle.

Relations.—It lies ventral to the splenius capitis, lateral to the semispinalis capitis (complexus) and medial to the longissimus cervicis (cervicalis ascendens).

Nerve-supply of the sacrospinalis.—From the lateral branches of the posterior divisions of the spinal nerves. The exact distribution of these branches is too complex to be treated here. The nerves for the iliocostalis arise from the eighth cervical to the first lumbar, those for the longissimus from the first cervical to the fifth lumbar.

Action of the sacrospinalis.—The sacrospinalis serves, when acting on one side, to bend the spinal column toward that side, and when acting on both sides, to extend the spinal column. The cranial portions of this musculature incline the head and neck and rotate them toward the side on which they lie, and when both muscles act they extend the head and neck. The iliocostalis muscle has the greatest power for producing lateral inclination. The iliocostalis lumborum depresses the ribs, while the iliocostalis cervicis (cervicalis ascendens) may aid in elevating them. The spinalis muscle serves merely as an extensor.

Variations of the sacrospinalis.—The slips of origin and insertion of the various parts of this muscle and the extent of fusion of the various parts vary greatly. Statistical data from which the most frequent conditions might be determined are wanting. Tendinous inscriptions may extend across the longissimus cervicis and other parts of the sacrospinalis.

B. Deep Lateral Dorsal System

The intertransversarii (figs. 414, 447).—These are vertical bands composed of short bundles which pass between the transverse processes of the cervical, lumbar, and the lower thoracic vertebræ.

(a) *Cervical* (fig. 414).—Ventral, lateral and dorsal muscles are found in the cervical region. The ventral and lateral muscles run between the ventral tubercles and tips of the transverse processes of the vertebræ, are homologous with the intercostal muscles, are supplied by branches from the anterior divisions of the corresponding spinal nerves, and have been described above (p. 422). The dorsal muscles run between the dorsal tubercles and belong to the intrinsic dorsal musculature. They are supplied by the lateral branches of the posterior divisions of the cervical nerves. (According to Lickley, both sets of cervical intertransverse muscles are supplied by the anterior divisions of the spinal nerves.) The three sets of muscles are, however, more or less fused. The first pair of muscles extends between the atlas and axis, the lowest passes to the transverse process of the first thoracic vertebra, or to the first rib close to this. The *obliquus capitis superior* (described later) belongs, however, to the posterior set of muscles, the *rectus capitis lateralis* (p. 423) to the lateral set. The vertebral artery runs vertically between each pair of muscles above the sixth, and the anterior division of each cervical nerve passes laterally between the artery and the dorsal muscle in each space, and then out between the ventral and lateral muscles. The posterior division of each cervical nerve passes medial to each dorsal muscle.

(b) *Thoracic.*—Small muscle fasciculi may extend between the transverse processes of the thoracic vertebræ and between the last thoracic and first lumbar. They are most frequent in the upper and lower thoracic regions. Often they are replaced by tendinous bands. In the second interspace the insertion may extend to the rib near the transverse process. The innervation is from the lateral branches of the posterior divisions of the spinal nerves.

(c) *Lumbar* (fig. 447).—In the lumbar region there is a lateral set of muscles connecting the adjacent margins of the transverse processes and a medial connecting the mammillary tubercle of one vertebra to the mammillary or the accessory tubercle of the vertebra next above. They extend between each two of the five lumbar vertebræ and sometimes also to the first sacral. They lie between the sacrospinalis and psoas muscles. The medial muscles are supplied by the lateral branches of the posterior divisions of the spinal nerves. The lateral muscles are supplied by branches from the junction between the two divisions of the corresponding spinal nerves. These branches probably belong to the anterior divisions.

Action.—The intertransverse muscles bend the vertebral column laterally, and when acting on both sides, make it rigid.

Variations.—The number of intertransverse spaces occupied by the muscles varies, especially in the thoracic region. They may be doubled or extend over more than one interspace.

C. Superficial Medial Dorsal System

The spinalis dorsi (fig. 445).—*Origin.*—By tendinous bands from the tips of the two upper lumbar and the last two thoracic spines.

Structure and insertion.—From the deep surface of the tendinous bands there arises a long slender muscle belly which is fused laterally with the longissimus dorsi. It is inserted by tendinous processes to the spines of the upper thoracic vertebræ, usually the second or third to the ninth.

Nerve-supply.—From the medial divisions of the sixth to ninth thoracic nerves.

The spinalis cervicis.—A muscle of inconstant development which arises from the spines of the two upper thoracic and two lower cervical vertebræ and extends to the spines of the second to the fourth cervical vertebræ. The nerve supply is from the dorsal divisions of the lower cervical nerves.

Action.—To extend the vertebral column.

Variation.—There is great variation in the development of the spinalis muscles. Similar fasciculi are sometimes found in the lumbar region and in the cervical region sometimes extend to the skull.

D. Deep Medial Dorsal System

1. *Vertebro-occipital Muscle*

The semispinalis capitis (complexus) (fig. 445).—This muscle is usually separated from the semispinalis muscles of the back and neck by a well-marked septum and has a distinctive structure.

Origin.—(1) By long tendinous fasciculi from the tips of the transverse processes of the upper five or six thoracic vertebræ and of the seventh cervical vertebra; (2) by short fleshy processes from the articular processes and bases of the transverse processes of the third to the sixth cervical vertebræ; and (3) by delicate fleshy fasciculi from the spinous processes of the upper thoracic vertebræ.

Structure and insertion.—The slightly diverging fiber-bundles form a long, flat belly which is inserted, partly by means of an aponeurosis which covers the muscle laterally, into the lower surface of the squamous portion of the occipital, between the superior and inferior nuchal lines. There is often a transverse tendinous inscription across the muscle opposite the sixth cervical vertebra, and less frequently one between the upper and middle thirds of the muscle. These are best marked in the medial portion of the muscle, which comes from the thoracic vertebræ and is sometimes separately designated as the *spinalis capitis* (*biventer cervicis*).

Nerve-supply.—It is supplied chiefly by the medial branches of the posterior divisions of the first four or five cervical nerves. The muscle also gets some twigs from the lateral branches.

Relations.—It lies dorsolateral to the suboccipital muscles and to the semispinalis cervicis. From this latter it is separated by a septum containing the descending branch of the occipital artery, the deep cervical artery, and the medial dorsal branches of the cerv cal nerves. It is covered laterally by the longissimus capitis (trachelomastoid), and dorsally by the splenius, and above the upper margin of the splenius by the trapezius.

Action.—To extend the head and to incline it slightly toward the same side.

Variations.—The origin of the muscle may extend to the eighth thoracic vertebra or merely to the first thoracic. It may be fused with the longissimus (transversalis) cervicis. A special fasciculus may run beneath the muscle from the upper thoracic vertebræ to the head. The origin from the spinous processes of the thoracic vertebræ is not constant. The part of the muscle arising from this origin may be looked upon as a spinalis capitis.

The semispinalis dorsi et cervicis (fig. 447).—This superficial transversospinal muscle sheet extends from the twelfth thoracic to the second cervical vertebra. The fasciculi which compose it arise by short tendons from the backs of the transverse processes, and are inserted by short tendons into the spines.

The semispinalis dorsi.—*Origin.*—From the sixth to the tenth or twelfth thoracic vertebræ.

Insertion.—The upper four to six thoracic and the last two cervical vertebræ. The fasciculi extend over four to six vertebræ.

Nerve-supply.—Third to sixth thoracic.

The semispinalis cervicis.—*Origin.*—From the upper five or six thoracic vertebræ.

Insertion.—Into the fifth to the second cervical vertebræ. The fasciculi extend over four to five vertebræ.

Nerve-supply.—Third to sixth cervical.

Relations.—This muscle lies beneath the longissimus dorsi and the semispinalis capitis (complexus) and over the following musculature.

Variations.—A semispinalis lumborum is a muscle rarely found extending from the lumbar to the lower thoracic vertebræ.

The multifidus (fig. 447).—This second layer of transversospinal musculature extends from the sacrum to the second cervical vertebra. It is best developed in the lumbar region and least so in the thoracic.

Origin.—(1) From the groove on the back of the sacrum between the spines and the articular elevations, from the dorsal sacroiliac ligaments, from the dorsal end of the iliac crest, and from the deep surface of the aponeurosis of the sacrospinal muscle; (2) from the mammary and accessory processes of the lumbar vertebræ; (3) from the backs of the transverse processes of the thoracic vertebræ; and (4) from the articular processes of the fourth to the seventh cervical vertebræ and the back of the transverse process of the seventh.

Insertion.—Spinous processes of the lumbar, thoracic, and lower six cervical vertebræ.

Structure.—The more superficial fasciculi arise by short tendinous processes, the deeper ones directly. The more superficial fasciculi extend to the fourth or fifth vertebra above, the middle to the third, and the deepest to the second above.

The rotatores.—These, the third layer of transversospinal muscles, extend from the sacrum to the second cervical vertebræ. They are composed of short fleshy fasciculi which extend to the second vertebra above (*rotatores longi*) and to the first above (*rotatores breves*). The fasciculi arise from the back and upper borders of the transverse processes or their homologues, and are inserted into the laminæ of the preceding vertebræ. They are best developed in the thoracic region. Some authors consider the rotatores breves confined to the thoracic region. In the cervical region the fasciculi usually run from articular processes to the bases of the spines, in the lumbar region from the mammary processes to the caudal margin of the laminæ of the arches.

3. *The Interspinal Muscles*

The **interspinales** consist of short fasciculi which extend from the upper surface of the spine of each vertebra near its tip to the lower surface of the spine of the vertebra above. In the neck the muscles lie in pairs between the bifid extremities of the vertebræ. In the lumbar

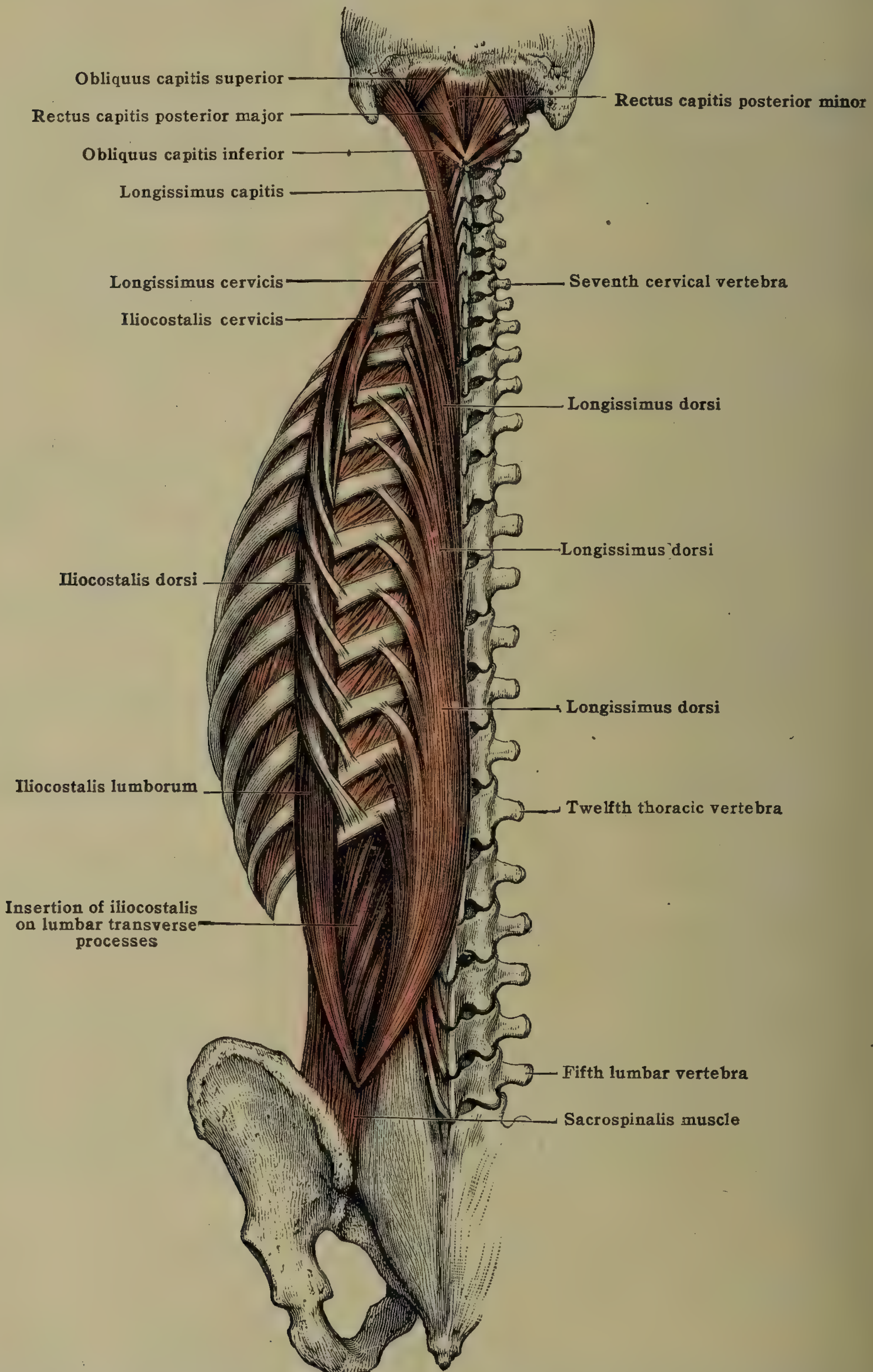


Fig. 446.—The Deep Muscles of the Back, after separating the Longissimus and Iliocostalis Divisions.

region they form broad bands attached to the whole length of the spinous processes and are separated by the interspinous ligaments. In the thoracic region they usually are undeveloped.

NERVE SUPPLY AND ACTION OF MEDIAL DORSAL MUSCLES

These muscles are all supplied by the medial branches of the posterior divisions of the spinal nerves. They extend the vertebral column when acting on both sides. When acting on one side, they produce a movement of rotation toward the opposite side.

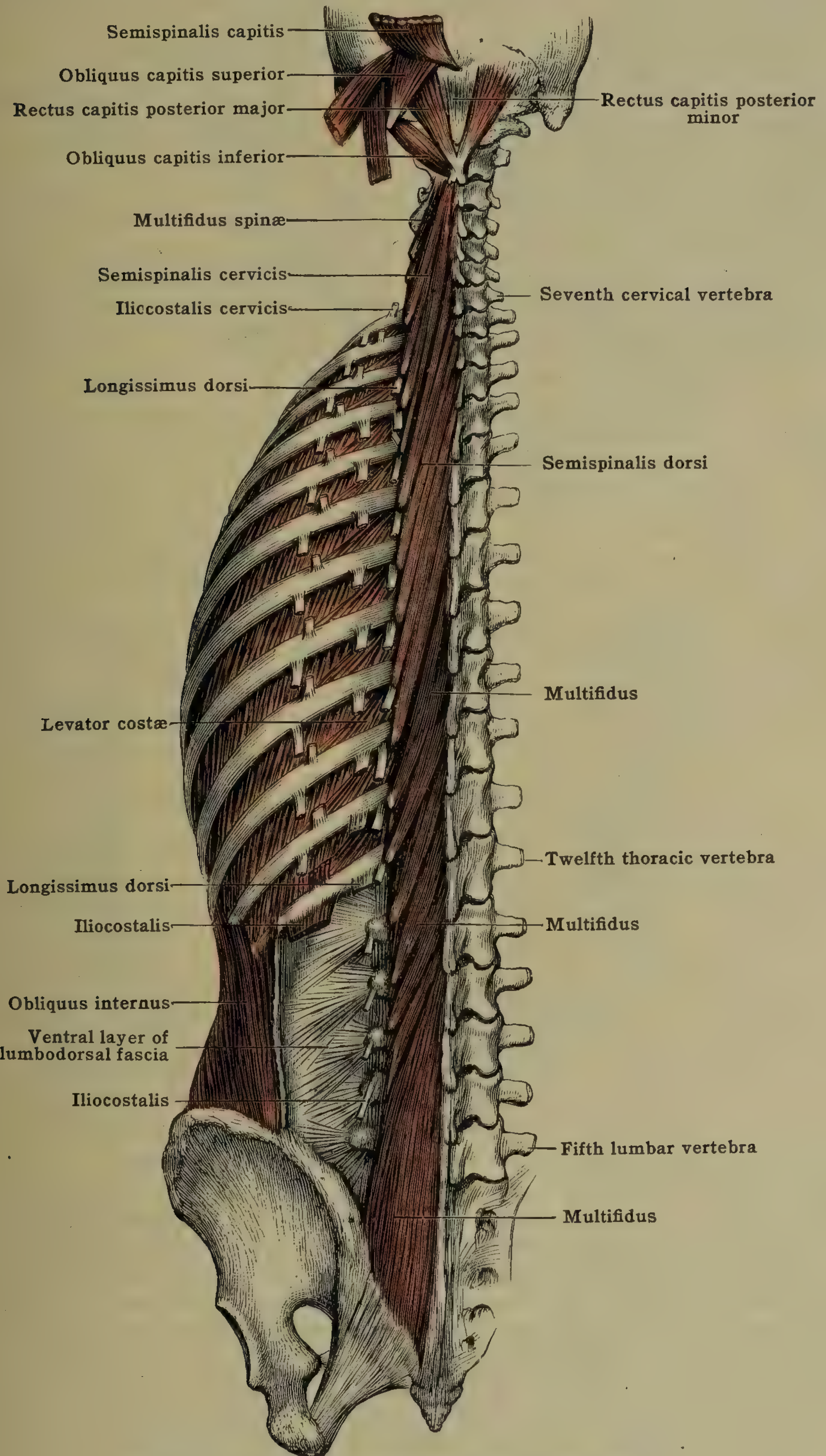


FIG. 447.—THE TRANSVERSOSPINAL MUSCLES.

E. SUBOCCIPITAL MUSCLES

(Figs. 446, 447)

The rectus capitis posterior major (rectus capitis dorsalis major NK).—*Origin.*—From the upper surface of the spine of the epistropheus.

Structure and insertion.—The muscle-fibers diverge to form a broad triangular band which is inserted into the lateral half of the inferior nuchal line of the occipital bone and the area below it. Its insertion is immediately below that of the obliquus superior.

The rectus capitis posterior minor (rectus capitis dorsalis minor NK).—*Origin.*—From the upper part of the side of the posterior tubercle of the atlas.

Structure and insertion.—The fiber-bundles diverge to form a flat, triangular sheet inserted below the medial third of the inferior nuchal line of the occipital bone on the inferior surface of the squama occipitalis.

The obliquus capitis inferior (obliquus atlantis NK).—*Origin.*—From the upper part of the side of the spine of the epistropheus (axis).

Structure and insertion.—The fiber-bundles form a fusiform belly which is inserted by a short tendon into the lower part of the tip of the transverse process of the atlas.

The obliquus capitis superior (obliquus capitis NK).—*Origin.*—From the back of the upper part of the transverse process of the atlas.

Structure and insertion.—The fiber-bundles diverge to form a flat, triangular muscle, inserted into the lateral third of the inferior nuchal line of the occipital bone, and above the lateral part of the insertion of the rectus capitis posterior major.

Nerve-supply.—These muscles are all supplied by the posterior branch of the suboccipital (first cervical) nerve. The branch to the two rectus muscles passes across the dorsal surface of the major rectus and supplies branches to the middle of the dorsal surface of each muscle. The branch to the superior oblique muscle enters the middle of the medial margin, that to the inferior oblique about the middle of its superior margin. The inferior oblique and major rectus muscles usually, the other muscles occasionally, receive branches from the second cervical nerve.

Relations.—The two oblique muscles with the rectus major serve to bound a small triangular space, the suboccipital triangle, through which pass the dorsal division of the suboccipital nerve and the vertebral artery. The two minor recti lie on the atlanto-occipital membrane in the upper part of the space bounded by the major recti. The muscles are covered medially by the semispinalis capitis (complexus), laterally by the longissimus and splenius capitis. In front of the two oblique muscles and the major rectus runs the vertebral artery. The great occipital nerve runs between the semispinalis capitis (complexus) and the inferior oblique and the two recti in a dense fatty connective tissue containing the extensive suboccipital venous plexus.

Action.—The rectus muscles and the superior oblique draw the head backward. The rectus major and the inferior oblique, when acting on one side, rotate the face toward that side.

Variations.—Each of these muscles may be doubled by longitudinal division. Accessory slips may connect the two recti with the semispinalis capitis. The **atlantomastoid** is a small muscle frequently found. It passes from the transverse process of the atlas to the mastoid process

IV. THE THORACOABDOMINAL MUSCULATURE

The thoracic and abdominal viscera are contained within cavities, the ventrolateral walls of which may be contracted and expanded by muscular action. The skeletal support for the intrinsic musculature of these walls consists of the ribs, the sternum and the vertebral column and the pelvis. The intrinsic musculature in the thoracic walls is situated chiefly between the ribs (*intercostal muscles*, figs. 449, 450) while in the region of the abdomen it extends in broad sheets from the lower part of the thorax to the pelvis (the *quadratus lumborum* and the *external* and *internal oblique*, *transverse*, and *rectus* muscles, figs. 451, 453, 454, 470). Between the two cavities, attached to the lower part of the thorax and to the lumbar vertebræ lies the dome-shaped diaphragm (fig. 455). The thoracic cavity extends on each side slightly above the first rib. The abominal cavity extends downward and backward into the pelvis, as the pelvic cavity.

The **function** of the intercostal muscles is to expand and contract the thoracic cavity for the sake of respiration. The shape of the ribs and their articulations with the vertebræ are such that a slight rotation of the neck of each rib will cause the shaft to swing outward and upward or in the reverse direction. The costal cartilages are elastic enough to permit this movement, and at the same time are strong enough to make the thorax an effective skeletal apparatus. Ninety joints are called into play in the movements of the thorax (24 between the heads of the ribs and the vertebræ, 20 between the tuberosities and the transverse processes of the vertebræ, 24 between the ribs and costal cartilages, 14 between the costal cartilages and the sternum, 6 between the costal cartilages and 2 intrasternal). When the shafts of ribs are swung outward and upward the thorax is enlarged in the anteroposterior and transverse axes. In the adult when standing the sternum may be raised nearly 3 cm., and protruded 1 cm. The cartilages of the lower ribs may be raised 4 to 5 cm. The sides of the thorax at the level of the second rib may be protruded 3 cm., and at the level of the eighth rib nearly as far. This extent of movement, however, is found only in forced respiration. In ordinary quiet respiration it is far less, the sternum being raised merely 3 or

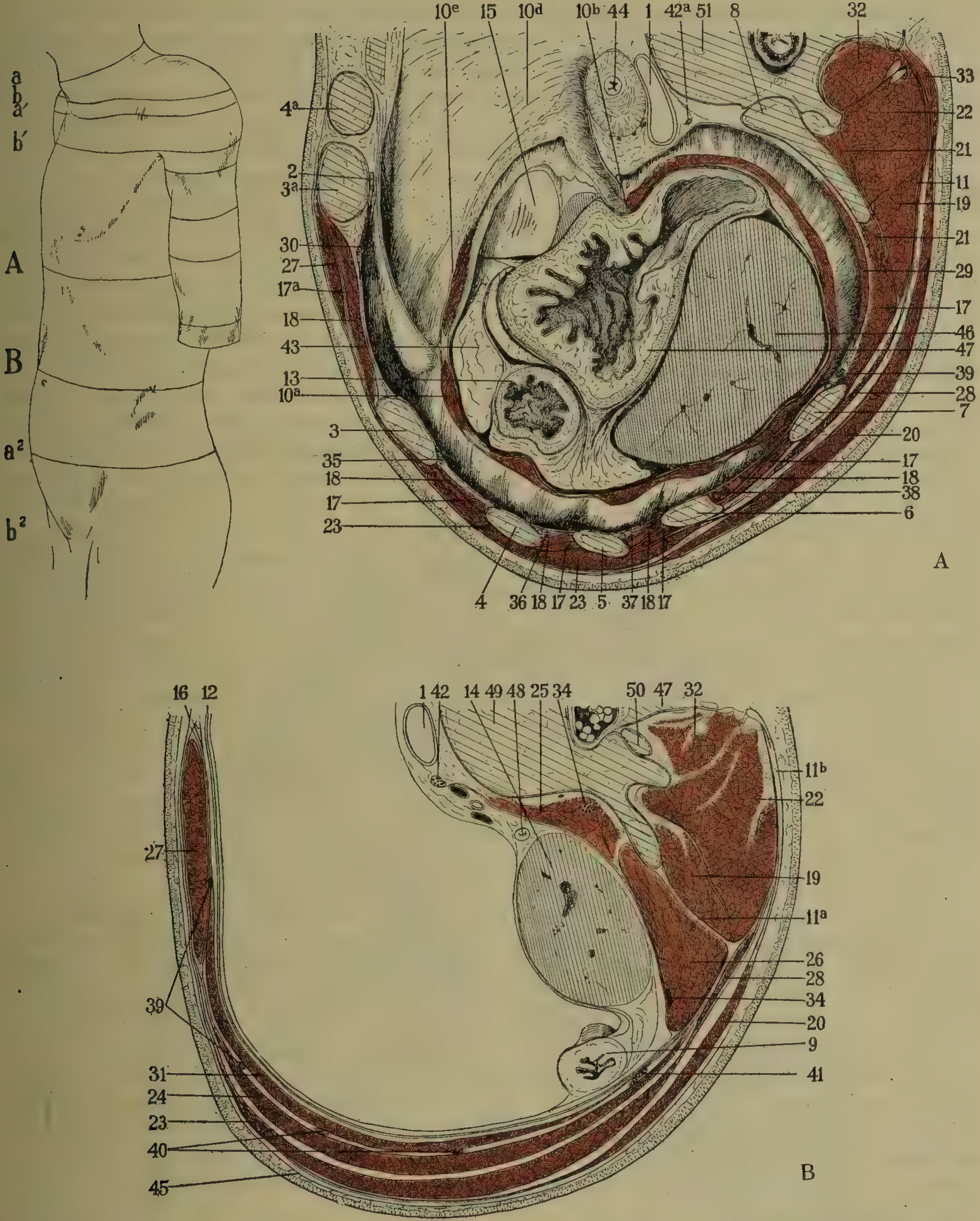


FIG. 448, A and B.—SECTIONS THROUGH THE LEFT SIDE OF THE TRUNK IN THE REGIONS SHOWN IN THE DIAGRAM.

The muscles of the body wall have been slightly pulled apart in order to reveal the relations of muscles, fasciæ, and aponeuroses. *a* and *b* in the diagram indicate sections A and B, fig. 413; a^1 and b^1, sections A and B, fig. 419; a^2 and b^2, sections A and B, fig. 471.

1. Aorta. 2. Arteria mammaria interna. 3. Costa VI—a, cartilage. 4. Costa VII—a, cartilage. 5. Costa VIII. 6. Costa IX. 7. Costa X. 8. Costa XI. 9. Descending colon. 10. Diaphragm—a, costal portion; b, lumbar portion; c, sternal portion; d, centrum tendineum. 11. Fascia lumbodorsalis—a, anterior layer; b, posterior layer. 12. Fascia transversalis. 13. Flexura colica sinstra (splenic flexure). 14. Kidney. 15. Liver. 16. Linea alba. 17. Musculi intercostales externi—a, ligament. 18. Mm. intercostales interni. 19. M. iliocostalis. 20.. M. latissimus dorsi. 21. M. levator costæ. 22. M longissimus dorsi. 23. M. obliquus abdominis externus. 24. M. obliquus abdominis internus. 25. M. psoas major. 26. M. quadratus lumborum. 27. M. rectus abdominis. 28. M. serratus posterior inferior. 29. M. subcostalis. 30. M. transversus thoracis. 31. M. transversus abdominis. 32. Mm. transversospinales. 33. M. trapezius. 34. Nervus lumbalis I. 35. N. thoracalis VI. 36. N. thoracalis VII. 37. N. thoracalis VIII. 38. N. thoracalis IX. 39. N. thoracalis X. 40. N. thoracalis XI. 41. N. thoracalis XII. 42. Sympathetic trunk—a, great splanchnic nerve. 43. Omentum majus. 44. Esophagus. 45. Scarpa's fascia. 46. Spleen. 47. Stomach. 48. Ureter. 49. Vertebra lumbalis II. 50. Vert. lumbalis III. 51. Vert. thoracalis X.

4 mm., and protruded 2 mm., and the thorax is enlarged at the sides merely 5 mm. (R. Fick). The chief muscles used in quiet inspiration are the external intercostals and the intercartilaginous parts of the internal intercostals.

During inspiration the diaphragm contracts so that the thoracic cavity is further enlarged perpendicularly. The extent of movement of the upper part of the diaphragm is estimated by R. Fick at from 1½—3 cm.

The ventrolateral abdominal muscles contract the thoracic cavity by depressing the thorax and by pushing the diaphragm upward. They directly contract the abdominal cavity. Contraction of the abdominal cavity is of aid in defecation and parturition. The abdominal muscles are also of value in flexion, abduction, and rotation of the vertebral column and pelvis.

The thorax, with its intrinsic musculature, is in large part covered by the musculature which extends from the trunk to the shoulder girdle and arm; dorsally by the trapezius and rhomboids, ventrally by the pectoral muscles, and laterally by the serratus anterior and the latissimus dorsi, as well as by the scapula and the muscles which pass from it to the humerus. The upper extremity on each side is largely supported from the spine by the trapezius, rhomboid and levator scapulæ muscles but it none the less exerts some pressure on the thorax and interferes to some extent with respiration. If the girdle and arm are fixed or raised the muscles which pass from them to the thorax are an aid in forced inspiration. Advantage of this is taken when in artificial respiration the arms are raised so as to lift the ribs through traction by the latissimus dorsi, the pectoralis muscles and the subclavius. Some of the muscles of the neck, especially the scalene muscles and the sternocleidomastoid, are likewise of value in forced inspiration.

Expiration is produced not only by the part of the internal intercostals which lie between the bony ribs, and by the abdominal muscles, but also by the lumbar iliocostales and by the quadratus lumborum.

The intrinsic muscles of the thorax and abdomen are derived from the twelve thoracic myotomes and the first one or two lumbar and are innervated by the corresponding nerves, while the musculature of the shoulder girdle and arm which covers the intrinsic muscles of the thorax is of cervical origin and is innervated by cervical nerves. The diaphragm is likewise of cervical origin and is innervated by the phrenic nerve from the cervical plexus.

The intrinsic muscles of the back extend over the thoracic musculature (external intercostals and levators of the ribs, fig. 447) and in turn are in part covered by muscles which extend dorsally from the thoracic region (posterior serrate muscles, fig. 444).

The intrinsic thoracoabdominal muscles are composed laterally of three layers of sheet-like muscles.

In the **external layer** the fiber-bundles run downward and ventralward. This layer is represented in the thoracic region by the external intercostal muscles, the levators of the ribs and the posterior serrate muscles. The fiber-bundles of the **external intercostals** (fig. 450), extend between each pair of ribs but between the costal cartilages are replaced by fibrous tissue, the *external intercostal ligaments.* The **levatores costarum** (fig. 447), extend from the transverse process of one vertebra to the rib which articulates with the next vertebra below and in some instances the fiber-bundles are continued to the second rib below.

The **serratus posterior superior and inferior** (fig. 444), are derivatives of the external oblique which during development wander in part over the intrinsic dorsal musculature. The *superior serrate* arises from the spines of the last two cervical and first two thoracic vertebræ and is inserted into the second to the fifth ribs. The *inferior serrate* muscle arises from the spines of the last two thoracic and first two lumbar spines and is inserted into the last four ribs. The fiber-bundles of this muscle therefore take a direction opposite to that of the other muscles of the group. These muscles aid in inspiration. In the abdominal region the external layer is represented by the **external oblique** muscle (fig. 451). This arises by digitations from the last seven ribs and is inserted into the crest of the ilium and by means of a broad flat aponeurosis into the linea alba in the mid-ventral line and into the inguinal ligament below. The external intercostal, levatores costarum, and posterior serrate muscles are innervated from branches which arise near the tubercles of the ribs. The external oblique muscles are innervated by branches which in large part arise in conjunction with or from the lateral

branches of the anterior divisions of the last seven thoracic nerves and frequently also by branches from the iliohypogastric.

The **middle layer** of the lateral thoracoabdominal musculature is composed of fiber-bundles which run downward and backward obliquely across the fiber-bundles of the external layer. In the thoracic region it is represented by the internal intercostal and subcostal muscles. The **internal intercostal** (fig. 450) muscles lie between the costal cartilages and between the ribs as far dorsalward as the angles, beyond which they are replaced by membranous tissue and by the **subcostal muscles.** The latter, instead of extending from one rib to the next rib below, extend to the second or third rib below. They are best developed in the lower part of the thoracic cavity. In the abdominal region the middle layer is represented by the **internal oblique muscle** (fig. 452). This arises from the lumbodorsal fascia, the crest of the ilium and the inguinal ligament and is inserted into the linea alba and into the inferior margins of the ventral extremities of the three lower ribs. The aponeurosis, which helps to form the sheath of the rectus, divides in the upper abdominal region into two layers, one of which passes in front and the other of which passes behind the rectus to be inserted into the linea

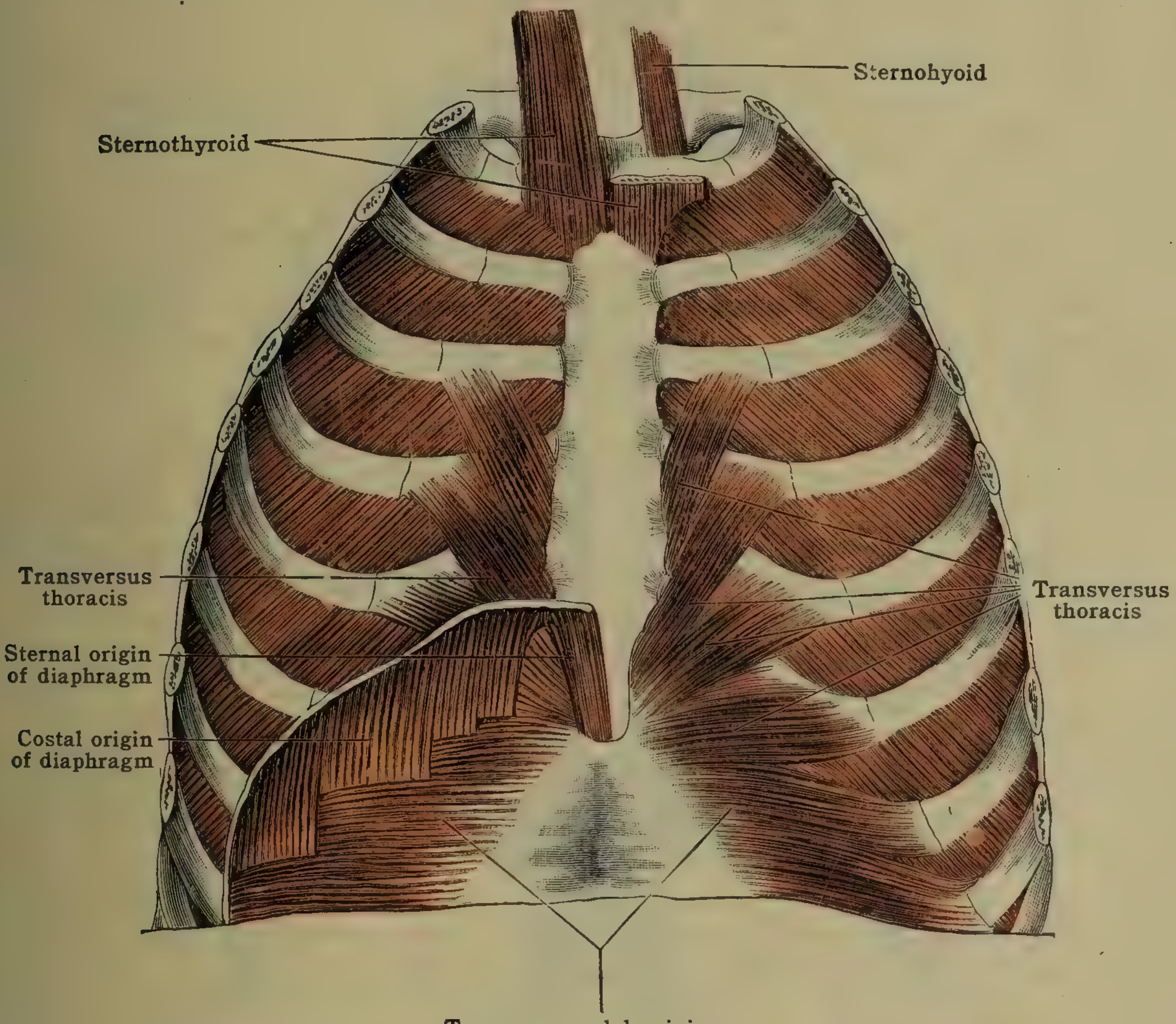


FIG. 449.—THE MUSCLES ATTACHED TO THE BACK OF THE STERNUM.

alba in the midventral line. In the lower third of the ventral abdominal wall both layers pass in front of the rectus. The fiber-bundles which compose the internal oblique muscles do not all follow the usual course of the fiber-bundles of this layer. At the level of the iliac crest they pass nearly transversely across the body and below here they slant downward and forward. Just above the inguinal ligament and medial to its center the internal oblique muscle is continuous with the thin **cremaster muscle** (fig. 453), which is prolonged over the spermatic cord and the tunica vaginalis of the testis and epididymis in the male and over the ligamentum teres in the female. The cremaster muscle is attached laterally to the inguinal ligament, medially to the outer layer of the sheath of the rectus near the insertion of the latter.

The **inner layer** of the thoracoabdominal musculature is composed of fiber-bundles which take a course transversely across the body. In the thoracic region it is represented by the **transversus thoracis** (fig. 449), a slightly developed muscle

which arises from the costal cartilages of the third to sixth ribs and is inserted into the lower part of the sternum and into the xiphoid process. In the upper portion of the muscle the fiber-bundles extend obliquely downward and forward instead of transversely. In the abdomen this layer is represented by the **transversus abdominis** (fig. 454) which arises from the cartilages of the lower seven ribs, from the lumbodorsal fascia, the iliac crest and lateral part of the inguinal ligament and is inserted into the linea alba by means of an aponeurosis which lies behind the rectus in the upper two-thirds of the ventral wall of the abdomen and in front in the lower third. It is intimately fused with the aponeurosis of the internal oblique.

The main trunks of the anterior divisions of the last five or six thoracic nerves give rise to branches which supply the muscles both of the middle and inner layers of the lateral thoracoabdominal musculature. In the abdominal region these trunks run in the main between the two layers. Some muscular branches are

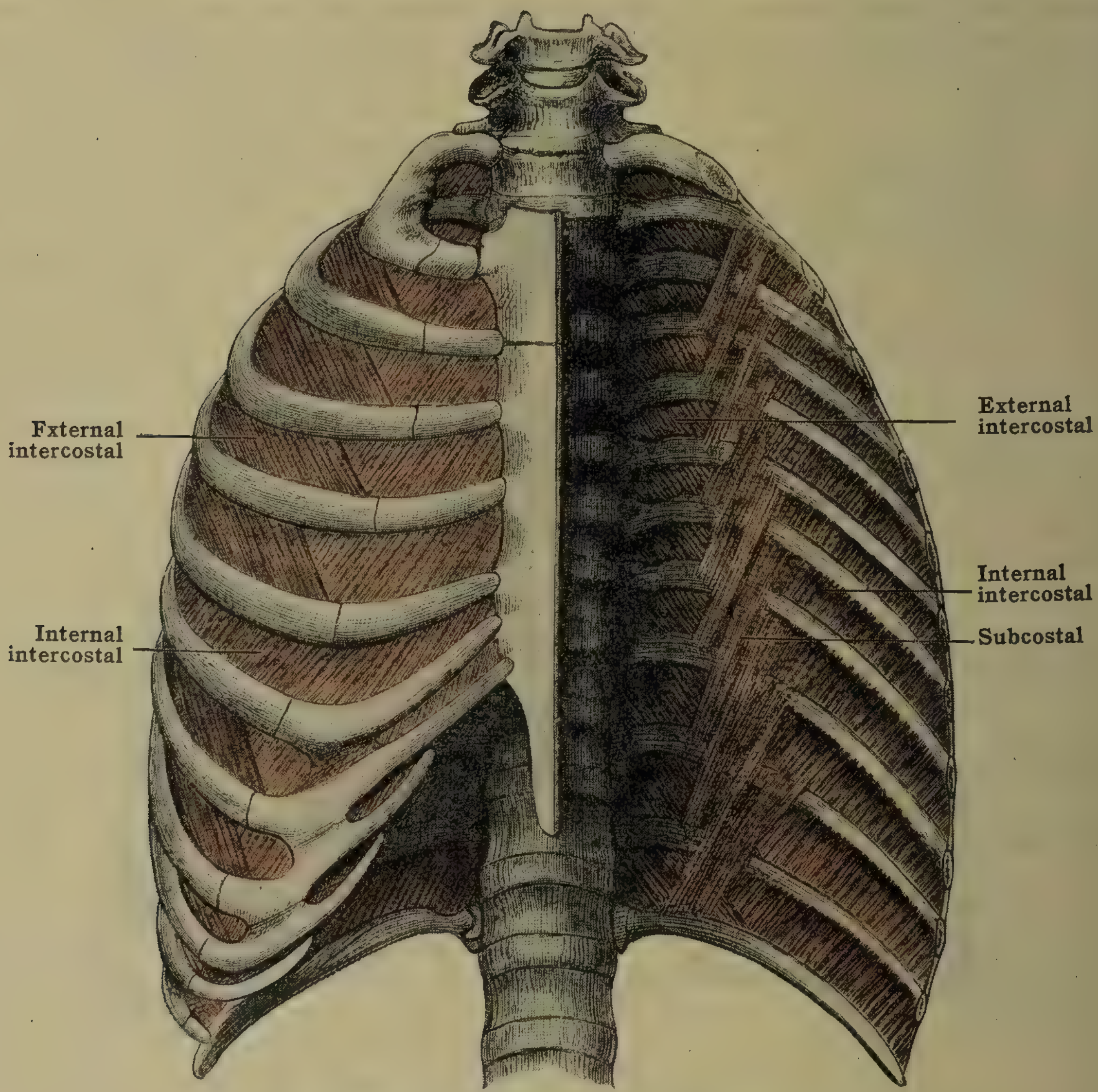


Fig. 450.—The Intercostal Muscles.

usually also supplied from the iliohypogastric and ilioinguinal nerves. In the thoracic region the intercostal nerves run external to the subcostal muscles, through the substance of the costal part of the internal intercostal muscles, and internal to the parts of the internal intercostals which lie between the costal cartilages. Eisler includes the subcostal muscles and that part of the internal intercostals which lies internal to the nerve trunk, with the inner rather than with the middle layer of the thoracic musculature.

The **ventral part** of the muscular thoracoabdominal wall is represented by a single muscle on each side, the rectus abdominis muscle, except just above the symphysis pubis where the rudimentary pyramidalis is usually found. The **rectus abdominis muscle** (fig. 452), is a band-like muscle which arises from the ventral surfaces of the fifth to the seventh costal cartilages and from the xiphoid process and is inserted into the superior ramus of the pubis. It is ensheathed by the aponeuroses of the lateral abdominal musculature described above. The compo-

nent fiber-bundles run nearly parallel with the midsagittal line. Transverse inscriptions partially divide the muscles into segments. It is innervated by the last six or seven thoracic nerves. The **pyramidalis** (fig. 452) is a small muscle which arises from the superior pubic ramus and is inserted into the linea alba for about a third of the distance to the umbilicus.

The **lateral intertransverse muscles** of the lumbar region described on p. 449 probably belong to the ventrolateral musculature of the trunk. The nerves supplying them come from the junction between the posterior and anterior divisions of the spinal nerves.

The **inguinal (Poupart's) ligament** and the **inguinal canal** (fig. 453), described in detail below, are of considerable practical interest because of the frequency of hernias in this region. In the quadrupeds the pressure of the weight of the abdominal viscera centers toward the umbilicus while in man it centers toward the ventral part of the line of attachment of the abdominal wall to the pelvis. The lower margin of the aponeurosis of the external oblique muscle is here strengthened to form the inguinal (Poupart's) ligament which extends from the anterior-superior iliac spine to the pubic tubercle. Near the latter it is reflected (curves medialward) to the pubic pecten forming the triangular **lacunar ligament** (Gimbernat's). The medial half of the inguinal ligament helps to bound a slit-like space, **inguinal canal,** through which in the male the spermatic cord passes to the scrotum, and in the female, the round ligament passes to the labium majus. This canal begins internally at the (internal) abdominal ring, which is situated above and medial to the center of the inguinal ligament. The canal, which is about 4 cm. long, extends medialward and downward to the subcutaneous (external abdominal) ring, a slit-like opening in the aponeurosis of the external oblique just above the inguinal ligament. The canal is bounded ventrally by the aponeurosis of the external oblique and the cremaster muscle, below by the reflected portion of the inguinal ligament, dorsally by the transversalis fascia and falx aponeurotica inguinalis and above by the transversus, internal oblique, and cremaster muscles.

The **quadratus lumborum** (fig. 470), which extends from the twelfth rib to the ilium and iliolumbar ligament, is supplied by direct branches of the lumbar nerves in series with the nerves supplying the musculature of the abdominal wall. It will, therefore, be taken up with the intrinsic thoracoabdominal muscles. It depresses the thorax and abducts and extends the spine. The psoas muscle, on the other hand, which also lies at the back of the abdominal cavity, represents an extension of the intrinsic musculature of the limb to the spinal column (see p. 521).

The **diaphragm** (fig. 455), a dome-shaped muscle which is attached to the lower margin of the thorax and to the upper lumbar vertebræ, and separates the thoracic and abdominal cavities, arises in the embryo in the region of the neck, and maintains cervical relations through its innervation by the phrenic nerves, which spring one on each side usually from the third to fifth cervical nerves. It does not belong morphologically with the other muscles considered in this section, but is here included because of its physiological and anatomical relations and the convenience of treating it in connection with the intrinsic thoracoabdominal muscles. A diaphragm completely separating the thoracic from the abdominal cavities is found only in the mammals. The central portion of the diaphragm is an aponeurosis or central tendon with a convex ventral and concave dorsal margin. Into this tendon is inserted the musculature which arises from the xiphoid cartilage, the cartilages and tips of the last six or seven ribs and by means of three crura from the sides of the first four lumbar vertebræ on each side.

In fishes and tailed amphibians the musculature of the body wall is composed of metamerically segmented musculature. In all higher vertebrates it is likewise at an early embryonic stage segmental, being composed of the ventrolateral portions of the myotomes. The ventral ends of the myotomes give rise to a ventral longitudinal muscle which runs on each side of the body next the midline in front, and retains more or less of the primitive segmentation. The rectus abdominis and the infrahyoid muscles represent this system in man. Very frequently traces of the system may also be seen on the upper thoracic wall in the form of slender muscular and aponeurotic slips. The rectus muscle in man is usually developed from the last seven thoracic myotomes. The pyramidalis becomes split off from its lower end. The lateral part of the ventrolateral portions of the thoracic myotomes usually gives rise to several strata of muscles which vary somewhat in different vertebrates, although quite similar among the mammals. In man the twelve thoracic and first two lumbar myotomes give rise to the lateral musculature of the thoracoabdominal wall.

The quadratus lumborum represents the ventrolateral portions of the lumbar myotomes with the exception of that portion of the first two which enter into the lateral abdominal musculature and of the fifth, which probably undergoes retrograde metamorphosis.

It will be noted that the abdominal wall is composed of musculature which has an origin chiefly from the thoracic myotomes. At an early stage of embryonic development both the thoracic and the abdominal viscera are covered by a non-muscular membrane. The myotomes extend into this from the thoracic region, and as the musculature is differentiated, it approaches the median line in front and extends distally to the pelvis. Owing to the rotation of the limbs the abdominal musculature is stretched ventrally over an area corresponding to the lumbar and sacral regions dorsally. The last part of the thoracoabdominal wall to be furnished with musculature is that about the umbilicus. Occasionally the process fails to be completed in this region.

Each spinal nerve supplies primarily the musculature derived from the myotome which lay caudal to it, and at first the musculature lies wholly superficial to the nerves. With subsequent differentiation the metamerism is somewhat obscured by anastomosis of nerves and fusion of myotomes; and a part of the internal oblique layer and all the transverse layer of the lateral musculature comes to lie on the inner side of the main nerve-trunks.

The fasciæ and the topographical relations of the thoracoabdominal muscles may be followed in the sections shown in figs. 419, 448, and 471.

FASCIÆ

Tela subcutanea.—As mentioned above, most of the intrinsic thoracic musculature is covered by other muscles, while the superficial layer of the abdominal musculature is subcutaneous. A panniculus adiposus, **Camper's fascia,** in which much fat may be deposited is usually easily distinguishable, especially in the lower part of the ventral wall of the abdomen, from a membranous fascial sheet which is loosely attached to the underlying fascial envelopment of the muscles. To this membrane has been applied the term **Scarpa's fascia.** Near the groin it is separated from the panniculus adiposus by blood-vessels and lymphatic glands. It is closely bound to the linea alba between the two rectus muscles, to the fibrous structures in front of the pubic bone, to the fascia lata below the inguinal ligament, and to the crest of the ilium.

Over the scrotum of the male and vulva of the female both layers of the tela subcutanea are continued. In the male the fat of the more superficial layer disappears and the two layers blend with the fundiform (suspensory) ligament and fascia of the penis and the dartos and septum of the scrotum.

Muscle fasciæ and sheaths.—The posterior serrate muscles (fig. 444) are enveloped by two adherent layers of an aponeurotic sheet that extends as a single membrane between them and is attached lateralward to the ribs and medialward to the spines of the thoracic vertebræ. The membrane between the muscles may represent the rudiment of a primitive continuous muscle such as is found in some lower vertebrates. This membrane may usually be easily separated from the aponeurosis of the latissimus dorsi on its superficial surface and the lumbodorsal fascia beneath.

The intercostal muscles are covered by delicate, adherent membranes on each surface. The external intercostal muscles are continued as aponeurotic bands between the costal cartilages. These serve here as fasciæ for the internal intercostals.

The external oblique muscle is covered externally by a dense, adherent membrane and internally by a more delicate membrane except where the muscle is attached to the ribs or fused with the external intercostal muscles. Ventrally and distally these membranes are fused beyond the fleshy portion of the muscle to the broad aponeurosis that serves to ensheath the rectus muscle and cover the lower part of the abdominal wall (fig. 453). Dorsally the membranes are in part attached to the ribs and in part are fused to form a membrane which becomes adherent to the deep surface of the latissimus dorsi in the thoracic region and to the lumbodorsal fascia in the lumbar region.

The internal oblique muscle and the transversus abdominis have similar membranous coverings which are fused to the aponeuroses of origin and insertion of these muscles. The membranes on the muscles are, however, much more delicate than that of the external oblique. More or less fusion between the two muscles with disappearance of the membranes covering the opposing surfaces takes place, especially in the lower part of the abdominal wall. The superficial muscle fasciæ of the external oblique and the fasciæ of the internal oblique are continued into the thin *cremasteric fascia* which covers the cremasteric muscle, spermatic cord and testis.

The diaphragm is covered on each surface by a more or less well-marked adherent membrane.

The **transversalis fascia** is a thin membrane which lies external to the peritoneum of the abdominal wall. It covers the peritoneal surface of the transversus muscle and its aponeurosis. Ventrally it is continued across the median line internal to the rectus abdominis. In the lumbar region the fascia divides at the lateral margin of the quadratus lumborum (fig. 448), one lamina of it passing dorsal to this muscle to be attached to the lumbodorsal fascia. The other lamina extends over the ventral surface of the quadratus and becomes fused with the psoas fascia. Proximally the transversalis fascia becomes fused with the fascial membrane adherent to the diaphragm. In the region of the iliac fossa the transversalis fascia is reflected from the transversus muscle to the iliopsoas fascia, with which it usually becomes fused. Sometimes, however, it may be traced as a very delicate membrane over the iliac artery and vein. As these vessels pass below the inguinal ligament a process from the transversalis fascia is usually reflected into their sheath.

The **sheath of the rectus** (figs. 448, 471) is formed externally in the upper portion of its extent by the aponeurosis of the external oblique which fuses below the costal margin with the external layer of the aponeurosis of the internal oblique. In the lower portion of the abdomen this fusion takes place nearer the linea alba than in the upper portion. In the lower third of its extent the rectus is covered ventrally by the fused aponeuroses of the two oblique muscles conjoined with that of the transversus. Internally the rectus is covered in the upper two-thirds

of the abdomen by the inner layer of the aponeurosis of the internal oblique conjoined with that of the transversus and by the transversalis fascia. In the lower third of the abdomen the aponeurosis of the internal oblique, together with that of the transversus, passes in front of the rectus, leaving the rectus in this portion of its abdominal surface covered merely by the transversalis fascia and the peritoneum. The line which marks the lower limit of the dorsal ensheath-

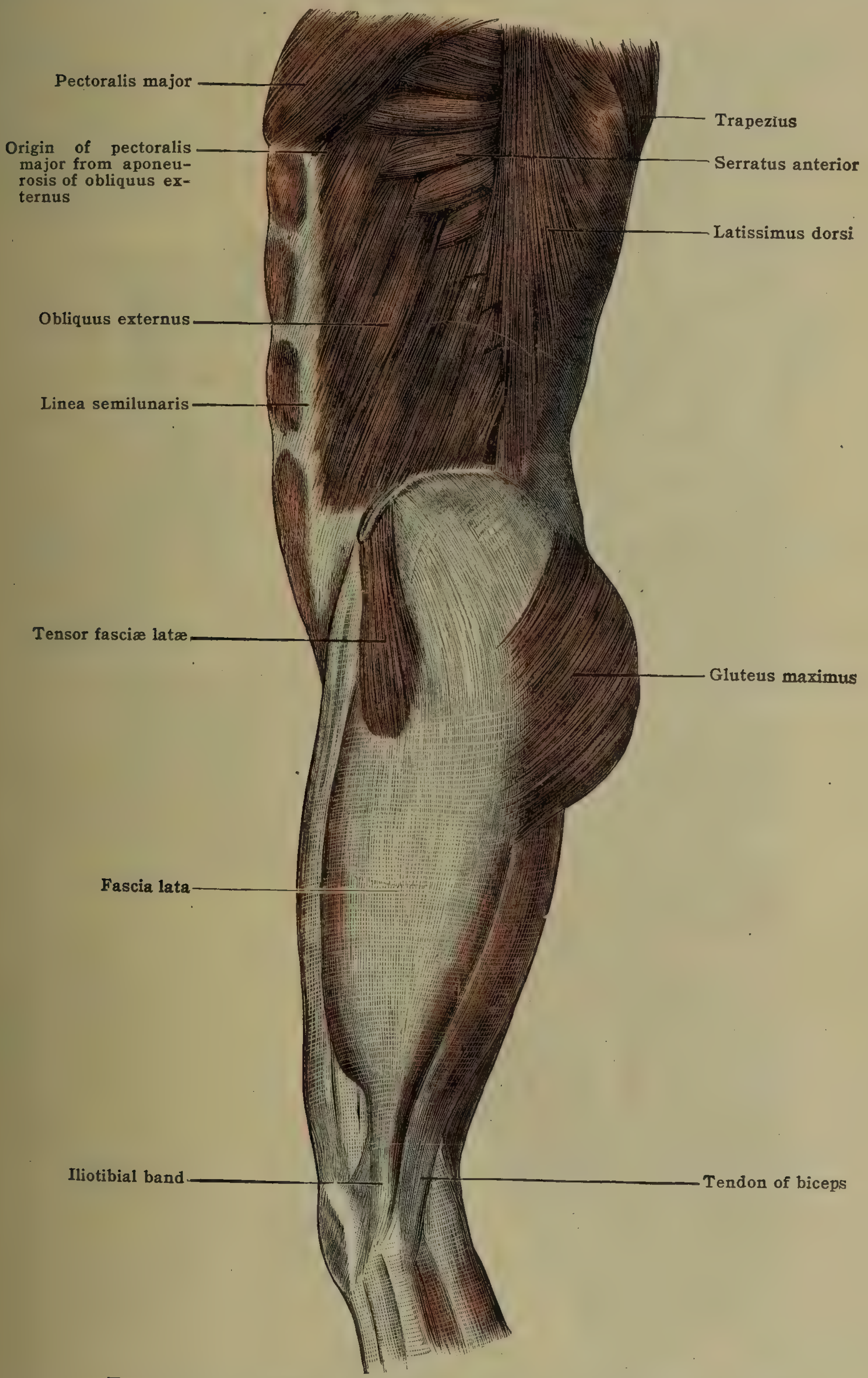


Fig. 451.—Superficial Musculature of Abdomen and Thigh.

ment of the rectus by the aponeurosis of the transversus muscle is called the **linea semicircularis**, or fold of Douglas. Between the transversalis fascia and the rectus just above the pubis there is a space filled with loose connective tissue or with fat. The linea alba is a poor site for incisions, as it is not very vascular and the resulting scar is weak.

Linea semilunaris.—At the lateral margin of the rectus muscle and sheath, the linea semilunaris is evident on the external surface of the body as a groove, especially when the muscles

are contracted. This groove extends from the pubic tubercle to the tip of the ninth costal cartilage, and forms one of the boundaries of the abdominal regions (fig. 974). The linea semilunaris shares the disadvantages of the linea alba as a site for incisions, and there is further danger of injury to the nerve supply to the rectus, which may involve a diffuse bulge of the atrophied muscle.

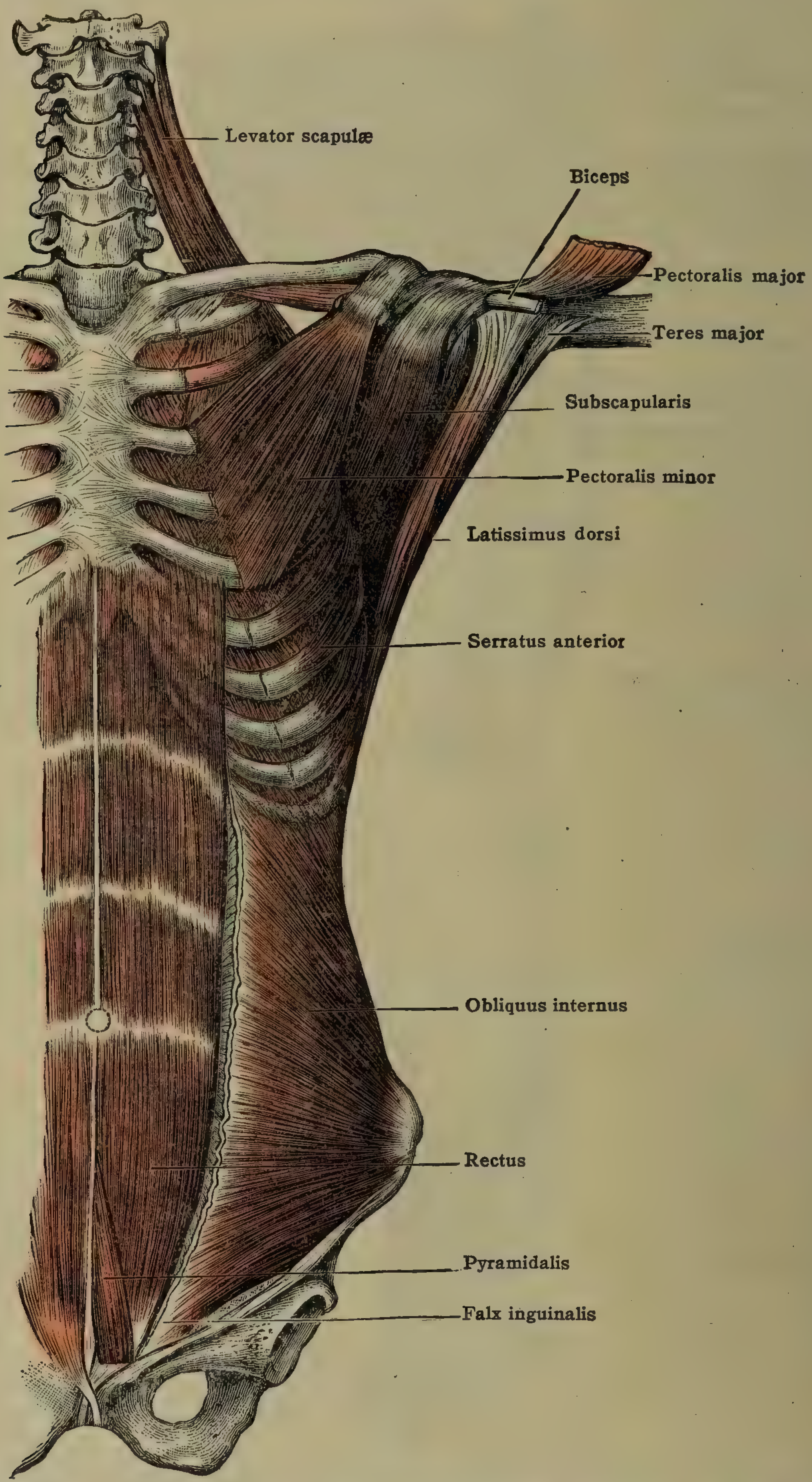


Fig. 452.—The Pectoralis Minor, Obliquus Internus, Pyramidalis, and Rectus Abdominis.

The pyramidalis lies beneath the ventral layer of the sheath of the rectus. From the latter it is sometimes separated by a distinct fascial layer.

Between the rectus muscles of each side the investing aponeuroses are firmly united into a dense tendinous band, the **linea alba** (figs. 448B, 453). This is broadest opposite the umbilicus. Above this it gradually grows narrower toward the xiphoid process to the ventral surface of

which it is attached. Hagenton has shown that the linea alba varies much in width. It is relatively wide in fat people and in fetuses. From the tip of the xiphoid process it is often separated by a bursa. Toward the symphysis pubis it extends as a narrow line. Just above the symphysis it divides to be attached on each side to the tubercle (spine) of the pubis. Behind it broadens into the *adminiculum lineæ albæ* which is attached on each side to the pubis. The linea alba is composed mainly of the interlacing of the fibers which pass into it from the aponeurotic sheaths of the rectus abdominis. From it and Scarpa's fascia, a few centimeters above the symphysis, there arises a broad elastic band, the *fundiform ligament* (superficial suspensory ligament) of the penis, which sends a fasciculus on each side of the penis. Below the penis these fasciculi unite. At the **umbilicus,** which is somewhat below the center of the linea alba, there is a circular opening encircled by dense fibrous tissue and filled with a thick connective tissue, extending from the tela subcutanea to the subserosa. The umbilicus is somewhat prone to hernia formation (p. 1278), and is occasionally the site of congenital fistulæ, which may originate in a Meckel's diverticulum or a patent urachus.

The *ventral layer of the lumbodorsal fascia* and its relations to the abdominal muscles also merit attention. This lies between the intrinsic dorsal musculature and the quadratus lum-

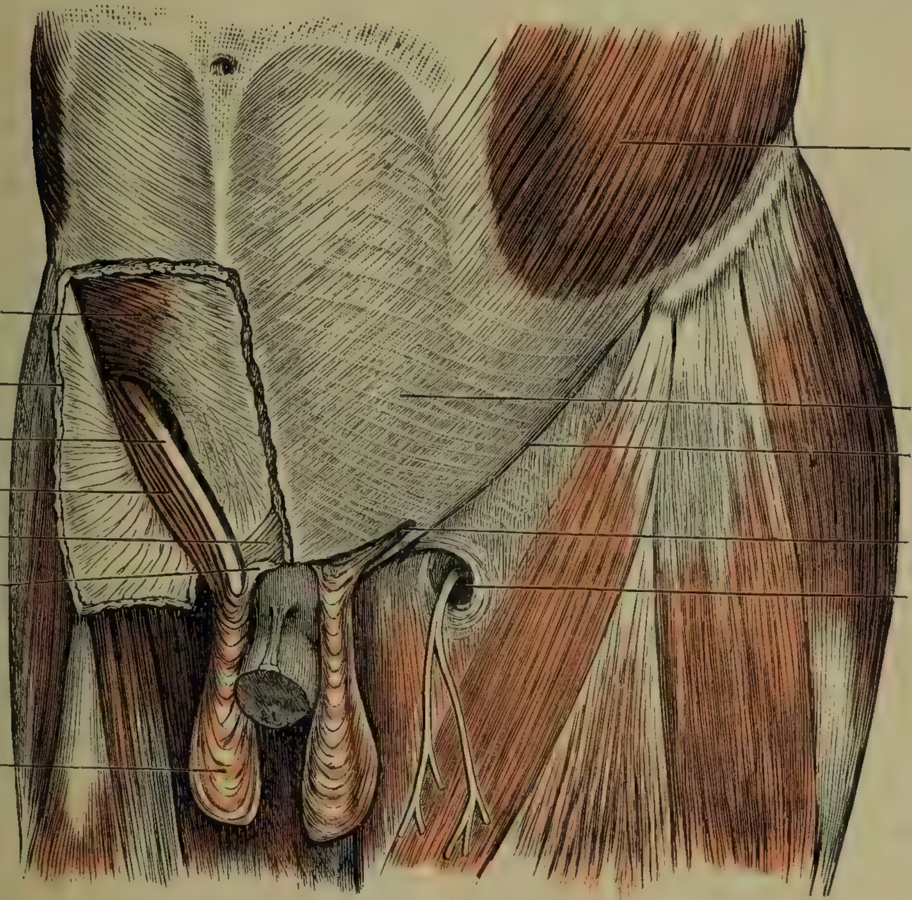


FIG. 453.—STRUCTURES OF INGUINAL REGION.

borum muscle and extends from the twelfth rib to the iliolumbar ligament. It is strengthened by the lumbocostal ligament which extends between the transverse processes of the first and second lumbar vertebræ and the twelfth rib, and by fibrous processes which extend into it from the transverse processes of the lumbar vertebræ to which it is attached. With the lateral margin of this ventral layer the dorsal layer of the lumbodorsal fascia is fused. The dorsal aponeurosis of the transversus muscle is united to the lumbodorsal fascia at the line of junction of the ventral and dorsal layers. The internal oblique muscle, covered externally by a fascia continued dorsally from the external oblique, arises in part from the dorsal layer of the lumbodorsal fascia near the junction of the two layers.

The **inguinal ligament** (Poupart's ligament) (figs. 451, 453, 454, 1018) is a strong band which extends along the lower margin of the aponeurosis of the external oblique from the anterior-superior iliac spine to the pubic tubercle. Internally the iliac fascia is fused to it. Distally the fascia lata of the thigh is attached to it. The deeper lateral abdominal muscles in part arise from it. Medially near the attachment of the ligament to the pubic tubercle (spine) diverging fibers are given off which pass inward and upward to the pecten (crest) of the pubis and give rise to the triangular **lacunar ligament** (Gimbernat's ligament). This is fused with the fascia of the pectineus muscle and bounds the femoral ring. Above the inguinal ligament near its medial extremity lies the external opening of the inguinal canal, the **subcutaneous** (external) **inguinal ring** [annulus inguinalis subcutaneus]. This opening is formed by the diverging of the lower medial fibers which compose the aponeurosis of the external oblique muscle. The superior fibers form the upper boundary, *superior crus* (crus mediale NK), of the ring and pass to the front of the symphysis pubis. The inferior fibers form the inferior boundary, *inferior crus* (crus laterale NK), of the ring and pass to the pubic tubercle (spine). Between these two fiber-bands *intercrural* (intercolumnar) *fibers* arch about the lateral boundary of the ring and serve to strengthen the anterior and inferior walls of the inguinal canal. Some of the fibers of the superior crus, intermingled with other fibers cross to the opposite side of the body and are inserted into the tubercle (spine) and crest of the pubis and into the superior crus of the opposite side. The structure thus formed is called the **reflected inguinal ligament** (Colles's ligament, or triangular fascia).

Inguinal canal [canalis inguinalis].—This term is applied to the slit in the lower margin of the abdominal wall through which, in the male, the spermatic cord passes, and in the female, the ligamentum teres. It is not a true canal. The inner end begins at the (internal) **abdominal ring** [annulus inguinalis abdominalis] (anulus inguinalis præperitonealis NK) (fig. 1017). This is situated just above and slightly medial to the middle of the inguinal (Poupart's) ligament. Below the ligament in this region lies the femoral canal through which the femoral vessels pass into the thigh. The (internal) abdominal ring is covered by the peritoneum and the transversalis fascia. The latter here sends a shallow funnel-like extension outward to be attached to the spermatic cord. The base of this funnel-like depression toward the inguinal (Poupart's) ligament is formed by a thickened band of tissue, the *tractus iliopubicus.* Medially and laterally the bundles of fibrous tissue which constitute this tract spread out fan-like, medially over the sheath of the rectus and toward the pubis, laterally over the transversus muscle and toward the crest of the ilium. The transverse abdominal muscle arises from the inguinal ligament nearly as far as the lateral margin of the abdominal ring. The fiber-bundles of this portion of the muscle course ventralward above the base of the funnel mentioned above and are inserted by tendons forming a more or less complete aponeurosis, the 'conjoined tendon, [falx inguinalis], common to it and the internal oblique into the ventral sheath of the rectus abdominis muscle, into the tubercle, crest and pecten of the pubis and sometimes into the pectineal fascia or the lacunar (Gimbernat's) ligament. Tendinous bands from the transversalis muscle curve downward medial to the (internal) abdominal ring and help to strengthen the transversalis fascia here. These bands constitute the *interfoveolar ligament* [ligamentum interfoveolare, Hesselbachi]. The fibrous bands constituting this ligament are attached to the lacunar ligament and the pectineal fascia.

From the abdominal ring the spermatic cord (or in the female the ligamentum teres) passes downward and foward in a space (inguinal canal) about 4 cm. long and then through the subcutaneous (external abdominal) ring which has been described in connection with the inguinal ligament. The ventral wall of the inguinal canal is composed of the aponeurosis of the external oblique, the intercrural fibers, and the cremaster muscle. Laterally it is also covered by the caudal portions of the internal oblique and transversus muscles. The caudal wall or floor of the space is formed chiefly by the lacunar (Gimbernat's) ligament and laterally also by the iliopubic tract. Cranialward the lateral part of the space is covered by the transversus and internal oblique muscles, the medial part by the cremaster muscle. The dorsal (internal) wall is formed mainly by the transversalis fascia. Medially the lacunar (Gimbernat's) ligament and the conjoined tendon (falx inguinalis), when this is well developed, help to form the dorsal wall. Lateral to these structures the dorsal wall is thinner but may be strengthened by a well developed iliopubic tract. Near the (internal) abdominal ring it is strengthened by the interfoveolar ligament, and sometimes by muscle slips (interfoveolar muscle).

Abdominal fossæ in the inguinal region (cf. fig. 981).—The hernias so frequent in this region make a special study of the inner surface of the abdominal wall of considerable practical importance. Medial to the abdominal (internal) inguinal ring the inferior internal epigastric vessels give rise to a slight fold (*plica epigastrica*) which slants medialward and upward toward the rectus muscle. From the lateral margin of the tendon of insertion of the rectus muscle upward toward the umbilicus over the obliterated umbilical artery there extends a better marked fold, the *plica umbilicalis lateralis.* Lateral to the plica epigastrica lies the **fovea inguinalis lateralis,** with the abdominal inguinal ring. Between the plica epigastrica and the plica umbilicalis lateralis lies the **fovea inguinalis medialis.** In the latter region the fascia transversalis which here forms the inner wall of the inguinal canal is strengthened by two longitudinal fibrous bands belonging to the aponeurosis of the transversalis muscle and described above, the interfoveolar ligament at the medial side of the (internal) abdominal ring, and the falx inguinalis (conjoined tendon) lateral to the rectus muscle. These bands vary in width. When they are narrow the part of the internal wall of the inguinal canal covered merely by the thin transversalis fascia and the peritoneum is relatively large and, since this region lies behind the subcutaneous (external abdominal) ring, opportunity is offered for direct inguinal hernia.

MUSCLES

A. Ventral Division

The rectus abdominis (fig. 452).—*Origin.*—Ventral surface of the fifth to seventh costal cartilages, the xiphoid process, and the costoxiphoid ligament.

Insertion.—The upper border of the body of the pubis and the ventral surface of the symphysis. (The origin and insertion are often described as reversed.)

Structure.—The muscle is long, flat, and somewhat triangular in form. Cranialward it is broad and thin; caudalward it becomes thicker as it converges toward the insertion. The fiber-bundles of the muscle have a longitudinal course. It is crossed by several incomplete, zigzag, transverse tendinous bands, **inscriptiones tendineæ** (lineæ transversæ), better developed on the ventral than on the dorsal surface of the muscle and intimately united to the ventral sheath of the rectus. One of these, corresponding segmentally to the tenth rib, is usually situated opposite the umbilicus. Another, corresponding to the ninth rib, is situated midway between this and the lower margin of the thoracic wall, and one corresponding to the seventh rib is found at the level of the xiphoid process. Between this and the one corresponding to the ninth rib an additional inscription is frequently found. Below the umbilicus an inscription corresponding with the eleventh rib is often found (30 per cent.). In these inscriptions many of the fiber-bundles have their origin and insertion. In the segments between these inscriptions, a localised tonic contraction of one or both recti may give rise to 'phantom' tumors in some hysterical cases. The thoracic attachments take place by means of band-like fasciculi which extend upward from the highest inscription, the fiber-bundles of these fasciculi being inserted by short tendinous bands. The pubic attachment of the muscle takes place by a short, thick tendon, usually divisible into two portions, of which the broader, lateral portion is

inserted into a rough area extending from the pubic tubercle (spine) to the symphysis, while the more slender medial portion is attached to the fasciæ in front of the symphysis pubis, where its fibers interdigitate with those of the opposite side. In addition to the attachments mentioned, some of the fiber-bundles are attached to the sheath of the rectus and many, after interdigitating, terminate in the intramuscular framework.

Nerve-supply.—The anterior branches of the six or seven lowermost intercostal nerves enter the deep surface of the muscle near its lateral edge. The cutaneous branches pass obliquely through its substance, while the muscular branches give rise to an intramuscular plexus. As a rule, the chief ventral branch of the tenth thoracic nerve enters the substance of the muscle slightly below the umbilical transverse inscription. The branches of the eleventh and twelfth nerves enter at a lower level. The main branch of the ninth nerve enters slightly below the preumbilical inscription; the eighth nerve, between this and the lower margin of the thorax. Either the sixth or seventh nerve may supply the fasciculi of origin. In addition to the main branches other smaller branches of the nerves of the abdominal wall are also usually distributed to the muscle. Each segment, either directly or through intramuscular plexuses, has a supply from more than one spinal nerve.

Action.—To depress the thorax and flex the spinal column. When the thorax is fixed the rectus serves to flex the pelvis upon the trunk.

Relations.—It lies between the transversalis fascia and the tela subcutanea and is ensheathed by the aponeuroses of the lateral abdominal muscles, as above described. The epigastric artery runs on its deep surface.

Variations.—The rectus muscle varies in the number of its tendinous inscriptions and in the extent of its thoracic attachment. It may extend farther than usual on the thorax. Frequently aponeurotic slips or slips of muscle on the upper part of the thorax indicate a more primitive condition in which the muscle extended to the neck. Absence of a part or the whole of the muscle has been noted. The muscles of the two sides may be separated by a considerable interval in the neighborhood of the umbilicus. The muscle is relatively thicker in men than in women.

The pyramidalis (fig. 452).—*Origin.*—Upper border of the body of the pubis.

Structure and insertion.—The fiber-bundles extend toward and are inserted into the linea alba for about a third of the distance to the umbilicus, and give rise to a flat, triangular belly.

Nerve-supply.—Usually through a branch of the twelfth thoracic, which may extend into the muscle through the rectus abdominis. Not infrequently a special branch extends into the muscle from the iliohypogastric or ilioinguinal, or rarely from the genitofemoral.

Action.—To draw down the linea alba in the median line.

Relations.—It lies between two laminæ of the anterior layer of the sheath of the rectus.

Variations.—It is missing in about 16 per cent. of instances (Le Double). Dwight has found it absent in 81 out of 450 males and in 60 out of 223 females dissected at the Harvard Medical School. It may extend upward to the umbilicus or be but very slightly developed. It may be double. In many of the mammals it is missing. It is well developed in the marsupials and monotremes.

B. Lateral Division

1. *Serratus Group* (fig. 444)

The serratus posterior superior.—*Origin.*—By a broad, thin aponeurosis from the ligamentum nuchæ and the spines of the last one or two cervical and the first two or three thoracic vertebræ.

Structure and insertion.—The fiber-bundles take a nearly parallel course downward and lateralward and give rise to a flat belly which ends by four fasciculi on the upper margin or the second to the fifth ribs, lateral to the iliocostalis.

Nerve-supply.—Through branches from the first four intercostal nerves. These nerves give rise to a plexus which passes across the deep surface of the muscle in the middle third between the tendons of origin and insertion.

Action.—To elevate the ribs to which the muscle is attached, and through them to enlarge the thorax.

Relations.—It lies upon the wall of the thorax and the intrinsic dorsal musculature and beneath the levator scapulæ, rhomboids, serratus anterior, and trapezius. Its fasciculi extend on the ribs to those of the serratus anterior (magnus).

The serratus posterior inferior.—*Origin.*—Through an aponeurosis, fused medially and inferiorly with the lumbodorsal fascia, from the last two or three thoracic and first two or three lumbar spines.

Structure and insertion.—From the aponeurosis arise four flat bands which are successively attached to the inferior margins of the last four ribs, lateral to the iliocostalis.

Nerve-supply.—From the ninth to eleventh intercostal nerves arise branches which form a plexus that extends across the deep surface of the muscle in the middle third between the tendons of origin and insertion.

Action.—To draw outward the four lower ribs and through them to enlarge the thorax. Together with the serratus posterior superior and the connecting aponeurotic fascia it aids in keeping the intrinsic dorsal muscles in place.

Relations.—It lies upon the intrinsic dorsal musculature, the lower dorsal part of the thorax and the lumbodorsal fascia, and beneath the latissimus dorsi, the trapezius, and their aponeuroses.

Variations.—The fasciculi of both muscles vary in number and may be replaced by aponeurotic slips. Aberrant muscle fasciculi, supracostales posteriores, may be found in the fascia which connects the two muscles. In several of the lower mammals the two muscles are normally continuous.

2. *External Oblique Group*

The intercostales externi (fig. 450).—These muscles extend in the intercostal spaces from the tubercles of the ribs to the costal cartilages. The intermediate muscles do not, however, often quite reach the cartilages. The first intercostal muscle may extend to the sternum. The others are continued through the intercostal region by thin aponeuroses, the **external intercostal ligaments,** the fibers of which have a direction corresponding to that of the muscle fiber-bundles. Dorsally the muscles are fused with the levatores, and ventrally the lower seven muscles are more or less fused with the corresponding fasciculi of the external oblique.

Origin.—From the lower margin of each rib external to the costal sulcus.

Structure and insertion.—The fiber-bundles take a parallel course obliquely forward and downward to the upper margin of the next rib. The proximal fiber-bundles are more oblique than the distal, and the muscles are best developed in the dorsal part of the intercostal spaces.

Nerve-supply.—By several branches from the corresponding intercostal nerves.

Action.—To elevate the ribs and enlarge the thorax. Acting on one side, they abduct toward that side and rotate toward the opposite side.

Relations.—They are covered externally by the pectoral muscles, the serratus anterior, and serrati posteriores, the levatores costarum, the sacrospinalis (erector spinæ), and the external oblique muscles. Internally they are separated by a slight amount of loose tissue from the internal intercostals, the membranes which continue these muscles medially, and from the subcostal muscles.

Variations.—When the twelfth rib is very small or is lacking, the eleventh intercostal muscle may be missing. When there is a supernumerary cervical or thirteenth thoracic rib, there may be an extra external intercostal muscle. Next to the first intercostal, the fourth most frequently reaches the sternum.

The levatores costarum (fig. 447).—These consist of a series of flat, triangular muscles, each of which *arises* from the tip and inferior margin of a transverse process and extends laterally with diverging fiber-bundles to be *inserted* into the dorsal surface of the rib below, from the tubercle to the angle. The first extends from the transverse process of the seventh cervical vertebra to the first rib. They increase successively in size from this to the last, which is attached to the twelfth rib. Those arising from the transverse processes of the eighth to the eleventh thoracic vertebræ send their more medial fiber-bundles across the rib below to join the lateral margin of the succeeding muscle (**levatores longi**). The levatores costarum are closely united to the external intercostals and are innervated by the intercostal nerves of the corresponding intercostal spaces. The first muscle is innervated by the eighth cervical nerve.

Action.—To bend laterally and extend the spinal column, and to rotate it toward the opposite side.

Relations.—They are covered dorsally by the longissimus dorsi and the iliocostalis.

Variations.—The first levator may be continued into the scalenus posterior. When greatly developed, the series of levators forms a serrate muscle.

The obliquus abdominis externus (fig. 451).—*Origin.*—By eight fleshy digitations from the external surface of the lower eight ribs immediately lateral to where they join the cartilages. The first five slips interdigitate with the serratus anterior (magnus), the last three with the latissimus dorsi.

Insertion.—(1) By a strong aponeurosis which extends over the rectus to the linea alba, where the more superficial fibers interdigitate across the median line, and to the inguinal (Poupart's) ligament; and (2) directly into the outer lip of the crest of the ilium. The aponeurosis over the rectus is usually partly fused with the aponeurosis of the internal oblique.

Structure.—The fiber-bundles which compose the flat fasciculi of origin diverge slightly as they pass forward and downward, and by fusion of their edges give rise to a flat sheet of muscle. The fasciculus taking origin from the fifth rib passes nearly directly ventrally, but the succeeding fasciculi incline somewhat downward, those from the seventh to the ninth ribs showing the greatest downward inclination. The lower margin of the fasciculus which arises from the seventh rib terminates opposite the umbilicus, that from the ninth rib extends toward the anterior superior spine of the ilium, and those from the last three ribs descend to the iliac crest. The first two fasciculi extend over the lateral margin of the rectus, the next two to its lateral edge. The fourth and fifth usually terminate along a line extending ventrally from the anterior superior iliac spine toward the rectus.

Nerve-supply.—The external oblique is supplied by rami from the lateral branches of the lower seven intercostal nerves and usually from the iliohypogastric as well. The rami of the first two or three nerves usually extend on the external surface of the muscle, while the others extend on the deep surface of the muscle as the cutaneous branches are passing through it toward the skin. The nerves of the external oblique take a more transverse direction than the fasciculi of the muscle. Thus the branch from the tenth intercostal nerve extends toward the umbilicus and that of the twelfth toward a point midway between the umbilicus and the symphysis pubis. The nerves have a segmental distribution corresponding with the primitive segmental condition of the muscle.

Action.—(1) To compress the abdomen; (2) to depress the thorax; (3) to flex the spinal column; and (4) to rotate the column toward the opposite side. With the thorax fixed it serves to flex and rotate the pelvis.

Relations.—It lies superficial to the lower ventrolateral margin of the thorax and the internal oblique muscles. It is partly covered by the latissimus dorsi muscle behind. Otherwise it is subcutaneous.

Variations.—It may have a more or less extensive origin from the ribs. Broad fasciculi not infrequently are separated by loose tissue from the main belly of the muscle either on its deep or superficial surface. Occasionally tendinous inscriptions are found. These transverse inscriptions are constant in many of the smaller mammals. The **supracostalis anterior** is a

rare fasciculus sometimes found on the upper portion of the thoracic wall. It is usually supplied by branches of the upper thoracic nerves and seems to be a continuation upward of the external oblique muscle. In some prosimians the external oblique extends normally to the first or second rib.

3. *Internal Oblique Group*

The intercostales interni (figs. 449, 450, 452).—These extend in the intercostal spaces from the angles of the ribs to the sternal ends of the spaces. The upper and lower muscles are usually continued dorsally slightly beyond the angles of the ribs, while the intermediate muscles frequently do not quite reach them. Dorsomedially the internal intercostals are continued in the form of thin fascial sheets across the inner surface of the external intercostals and become fused with the subcostals.

Origin.—Near the angles of the ribs they arise from the internal lip of the costal sulcus. More ventrally they arise mainly from the external lip of the sulcus, but also in part from the internal lip.

Structure and insertion.—The fiber-bundles take a parallel course downward and dorsalward to the upper margin of the rib below. They are less obliquely placed than those of the external intercostals. The muscles are thicker in front and grow thinner dorsally. They contain less fibrous tissue than the external intercostals.

Nerve-supply.—From numerous branches of the corresponding intercostal nerves.

Actions.—Investigators disagree as to the functions. It is probable that the portions of the muscles between the ribs contract, those between the costal cartilages expand, the thorax.

Relations.—Between the ribs they are covered by the external intercostal muscles and between the costal cartilages by the external intercostal ligaments. Between the internal and external muscles there is some loose areolar tissue. Proximally, for a short distance, the intercostal nerve in each interspace runs between the external and internal intercostal muscles, but more distally it runs first in the substance of and then on the internal surface of the internal intercostal. Eisler distinguishes that portion of the internal intercostal muscle which lies external to the nerve as the intercostalis intermedius, that which lies internal as the true internal intercostal. The terminal branches of the first six nerves, however, pass through the muscle on their way to the skin, while the last six pass beneath the inferior margin of the thorax. Internal to the internal intercostal muscle lie the transversus (triangularis sterni) and subcostal muscles, the diaphragm, and the pleural membranes. The more distal internal intercostal muscles are continuous with the internal oblique and the subcostal muscles.

Variations.—The tenth and eleventh internal intercostal muscles normally are but slightly developed and often may be wanting. The internal intercostals of the first three spaces may extend to the vertebræ.

The subcostales (figs. 450).—These muscles are due to an extension over two or more intercostal spaces of those fiber-bundles of the internal intercostal muscles which lie in the proximal part of the interspaces. They arise near the angles of the ribs, and are usually well developed only in the lower part of the thorax. The component fiber-bundles keep the general direction of the internal intercostals, but they converge toward the tendons of insertion, which are attached in each case to the second or third rib below, between the angle and the neck.

Nerve-supply.—The main nerve of supply for each muscle comes from the intercostal nerve running below the rib from which the muscle takes origin.

Action.—To depress the ribs and contract the thorax.

Relations.—They lie on the inner side of the internal and external intercostals and the ribs, and are covered by the pleural membranes.

Variations.—They vary much in development. Next to the lower fasciculi, the fasciculi in the cranial part of the thorax are those usually best developed.

The obliquus abdominis internus (fig. 452).—*Origin.*—From the lumbodorsal fascia the intermediate lip of the ventral two-thirds of the iliac crest, and the lateral half of the inguinal ligament.

Structure and insertion.—From the origin the fiber-bundles radiate forward in a flat sheet. The most dorsal extend to the lower three ribs, where they become continuous with the internal intercostals. The rest extend toward the lateral margin of the rectus, the upper ones toward the xiphoid process, the intermediate toward the umbilicus, the lower ones somewhat obliquely downward across the lower part of the abdomen. The fiber-bundles which extend toward the rectus terminate in an aponeurosis which in its upper two-thirds divides into two layers, one of which passes in front of and the other behind the rectus muscle to the linea alba. In the lower third the aponeurosis passes as a single membrane in front of the rectus. In the neighborhood of the subcutaneous inguinal (external abdominal) ring the muscle is continued into the cremaster. Medial to the ring some fasciculi are attached to the tubercle of the pubis and to the symphysis.

Nerve-supply.—From branches of the last three intercostal and the iliohypogastric, ilioinguinal and genitofemoral (?) nerves as these pass between this muscle and the transversus.

Action.—To depress the thorax, flex the vertebral column, and bend and rotate it toward the side on which the muscle is placed. When the thorax is fixed, the muscle serves to flex and rotate the pelvis.

Relations.—It lies between the external oblique and the transversus. The trigonum lumbale (triangle of Petit) is an area, variable in size, between the posterior margin of the external oblique, the lateral margin of the latissimus dorsi, and the crest of the ilium. In this area the internal oblique is subcutaneous. Through this triangle, when the muscles are weak, there may appear occasionally a lumbar abscess, and very rarely a lumbar hernia.

Variations.—The attachments and the extent of development of the fleshy part of the muscle vary considerably. Occasionally tendinous inscriptions are found in the muscle which indicate a primitive segmental condition.

The cremaster (fig. 453).—The cremaster muscle is found well developed only in the male. It represents an extension of the lower border of the internal oblique muscle and possibly also of the transverse over the testis and spermatic cord.

Origin.—(1) Lateral, thick and fleshy, from about the middle of the upper border of the inguinal ligament, and (2) medial, thin and tendinous, from the sheath of the rectus muscle and the tubercle (spine) of the pubis.

Structure.—The lateral head is applied to the lateral side, the medial head to the medial side, of the spermatic cord. Both pass with this through the subcutaneous (external abdominal) ring of the inguinal canal and become spread in loops over the testis. Ensheathing the muscle and between the somewhat scattered fiber-bundles which compose it, there extends a thin membranous layer of connective tissue, the **cremasteric (Cowper's) fascia.**

Nerve-supply.—The genital nerve (external spermatic), usually joined by a ramus from the ilioinguinal nerve, gives rise to branches which spread over the muscle.

Action.—To lift the testis toward the subcutaneous inguinal (external abdominal) ring.

Relations.—It is covered by the aponeurosis of the external oblique, the cremasteric fascia, the dartos, and the skin. It covers the spermatic cord and the testis.

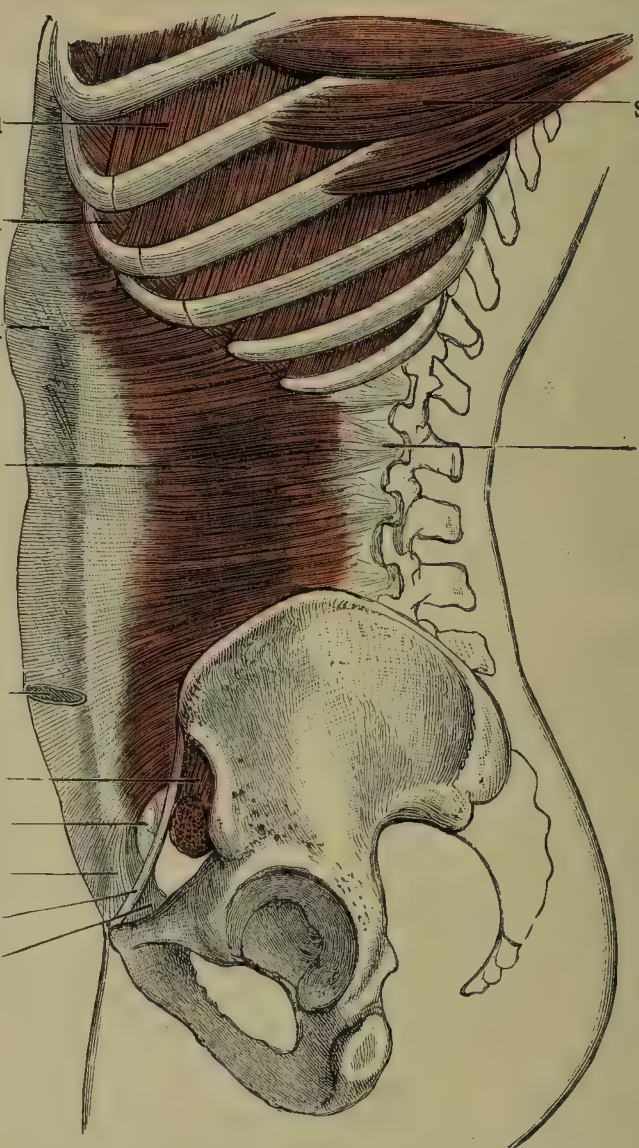


Fig. 454.—Transversus Abdominis and Sheath of Rectus.

Variations.—In the female the muscle is represented by a few fasciculi on the round ligament. It may arise wholly from the transversalis fascia or be somewhat fused with the transversus muscle. The latter condition is especially frequent in muscular individuals.

4. *Transversus Group*

The transversus thoracis (triangularis sterni) (fig. 449).—*Origin.*—By aponeurotic bands from the dorsal surface of the lower half of the body of the sternum and the xiphoid process.

Structure and insertion.—The muscle is composed of several flat, thin fasciculi, partly fibrous, more or less isolated, which are inserted by aponeurotic bands into the dorsal surface of the cartilages of the second or third to the sixth ribs, and occasionally also into the tips of the bony portions of the ribs. The lower fasciculus is closely related to the cranial margin of the transversus abdominis.

Nerve-supply.—By rami from the ventral portions of the second to the sixth intercostal nerves. These nerves give rise to a longitudinal plexus across the deep surface of the muscle near the middle of the constituent fasciculi.

Action.—To depress the ribs in expiration.

Relations.—The sternum, the costal cartilages, internal intercostal muscles, and the internal mammary vessels lie in front and the pleura and pericardium behind the muscle.

Variations.—It is an exceedingly variable muscle, both in the extent of its attachments and in the development of the individual fasciculi. The fasciculi vary in number from one to six. With this muscle Eisler would class the subcostal muscles and those portions of the internal intercostal muscles which lie internal to the intercostal nerves.

The transversus abdominis (figs. 449, 454).—*Origin.*—Directly from—(1) the inner side of the cartilages of the lower six ribs by dentations which interdigitate with the attachments of the diaphragm; (2) the internal lip of the iliac crest and lateral half of the inguinal ligament; and (3) through an aponeurosis from the lumbodorsal fascia.

Structure and insertion.—The fiber-bundles give rise to a broad, thin belly and take a nearly transverse course across the inner side of the abdominal wall. The lowermost fibers, however, are inclined obliquely toward the pubis. The fleshy portion of the muscle terminates in a strong aponeurosis along a curved line, which extends above well under the rectus and emerges lateral to the rectus opposite the umbilicus, whence it extends toward the middle of the inguinal ligament. In the upper two-thirds of the abdomen the aponeurosis extends behind the rectus to the linea alba and fuses with the inner lamina of that of the internal oblique. In the lower third of the abdomen it extends in front of the rectus to the linea alba, and is here also fused with the aponeurosis of the internal oblique. Some of the fibers are continued into the aponeurosis of the muscle of the opposite side. The lower attachment of the muscle is somewhat more complex. The fiber-bundles here bend around the spermatic cord, on the medial side of which they are spread out to be attached to the lacunar (Gimbernat's) ligament and pectineal fascia, the pubis, and the sheath of the rectus. The attachment to the lacunar ligament and pectineal fascia takes place by means of an aponeurotic band, the more lateral fibers of which are dense and curve below the spermatic cord to the lacunar ligament and the pectineal fascia below this. This band is called the **interfoveolar ligament.** It is composed partly of bundles of fibers prolonged from the aponeurosis of the opposite transversus, and bounds the abdominal ring medially and below. Medially the transversus is united to the upper part of the os pubis, and to the sheath of the rectus by an aponeurotic band, the **falx inguinalis** (conjoined tendon). Between the interfoveolar ligament and the falx inguinalis the transversalis fascia forms the posterior wall of the inguinal canal. In this area a detached band of muscle-fibers is sometimes found. This is called the **musculus interfoveolaris.**

Nerve-supply.—The transversus is supplied with nerves by the last five or six thoracic and the iliohypogastric, ilioinguinal and genitofemoral nerves as these course forward between this muscle and the internal oblique.

Action.—The chief function is to compress the abdominal viscera. Through the portions extending between the lower margins of the thorax on each side it serves to contract the thorax and so may aid in expiration.

Relations.—It lies on the inner side of the lower ribs, the internal oblique and rectus muscles, and is covered on the deep surface by the transversalis fascia.

Variations.—It is very rarely absent. It shows considerable variation in the extent of its development. The **pubotransversalis** is a small muscle which may extend from the superior ramus of the pubis to the transversalis fascia near the abdominal inguinal ring. The **puboperitonealis** is a similar muscle which may pass from the pubic crest to the transversus near the umbilicus. The **tensor laminæ posterioris vaginæ musculi recti abdominis,** essentially like the preceding, may extend from the inguinal ligament to the rectus sheath on the deep surface of the rectus muscle near the umbilicus. The **tensor laminæ posterioris vaginæ musculi recti et fasciæ transversalis abdominis** likewise extends from the transversalis fascia near the abdominal inguinal ring to the fold of Douglas.

C. Lumbar Muscle

The quadratus lumborum (fig. 470).—*Origin.*—From—(1) the internal lip of the iliac crest near the junction of the middle and dorsal thirds, and the iliolumbar ligament; (2) the transverse processes of the three or four lower lumbar vertebræ; and (3) the lumbodorsal fascia.

Structure and insertion.—From the origins there arises a complex quadrangular muscle belly from which spring the fasciculi of termination. These extend to—(1) the transverse processes of the upper three or four lumbar vertebræ; (2) to the fiber-bands which extend out laterally in the lumbar fascia from the transverse processes; and (3) to the medial part of the lower border of the twelfth rib.

Nerve-supply.—Through direct branches from the first three or four lumbar nerves.

Action.—It serves primarily to produce lateral flexion of the spinal column. When both muscles act together, they produce extension of the column. The muscle also serves to depress and fix the twelfth rib.

Relations.—It rests posteriorly on the lumbodorsal fascia and the transverse processes of the lumbar vertebræ. Its medial edge is partly covered by the psoas. In front of it also lie the kidney, the intestines, and the lumbar arteries and nerves. It is ensheathed by membranes continued over each surface from the transversalis fascia. Of these, the anterior is the better marked and is called the **lumbar fascia.**

Variations.—There is much individual variation in the internal structure of the muscle and in its attachments. Its insertion may extend to the eleventh rib.

The psoas major and minor belong essentially to the musculature of the lower limb and are there described (p. 521).

D. The Diaphragm

The diaphragm (figs. 449, 455).—This dome-shaped musculomembranous sheet has, when seen from above, something of the outline of a kidney. It consists of a pair of muscles which arise one on each side from the thoracic wall and are inserted into a central tendon. Lateral to the tendon the diaphragm projects higher into the thoracic cavity than in the central area.

On the right, in moderate expiration, it extends in adults to the height of the medial extremit of the fifth rib, and on the left to the fifth interspace.

Origin.—On each side from—(1) the lower border and back of the xiphoid process and th adjacent aponeurosis of the transversus abdominis or from the tendinous arch extending fror the tip of the xiphoid process to the cartilages of the fifth and sixth ribs, (*sternal portion*); (2 the lower border and inner surfaces of the cartilages of the seventh and eighth ribs, the cartilage and osseous extremity of the ninth rib and the osseous extremities of the last three ribs (*costa portion*); and (3) from the lumbar vertebræ (*lumbar portion*). The lumbar portion is divide somewhat irregularly into three crura, between which pass blood-vessels and nerves.

The **lateral crus** arises from the lateral surface of the bodies of the first two lumbar vertebr and from fibrous thickenings of the fascia over the psoas and quadratus lumborum muscles Of these, one, the **medial lumbocostal arch** (internal arcuate ligament), extends from the bod of the second lumbar vertebra to the transverse process of the same vertebra; the other, th **lateral lumbocostal arch** (external arcuate ligament), extends from the tip of the transvers process of the second lumbar vertebra to the twelfth rib. The lateral crus is only inconstantl attached to this. The **intermediate crus** arises from the ventrolateral surface of the body c the second lumbar vertebra from the sides of the bodies of the first two lumbar vertebræ an from the intervening disks. The **medial crus** arises from the front of the bodies of the third an the fourth lumbar vertebræ. On the left side it usually extends only to the third vertebra and it does not always extend to the fourth on the right. The extremity and medial margi

FIG. 455.—THE DIAPHRAGM. (Viewed from below.)

of this crus are tendinous, the lateral portion fleshy. On the second, third, and fourth, and the lower part of the first lumbar vertebræ the medial crus of each side is separated from its fellow by the **hiatus aorticus** (for the aorta and thoracic duct). Over the first lumbar vertebra they are fused by a process which extends from the right crus into the lower ventral surface of the left. Above here the right crus may be divided into two parts, one of which, fused with the left crus, passes on the left of the **hiatus esophageus**, while the other passes on the right. Sometimes the hiatus esophageus lies between the right and left crura. Frequently the left crus gives off a slip which passes to the ventral surface of the right below the hiatus.

The **costal portion** arises by a series of dentations which do not correspond perfectly in number with the ribs. Some costal cartilages have two dentations attached to them. It interdigitates with the transversus abdominis but in part arises from tendinous arches which bridge the origin of the transversus in the last three interspaces.

Structure and insertion.—The central tendon has somewhat the shape of a trifoliate leaf, the place of the stem being taken by the region occupied by the vertebral column, one leaflet lying on each side of this and one in front. The ventral part is usually placed somewhat to the left and is more or less completely fused with the left leaflet. Between the ventral and the right leaflets there is a large opening through which passes the inferior vena cava, the **foramen venæ cavæ**. The leaflets are fused in front and behind this.

The fleshy portion of the muscle is composed of fiber-bundles which pass at first nearly vertically upward and then arch over to be attached to the margins of the central tendon. The sternal portion of the muscle is the shortest. It is often separated from the costal portion by a small space through which the superior epigastric vessels pass.

Nerve-supply.—From the phrenic nerves, one of which arises on each side from the third to the fifth cervical nerves. Each nerve penetrates the diaphragm lateral to the central tendon and breaks up into an extensive plexus on the inferior surface of the muscle. Some of the lower intercostal nerves also contribute to the sensory innervation of the margin of the muscle and pos-

sibly also slightly to the motor innervation. The sympathetic nerves furnish fibers for the blood-vessels.

Action.—To enlarge the thoracic cavity and thus cause inspiration. According to R. Fick, however, the diaphragm plays a less important part in inspiration than is usually assumed for it. The middle part of the central tendon is united to the pericardium and through this to the cervical fascia, and is, therefore, not very moveable. In the contraction of the muscle it is the dorsal and lateral portions which in the main are flattened. The diaphragm aids in defecation, parturition and vomiting, by the pressure it exerts on the abdominal viscera. It also acts as a constrictor of the esophagus. For a discussion of the action of the diaphragm relative to the intercostal muscles in normal and pathological conditions, see C. F. Hoover, Arch. Int. Med., 1917, vol. 20, p. 701.

Relations.—Above lie the heart and the lungs; below lie the liver, stomach, duodenum, pancreas, spleen, kidneys, and suprarenal bodies.

Variations.—The sternal portion of the muscle is frequently absent. Infrequently the diaphragm is incompletely developed dorsally on the left side. This condition is rarer on the right side. The extent of the various insertions of the diaphragm shows considerable individual differences. The vertebral portion of the muscle may be slightly fused with the psoas or with the quadratus lumborum. Some fusion of the ventral portion of the muscle with the transversus thoracis has also been seen. Small fasciculi may pass to neighboring structures: the esophagus, stomach, liver, mesentery, etc. Muscle fasciculi are frequently found in the central tendon.

V. MUSCULATURE OF THE PELVIC OUTLET

In order to understand the musculature of the pelvic outlet it is necessary first to consider briefly the structure of the pelvis minor. It is bounded laterally and in front by the ilium below the terminal (iliopectineal) line, the ischium and the pubis, and by the obturator membrane and the sacrospinous (small sciatic), sacrotuberous (great sciatic) and the interpubic ligaments. The pubis, ischium and the obturator membrane are covered by the obturator internus muscle (figs. 457, 463) which here takes its origin and which converges toward and passes through the lesser sciatic notch on its way to its insertion on the great trochanter of the femur. The piriformis muscle (figs. 459, 466), which arises from the sides of the pelvic surface of the sacrum, from the posterior border of the great sciatic notch and the neighboring part of the sacrotuberous (great sciatic) ligament nearly fills up the great sciatic notch on its way to its insertion on the great trochanter. The walls of the pelvis are thus padded by muscles which belong to the limb. The muscles are covered by fascia best developed over the obturator internus muscle as the obturator fascia. The gluteus maximus muscle (figs. 451, 456, 461, 463), which arises from the back of the ilium, the sacrum, and the coccyx, and is inserted into the femur and the fascia of the thigh overlaps to some extent the sacrotuberous ligament, and in the standing position the tuberosity of the ischium so that its lower margin forms an accessory boundary to the pelvic outlet.

The outlet of the pelvis thus bounded by bone, ligaments and by muscles belonging to the lower extremity presents two triangles (figs. 456, 457), an anterior or urogenital triangle, with the base between the two ischial tuberosities and the apex below the symphysis pubis, and a posterior or rectal with the base between the ischial tuberosities and the apex at the coccyx. The outlet is closed by a special musculature forming the pelvic floor and divisible into three groups of muscles and fascia; those of the pelvic diaphragm and anus, those of the urogenital diaphragm, and those of the external genitalia.

The pelvic floor and associated structures occupying the pelvic outlet constitute the *perineum.* The term perineum is also used in a more restricted sense by obstetricians to indicate merely the region between the anus and the vulva. As seen in a midsagittal section (fig. 1132), this latter region forms the base of a wedge-shaped mass, known as the *perineal body*, separating the vagina from anal canal.

The pelvic floor has recently been carefully described by A. W. Meyer, Calif. and Western Med., 1927, vol. 27, no. 6 and 1928, vol. 28, no. 1.

The *pelvic diaphragm* [diaphragma pelvis] extends from the upper part of the pelvic surface of the pubis and ischium to the rectum which passes through it to be surrounded by the external sphincter. The urogenital trigone or *urogenital diaphragm* [diaphragma urogenitale] lies between the ischiopubic rami superficial to the pelvic diaphragm and surrounds the membranous urethra and in the female also the vagina. The *external genital* muscles lie superficial to the trigone.

The muscles of the **pelvic diaphragm** are two in number on each side, the coccygeus, and the levator ani (figs. 458–460). The **coccygeus** arises from the ischial spine and is inserted into the lateral margin of the lower sacral and the upper coccygeal vertebræ. It is closely applied to the pelvic surface of the sacro-

spinous (small sciatic) ligament. It helps to support the pelvic and abdominal viscera, flexes and abducts the coccyx.

The **levator ani** (figs. 458–460) arises from the inner side of the pubis, along a line extending laterally from the inferior margin of the symphysis to the obturator canal, and from the obturator fascia along a line, the *arcus tendineus*, extending from the pubis to the spine of the ischium. The levator ani is inserted into the median raphé back of the anus, the anococcygeal raphé, into the tip and sides of the coccyx and into an aponeurosis, which is attached to the anterior sacrococcygeal ligament. It is divisible into three portions, a *pubococcygeal*, an *iliococcygeal*, and a *puborectal*. The levator ani muscles of the two sides are separated by a slit which extends from the rectum to the symphysis pubis and in which in the male lie the lower part of the prostrate, and the membranous urethra (fig. 459), and in the female the vagina and urethra (fig. 458). Back of the rectum

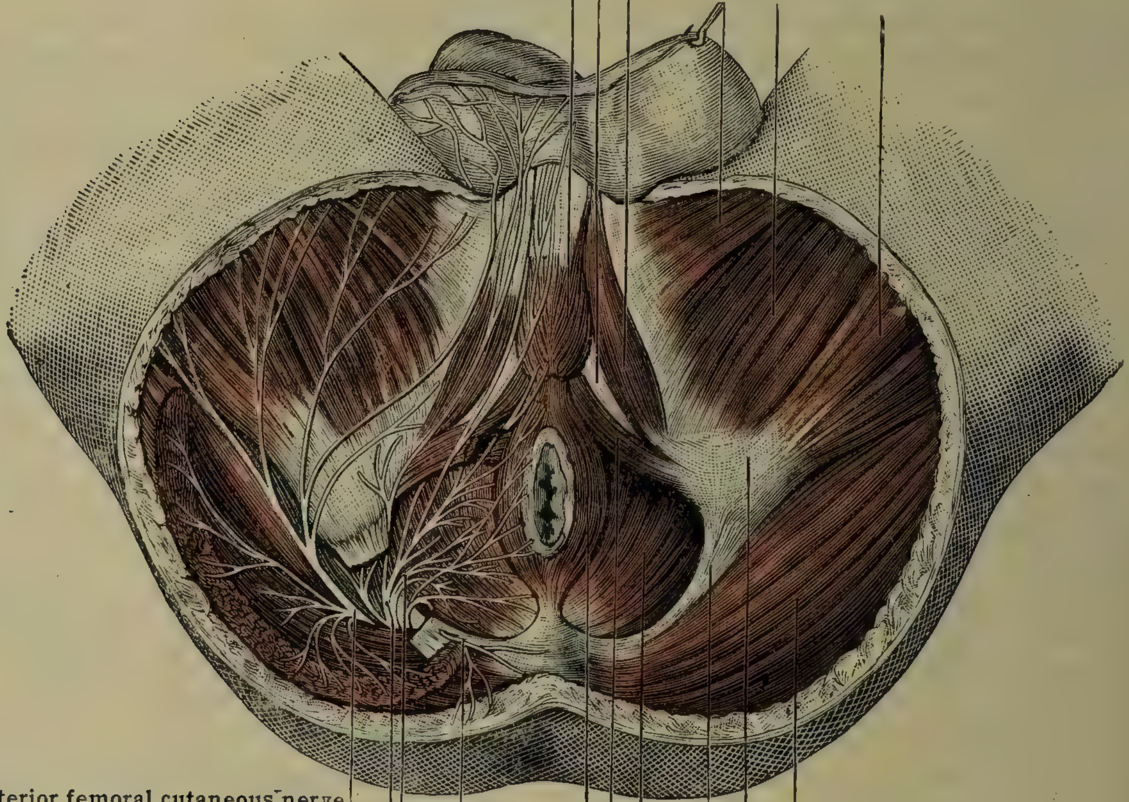


FIG. 456.—THE MALE PERINEUM. (Modified from Hirschfeld and Leveillé.)

some of the fiber-bundles from the muscles of the two sides interdigitate, while others terminate in the anococcygeal raphé. A few fiber-bundles also interdigitate across the median line, in front of the rectum (pubococcygeal, fig. 458) and some are inserted into the walls of the rectum. The levator ani and coccygeal muscles of the two sides form a funnel-shaped muscular support for the pelvic viscera (fig. 462). When the abdominothoracic diaphragm contracts, as during inspiration, part of the pressure on the viscera is transmitted to the pelvic diaphragm which resists the pressure and elevates the viscera when the abdominothoracic diaphragm relaxes. The levator ani muscle also constricts the rectum and pulls it forward and in the female constricts the vagina from side to side.

As it passes through the pelvic diaphragm, the rectum for about two and a half centimeters is surrounded by a special **external sphincter** muscle (figs. 456 and 460), divisible into three concentric layers as described below. This muscle, especially differentiated from the primitive sphincter of the cloaca,

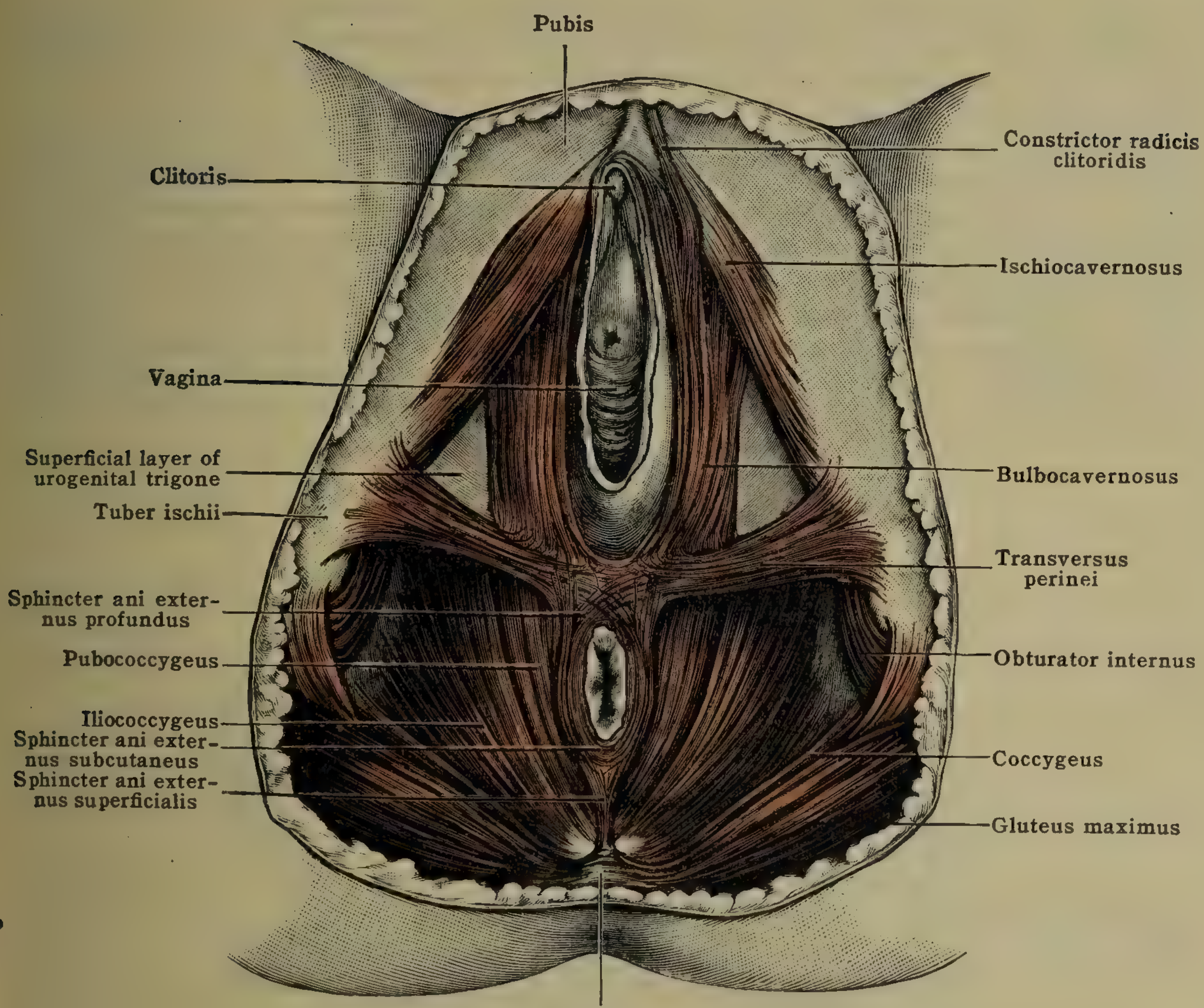


FIG. 457.—THE PERINEAL MUSCLES IN THE FEMALE.

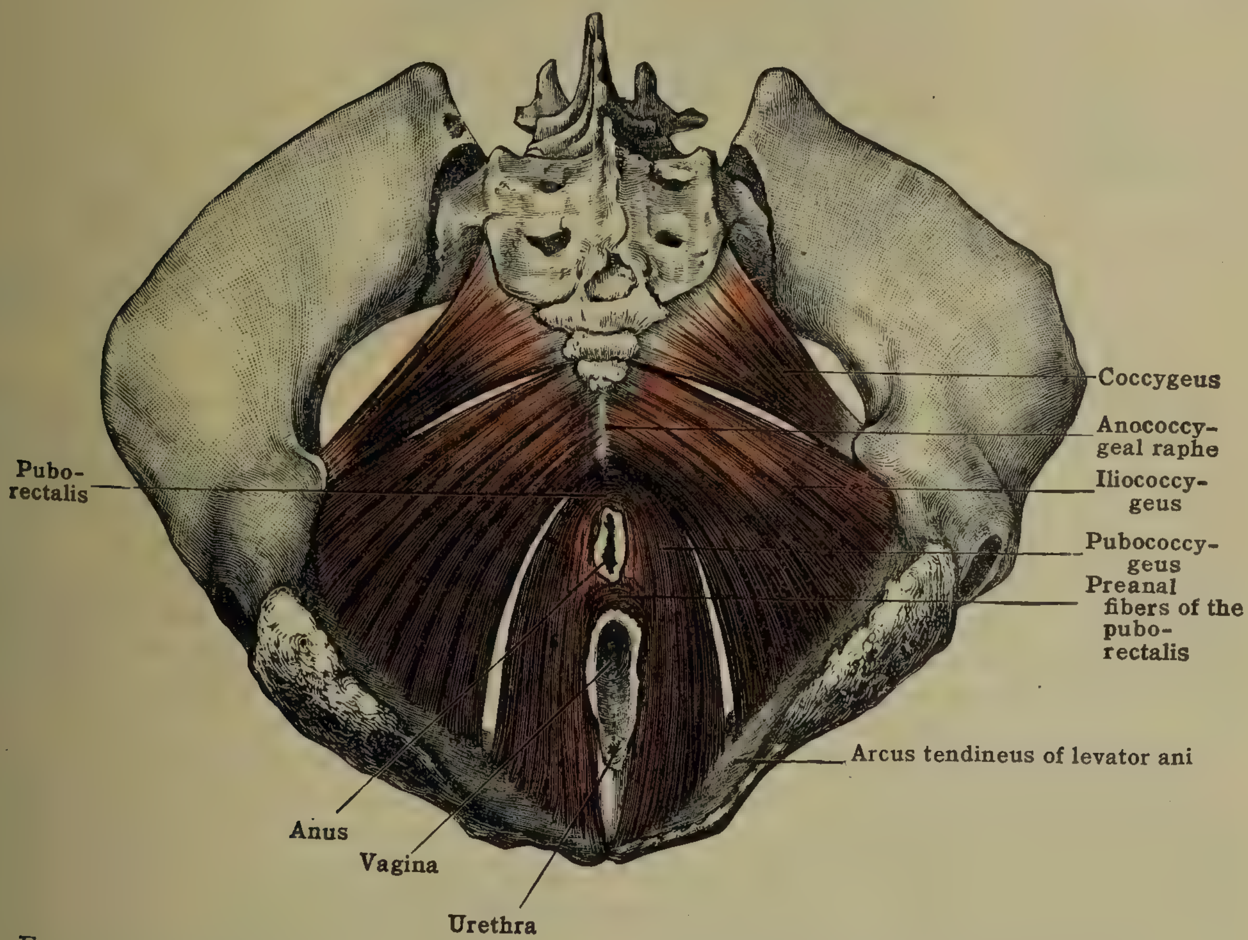


FIG. 458.—THE PELVIC DIAPHRAGM IN THE FEMALE, FROM BELOW AND BEHIND.

serves to close the rectum. It is supplemented by a sphincter of smooth muscle which lies immediately beneath the mucous membrane of the anus. It is attached behind to the coccygeus, and in front to the central tendon of the perineum described below.

The lateral origin of the levator ani, as above described and as shown in figs. 459, 460, 462, is considerably above the osseous and muscular margin of the pelvic outlet. The muscles of each side converge toward the postanal region so that a space is left between the lateral wall of the pelvis, and the levator ani and external sphincter (fig. 462). This space, the **ischiorectal fossa,** is filled with fat (figs. 461, 464). It is deepened laterally by the lower margin of the gluteus maximus muscle (fig. 461). In the fascial canal (Alcock's canal) in the lateral wall of the fossa run the internal pudic (pudendal) vessels and nerves (fig. 463). Above the pelvic diaphragm in the median part of the pelvic cavity are found the bladder,

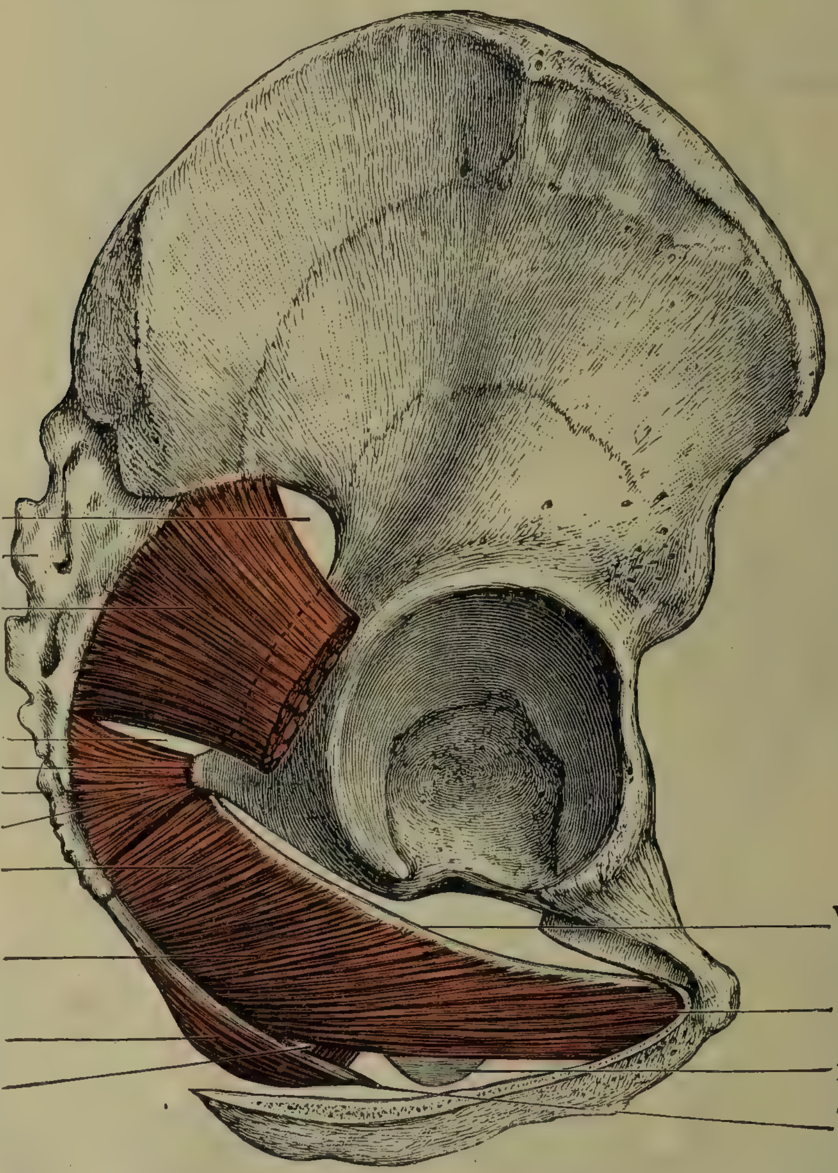


Fig. 459.—Lateral View of Muscles of the Floor of the Pelvis.
(A portion of the ischial and pubic bones sawn away.)

the ampulla of the rectum, and the prostate gland (in the male) or the vagina and uterus (in the female). Laterally on each side there is a subperitoneal space, filled with connective tissue and containing blood-vessels and nerves (fig. 464). Fasciæ invest each surface of the pelvic diaphragm (*diaphragmatic fascia*) and extend about the viscera (*endopelvic fascia*).

The muscular apparatus of the anterior or urogenital triangle of the pelvic outlet is much more complicated than that of the posterior or rectal triangle just described. We have seen that between the levator ani muscles of each side in front of the rectum there is a slit which extends to the symphysis pubis and that through it, the lower part of the prostate and the urethra extend in the male, the urethra and the vagina in the female. Between the ischiopubic rami there is stretched a triangular muscular and fibrous membrane, which likewise surrounds these urogenital ducts and which serves to strengthen the pelvic wall in this region. This structure is known as the **urogenital diaphragm (trigone)** (figs.

461, 465, 467). The musculature within it includes two muscles, the sphincter urogenitalis (urethræ) and the deep transverse perineal muscle. The *sphincter* embraces the urethra and associated structures. The component fiber-bundles arise chiefly from the fibrous tissue in the angle beneath the symphysis pubis, but partly also from the descending pubic rami. They pass analward and medialward on each side of the urethra and then partly interdigitate across the median line, partly terminate in a median raphe. Some fiber-bundles embrace in the male the lower part of the prostate and Cowper's gland. In the female the fiber-bundles of the sphincter partly terminate in the wall of the vagina. Some of them are continued downward on each side of the vagina and interdigitate with fiber-bundles from the deep transverse perineal muscle. The *deep transverse perineal* muscle (fig. 467) arises on each side from the ischiopubic

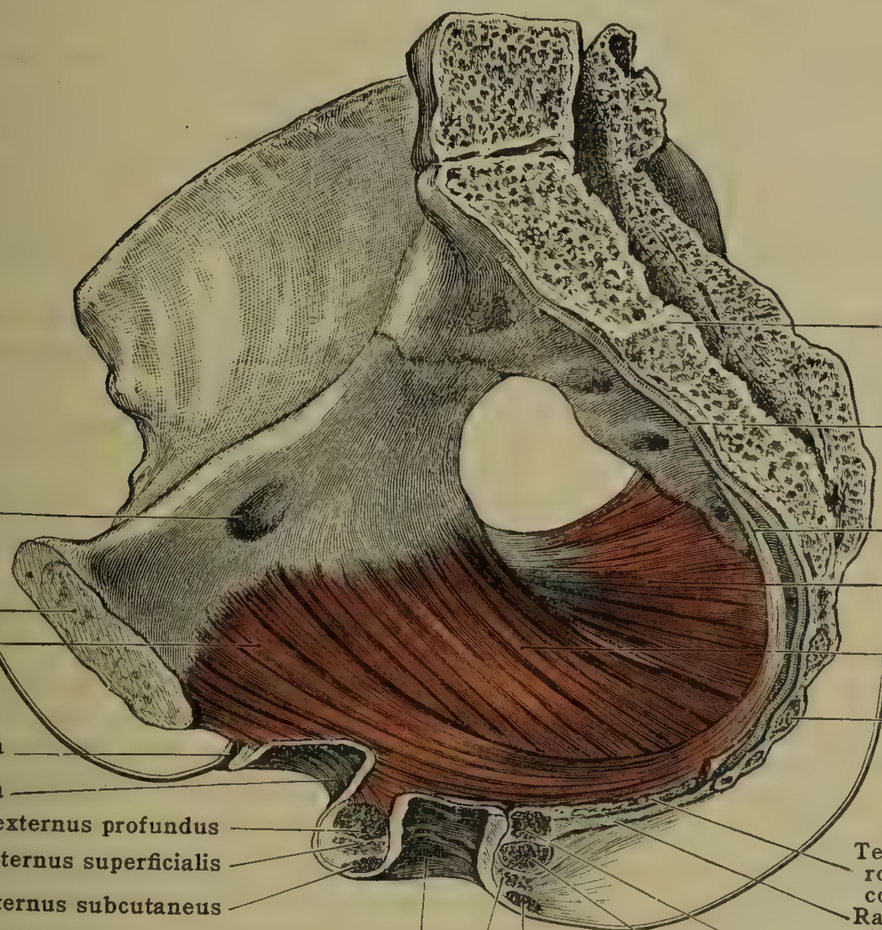


FIG. 460.—SAGITTAL SECTION OF THE PELVIS TO SHOW THE PELVIC DIAPHRAGM AND EXTERNAL SPHINCTER ANI.

ramus. It constitutes a flat band of muscle, the fiber-bundles of which in part interdigitate across the median line, and in part are inserted into a median raphe.

The musculature of the urogenital diaphragm is enclosed between two well marked **fascial layers** (fig. 461, 465), the deep (superior) and superficial (inferior) layers of the urogenital diaphragm. The anterior margins of the two fascial layers are fused to form the transverse ligament of the pelvis which extends between the inferior pubic rami, beneath the dorsal nerves and veins of the penis (clitoris). At the anal margin of the musculature these two layers are also fused with one another. The deep layer of the urogenital diaphragm forms the floor of the anterior recess of the ischiorectal fossa (fig. 465).

Superficial to the urogenital diaphragm lie the external genitalia (figs. 456, 457). Voluntary muscle is here found in connection with the crura of the penis (clitoris) and the bulb of the penis (vestibule). Although the musculature in the two sexes is fundamentally similar, nevertheless, owing to the differences in the structure of the genitalia in the two sexes, it is convenient to take up first the external genital musculature in the male and then that in the female.

In the male the crus penis, the posterior part of the corpus cavernosum, is relatively large. It lies in the groove between the ischiopubic ramus and the urogenital diaphragm (fig. 467), to the former of which it is firmly united. It is

enwrapped on its free medial surface by the **ischiocavernosus** muscle (erector penis) (figs. 464, 467). The fiber-bundles of this muscle arise from the ischial tuberosity and from the ischiopubic ramus on each side of the attachment of the crus. It is inserted into the medial and ventral surfaces of the crus near the attachment of the suspensory ligament. Some of the fiber-bundles may frequently be traced to the dorsal surface of the root of the penis (levator penis muscle).

The corpus spongiosum [corpus cavernosum urethræ] terminates posteriorly in the bulb which lies on the urogenital diaphragm between the two crura (figs. 456, 464). It is united to the superficial layer of the trigone (fig. 464). It is enveloped by the **bulbocavernosus** muscle, composed of right and left halves united by a median raphe on the superficial surface of the bulb (fig. 456). Each half consists of several superimposed layers of fiber-bundles described below. The component fiber-bundles arise from the superficial layer of the urogenital diaphragm, from fibrous tissue on the dorsum of the bulb in the angle between the two crura, from the lateral surface of the corpus cavernosum penis in front of the ischiocavernosus and from the dorsal surface of the penis. It is inserted into a tendinous structure situated in front of the anus, the central tendon of the perineum, and into the median raphe on the free surface of the bulb. By its contraction the bulbocavernosus forces semen or urine from the bulbous part of the uretha.

The **superficial transverse muscle** of the perineum (figs. 456, 457) arises on each side from the ascending ramus of the ischium and is inserted into the central tendon of the perineum. It is frequently weakly developed. It acts with the deep transverse perineal muscle in fixing the perineum and thus offering support for the action of other muscles.

In the **female** (fig. 457) the *ischiocavernosus* does not differ markedly from that in the male although usually smaller. The superficial transverse muscles are, on the other hand, usually relatively better developed. The central tendon of the perineum is likewise usually better developed in women and is more elastic, a characteristic of value in childbirth.

The chief difference in the musculature in the two sexes is found in the *bulbocavernosus* (fig. 464). This, in the female, arises from the back of the clitoris, the corpus cavernosum and the trigone. It covers the outer side of the bulb of the vestibule and the gland of Bartholin. It is inserted into the central tendon of the perineum. The chief function of the pair of muscles is to constrict the vagina.

The external genital muscles are covered by a deep layer of the tela subcutanea, Colles' fascia, which is firmly fused with the urogenital diaphragm at the posterior margin of the latter. The nerve supply of these muscles is from the pudendal nerve.

MORPHOLOGICAL REMARKS

While the shoulder-girdle and the muscles which extend from this and from the trunk to the upper extremity are superficially placed with respect to the trunk, and do not interrupt the trunk musculature the reverse is true of the hip-girdle and the musculature of the lower extremity. The hip-girdle is firmly united to the spinal column at the sacrum. The muscles which arise from the trunk and are attached to the lower limbs are few in number compared with those of the upper extremity and, unlike the latter, are deeply placed. Thus the psoas major muscle (fig. 470) arises on each side of the lumbar region of the spinal column at the back of the abdominal cavity and is inserted into the femur and the piriformis (fig. 470) arises from the front of the sacrum at the back of the pelvic cavity and is inserted into the great trochanter of the femur. The skeleton and musculature of the lower extremity, furthermore, markedly interfere with the continuity of the trunk musculature which in the lower vertebrates and in the human embryo may be followed continuously to the caudal end. The interruption is much less marked behind than in front. The intrinsic dorsal spinal musculature extends well down over the back of the sacrum, but on the back of the lower end of the sacrum and on the back of the coccyx there is found merely the inconstant sacrococcygeus posterior. Of the ventrolateral musculature the musculature of the abdominal wall, as is indicated by its innervation, is derived from the lower thoracic and the first one or two lumbar myotomes; the quadratus lumborum, at the back of the abdominal cavity (fig. 470), from the first three or four lumbar myotomes. Beyond here there is an interruption until we come to the musculature of the pelvic outlet which, in part, may be looked upon as modified trunk musculature belonging to the last three sacral myotomes. The intervening region is 'cut out' for the reception of the base of the lower extremity.

It is of interest to note that more and more of the ventrolateral wall of the trunk is 'cut out' as the midventral line is approached. Thus while the quadratus lumborum behind represents spinal segments as far caudal as the third or fourth lumbar, the rectus abdominis in front represents segments merely as far caudal as the twelfth thoracic. Similarly while the

coccygeus at the back part of the pelvic outlet represents the third and fourth sacral segments, the levator ani at the front represents chiefly the fourth.

The musculature which in the tailed mammals is used to move the tail as well as to wall off the pelvic cavity and close rectal and urogenital openings, in man is modified wholly for the latter functions. It constitutes the pelvic diaphragm.

The musculature of the urogenital diaphragm of the external genitalia and anus in man is differentiated from the primitive sphincter of the cloaca.

FASCIÆ

The **tela subcutanea** in the male perineal region contains many bundles of smooth muscle fibers continuous with and similar to the dartos of the scrotum (corrugator cutis ani). At the sides where it passes over the lower margin of the gluteus maximus it contains a large amount of fat, but in the dorsal region over the coccyx and sacrum, as in the midperineal region, the fat is limited in amount. In the labia majora of the female perineum there is much fat in the tela subcutanea.

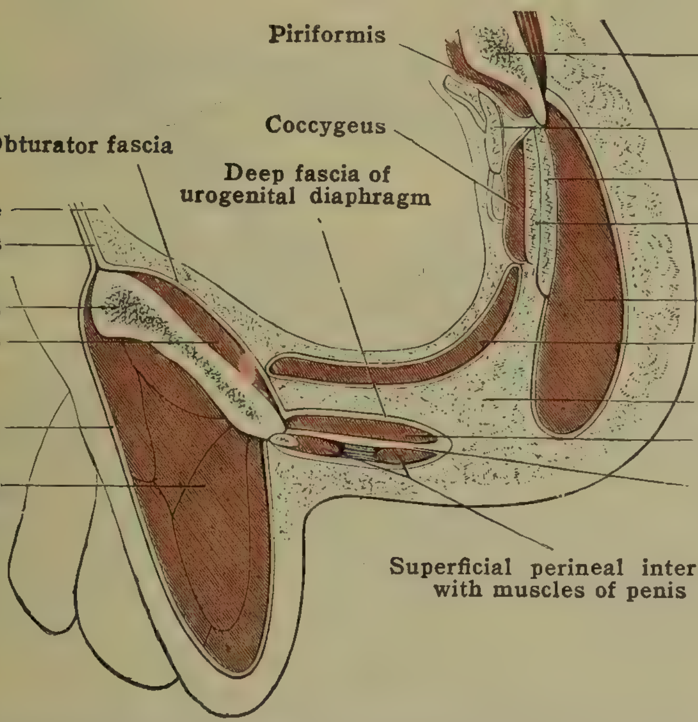


Fig. 461.—Sagittal Section through the Urogenital and Pelvic Diaphragms and Ischiorectal Fossa to the Left of the Middle Line. (Diagrammatic.)

The **ischiorectal fossa** (figs. 461, 463, and 464) is bounded laterally by the obturator internus muscle and fascia, the tuberosity of the ischium and the ischiopubic ramus, medially by the levator ani and coccygeus muscles and fasciæ, ventrally by the dorsal aspect of the urogenital diaphragm and dorsally by the gluteus maximus muscle. An *anterior recess* extends forward well toward the body of the pubis between the levator ani, the ischiopubic ramus and the urogenital diaphragms. A *posterior recess* may likewise be traced backward beneath the lower edge of the gluteus maximus (figs. 461, 463). The fossa is filled with loose fatty tissue continuous with that of the tela subcutanea. Through it pass the hemorrhoidal, and long and short perineal branches of the pudic artery and nerve. The main trunks of these vessels and nerves lie in a special fascial compartment (Alcock's canal) in the lateral wall, fig. 463.

The external genitalia are covered by a special deep layer of the tela subcutanea, the superficial perineal (Colles') fascia (fig. 464). This is attached on each side to the lower margin of the ischiopubic ramus and to the ischial tuberosity. At the posterior margin of the superficial transverse perineal muscle it fuses with the two fascial layers of the trigone. It is adherent to the central tendon of the perineum and to the raphe of the bulb. Anteriorly it is continuous with the deep layer of the tela subcutanea covering the scrotum, the penis, and the lower part of the abdominal wall. In rupture of the urethra urine is prevented, by the attachments of the tela, from getting further back than the posterior edge of the trigone, but anteriorly it may extend to the surface of the abdomen. Here it may extend upward for a considerable distance, but it is kept from the thighs by the attachments of the deep layer of the tela subcutanea (Scarpa's fascia) to the inguinal ligament. Beneath the superficial perineal fascia are found the crura of the penis and their muscles, the bulb of the corpus spongiosum and its muscles, the superficial transverse perinei muscles, and the perineal vessels and nerves (fig. 464).

Muscle-fasciæ.—The muscles of the urogenital diaphragm, the urogenital (urethral) sphincter and the transversus perinei profundus, are contained between two fascia layers, which constitute the superficial (inferior) and deep (superior) layers of the urogenital diaphragm.

The *superficial* (*inferior*) *layer* (figs. 456, 457, 461, 464, 465) which lies between the external genitalia and the urogenital diaphragm, is composed of strong bands of fibrous tissue which extend transversely across the subpubic arch and are attached to a ridge on the ischiopubic rami. It is separated from the arcuate (subpubic) ligament by a mass of fibrous tissue through which the dorsal veins and nerves of the penis (clitoris) run, and in which there is a venous plexus. Beneath this tissue a fibrous band, the *transverse ligament* (lig. praeurethrale NK) extends between the descending pubic rami. This represents a region of fusion of the deep and superficial layers of the fascia of the trigone. Posterior to the deep transverse muscle the two layers

are likewise fused. The superficial layer is better developed in the front than in the back par of the space. It is pierced by the urethra (about 3 cm. below the symphysis) by the ducts o the bulbourethral (Cowper's) glands, the arteries of the bulb, and the dorsal nerves and arterie of the penis. In the female it is pierced by the vagina as well as by the structures mentione above.

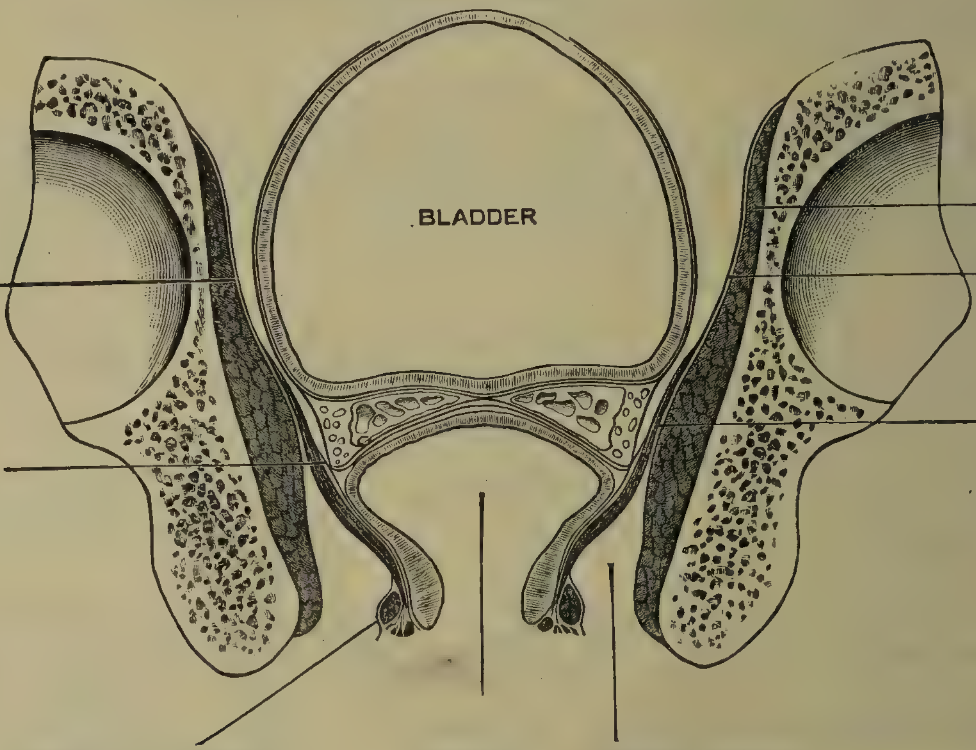


FIG. 462.—DIAGRAM TO SHOW THE FASCIÆ OF THE PELVIS IN FRONTAL SECTION. (After Holl.)

Beneath the superficial layer of the fascia of the trigone, in addition to the muscles of th urogenital diaphragm, there are found the membranous urethra, the bulbourethral glands (Cowper's), the internal pudic arteries and the pudic nerves (in part).

The *deep* (*superior*) *layer of the urogenital diaphragm* (figs. 461, 464, 465) lies between th muscles of the urogenital diaphragm and the ischiorectal fossa and levator ani. It may b looked upon as a continuation of the obturator fascia across the pubic arch. Posterior to th deep transverse perineal muscle it fuses with the superficial layer of the fascia of the urogenita diaphragm. In this region in the male it fuses with a fascial membrane, the *prostaticoperinea*

FIG. 463.—HORIZONTAL SECTION SHOWING THE ISCHIORECTAL FOSSA AND ITS RELATIONS.

fascia, which extends upward between the rectum and prostate, and is attached to the posterior wall of the latter. In the female it is fused with the fibrous tissue which lies between the vagina and the rectum.

The muscle-fasciæ of the pelvis (figs. 462–464, 471) have been described in various ways by different authors. They may be subdivided into parietal and diaphragmatic.

The parietal fasciæ (fig. 462) cover the muscles which extend from the interior of the pelvis to the thigh (the obturator internus and piriformis muscles). Above, the fascia on each side is attached to the linea terminalis and is continuous with the fascia transversalis and the iliac

fascia. It is attached to the margins of the greater and lesser sciatic notches and to the ischiopubic ramus and the body of the pubis. Between the ischiopubic rami it is stretched across the subpubic arch and forms the superior or deep layer of the urogenital diaphragm described above. The portion of parietal pelvic fascia over the obturator internus muscle is called the obturator fascia.

The **diaphragmatic pelvic fasciæ** cover both surfaces of the pelvic diaphragm and are reflected upon the viscera. The fasciæ covering the two surfaces of the levator ani are attached to the parietal (obturator) fascia along the line of origin of the muscle.

The line of attachment of the levator ani divides the obturator fascia into two parts (fig. 462), a pelvic part above the line of attachment, covered by peritoneum, and an ischiorectal part below the line of attachment. The latter bounds the lateral wall of the ischiorectal fossa. The former part is much the thicker. It consists morphologically of two fused membranes, the obturator fascia proper and the aponeurosis of the iliococcygeal portion of the levator ani, which although usually fused with the obturator fascia, may frequently be traced to the terminal (iliopectineal) line from which in tailed mammals this portion of the levator takes origin. The two layers of fascia also become continuous at the medial margin of the muscle where this faces the urogenital passage (fig. 462). Posteriorly, the inner layer fuses with the tendinous insertion of the pubococcygeus portion of the muscle and the fasciæ of the muscles of each side are continuous. It also fuses with a fascia covering the coccygeus muscle.

The thin perineal layer of the levator fascia behind the rectum fuses with that of the opposite side and is attached to the coccyx and the anococcygeal raphe. About the anus it helps to form a covering for the external sphincter. Ventrally it is attached to the ischiopubic rami. It forms the medial wall of the ischiorectal fossa.

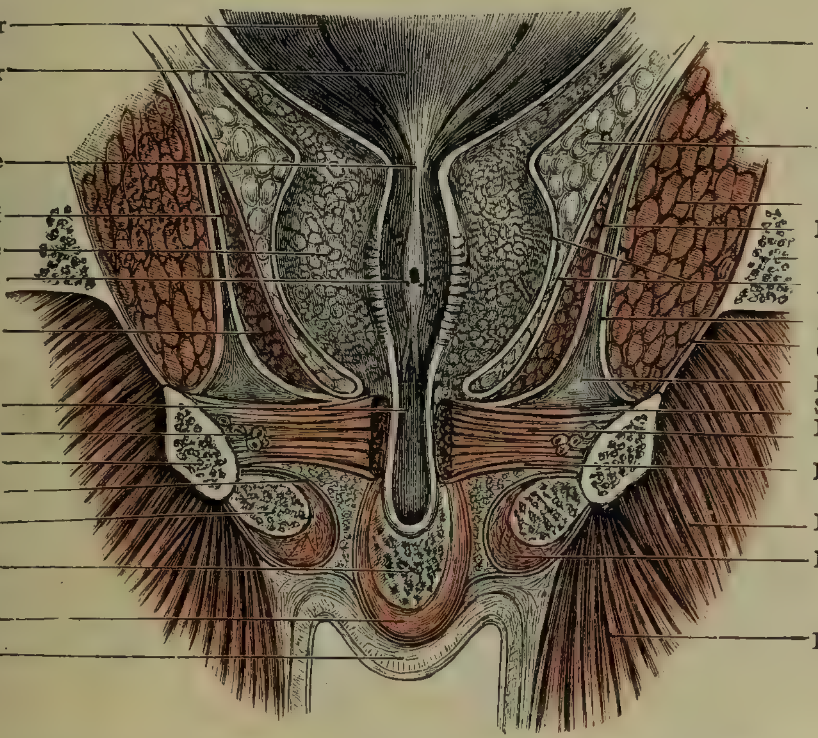


FIG. 464.—VERTICAL FRONTAL SECTION OF THE PELVIS, SHOWING FASCIÆ. (Modified from Braune.)

Endopelvic fascia (figs. 463, 464).—The peritoneum is reflected from the pelvic wall onto the viscera much higher up than the level at which the viscera are attached to the pelvic diaphragm. Between the pelvic fascia covering the deep surface of the pelvic diaphragm (levator ani and coccygeus muscles) and the peritoneum there is thus left a space, subperitoneal space. In the median plane in this region in the male are found the bladder, prostate, seminal vesicles, the ureter and ductus deferens in their course near the bladder, and the ampulla of the rectum. In the female we find here the bladder, the vagina, the uterus, and the ampulla of the rectum. Between these medially placed viscera and the lateral wall of the pelvis there is an irregularly shaped space, *cavum pelvis subperitoneale*, bounded above by peritoneum, below by the fascia covering the pelvic diaphragm and filled with connective tissue of varying density. The tissue in this space in the female is continuous with that between the two peritoneal surfaces of the broad ligament. Between the viscera in the subperitoneal region and about their walls the connective tissue is more or less definitely condensed into membranes which constitute the endopelvic fascia, variously described by different authors. The fascia covering the pelvic diaphragm, especially that on the deep surface, is fused to the endopelvic fascia where the viscera pass through the pelvic diaphragm. In the connective tissue of the subperitoneal space are found the hypogastric artery and vein and their chief branches, and various visceral nerves. The subperitoneal space above the pelvic diaphragm is to be compared with the subcutaneous space below the pelvic diaphragm known as the ischiorectal fossa and described above.

MUSCLES

A. MUSCLES OF THE PELVIC DIAPHRAGM, COCCYX, AND ANUS

The **coccygeus** (figs. 458, 459, 460, 466).—*Origin.*—From the ischial spine and the neighboring margin of the great sciatic notch. *Structure and insertion.*—The fiber-bundles diverge

to be inserted partly directly, partly by means of an aponeurosis, into the lateral margin of the fourth and fifth sacral vertebræ and of the coccyx. Usually the muscle is composed in considerable part of tendinous connective tissue, especially on the dorsal side of the cranial portion, and the ventral side of the caudal portion.

Nerve-supply.—From the pudendal plexus several small nerves enter the cranial margin and pelvic surface of the muscle. They arise usually from the third and fourth sacral nerves.

Action.—Insofar as the muscle produces movement it flexes and abducts the coccyx.

Relations.—Ventrally the muscle bounds the pelvic cavity, from which it is separated by the pelvic fascia, beneath which runs the nerve to the levator ani muscle. The dorsal surface is partly covered by the sacrospinous (lesser sciatic) ligament and helps to bound the ischiorectal fossa (posterior recess).

Variations.—The muscle varies greatly in the extent of its fleshy development. It may be doubled. It may be partially fused with the levator ani. Occasionally it is absent.

The **sacrococcygeus anterior** (fig. 466).—This inconstant muscle, when well developed, arises from the sides of the fourth and fifth sacral and from the front of the first coccygeal vertebra and from the sacrospinous ligament. The short fiber-bundles which compose it make up a somewhat irregular belly which is inserted into the anterior sacrococcygeal ligament and into the second to fourth coccygeal vertebrae dorsal to the insertion of the levator ani. The innervation is from the fourth and fifth sacral nerves.

The **sacrococcygeus posterior** is an inconstant muscle consisting of a few muscle bundles which extend from the dorsal surface of the lower sacral vertebræ or from the posterior iliac spine to the dorsal surface of the coccyx. It lies beneath the superficial layer of the sacrotuberous (great sciatic) ligament.

The **levator ani** (figs. 456, 457, 458, 462, 463) is divisible into three portions, the iliococcygeus, the pubococcygeus and the puborectalis.

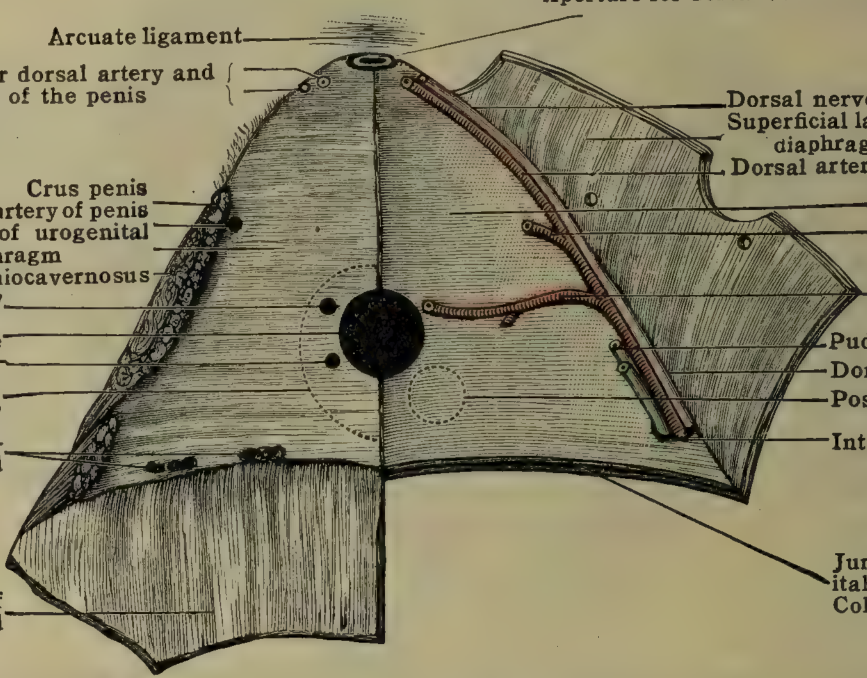


Fig. 465.—Diagram of the Superficial and Deep Layers of the Urogenital Diaphragm.

The *iliococcygeus* (fig. 460) *arises* from the arcus tendineus (white line). This extends from the ischial spine and posterior part of the arcuate line to the superior ramus of the pubis near the obturator canal, curving downward for a variable distance below the obturator canal. The constituent fiber-bundles form a muscular sheet which is inserted into the side of the coccyx and into the median raphe (anococcygeal) which extends from the tip of the coccyx to the rectum. Many fiber-bundles cross the median line.

The *pubococcygeus* (figs. 458, 460) *arises* from the inner surface of the os pubis, along a line extending from the lower margin of the symphysis pubis to the obturator canal, and from the arcus tendineus as far backward as the origin of the iliococcygeus. The fiber-bundles form a sheet of muscle which passes backward, downward, and medialward past the urogenital organs and the rectum on each side and is *inserted* by means of an aponeurosis into the anterior sacrococcygeal ligament. Back of the rectum some of the fiber-bundles of the muscle sheets of each side interdigitate across the median line. Some of the more superficial fibers are inserted into the deep part of the anococcygeal raphe. Some of the fiber-bundles which arise nearest the symphysis are inserted on each side into the rectum. The pubococcygeus lies to some extent on the pelvic surface of the insertion of the iliococcygeus.

The *puborectalis* (fig. 458) *arises* (a) from the body and descending ramus of the pubis beneath the origin of the *pubococcygeus*, (b) from the neighboring part of the obturator fascia and (c) from the fascia covering the pelvic surface of the urogenital diaphragm. The fiber-bundles form a thick band on each side of the rectum behind which those of each side are inserted into the anococcygeal raphe. Many fiber-bundles may be traced into the muscle of the opposite side. Some of the more superficial fiber-bundles are reflected medialward in front of rectum and may be followed into the superficial transverse perineal muscle, others may be followed into the sphincter ani externus, or even to the skin.

Nerve-supply.—By a special nerve which arises usually from the fourth sacral, runs across the pelvic surface of the muscle and gives a special branch to each portion.

Action.—To flex the coccyx, raise the anus and constrict the rectum. It resists the downward pressure which the thoracoabdominal diaphragm exerts on the viscera during inspiration.

Relation.—Between the right and left muscles in front lie the urethra and the lower part of the prostate in the male, the urethra and vagina in the female. In the triangle between the ischiopubic rami of each side lies the urogential diaphragm separated from the puborectal part of the muscle by the deep layer of the trigone from which some of the fibers of the latter arise. Back of the urogenital diaphragm the muscle helps to bound the ischiorectal fossa.

Variations.—The muscle shows great individual variation in structure which causes it to be variously described by different authors.

The **sphincter ani externus** (figs. 456, 457, 459, 460, 462) is made up of bundles of muscle fibers which surround the anus for nearly two centimeters. It is elliptical in form. Behind the anus the fiber-bundles of each side in part interdigitate, forming a ring. They are attached

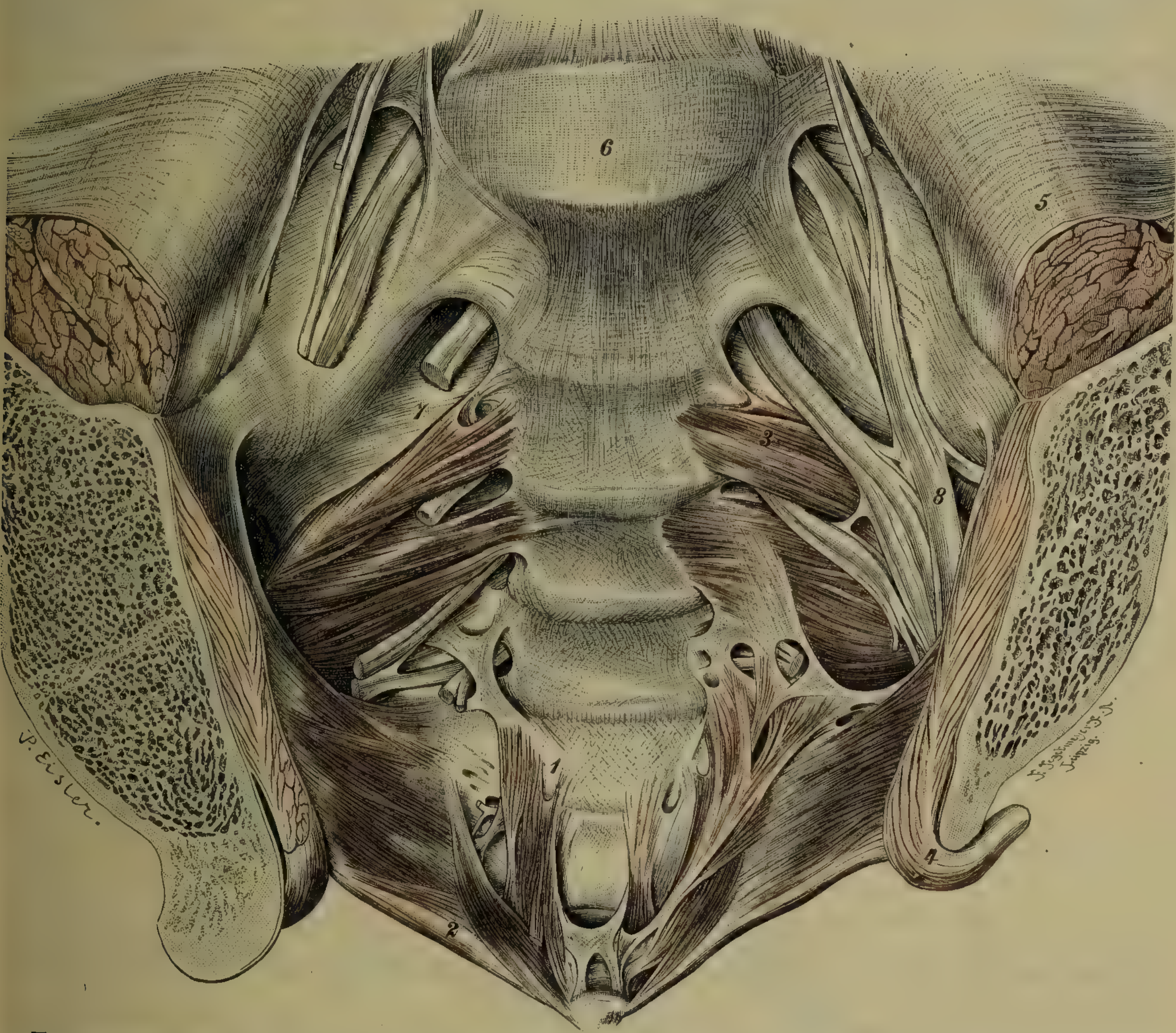


Fig. 466.—Ventral Coccygeal Muscles (After Eisler.)—1. M. sacrococcygeus anterior 2. M. coccygeus. 3. M. piriformis. 4. M. obturator internus. 5. Fascia iliaca, above the iliopsoas. 6. Fibrocartilago intervertebralis lumbosacralis. 7. Ventral trunk of first sacral nerve. 8. Sacral plexus.

to the skin, and in part are attached through a tendon, the *ligamentum anococcygeum*, to the back of the coccyx. In front of the anus the fiber-bundles also in part interdigitate with one another, in part are inserted into the skin and in part interdigitate with the fiber-bundles of the transverse perineal and bulbocavernosus muscles. At the point where these muscles meet, about two and a half centimeters in front of the anus, there may be a visible mass of fibrous tissue, the *central tendon of the perineum*, but this is not always distinct. It is usually better developed in the female than in the male perineum. The external sphincter is divisible into three portions, a subcutaneus, a superficial and a deep (fig. 460). The three parts are connected by fiber-bundles, and are not always distinct. The *subcutaneous division* is small and immediately encircles the anal orifice. The *superficial division* lies deeper than the subcutaneous ring and descends further toward the rectum. It is shown in figs. 456, 457. It is the only part attached to the coccyx. In front it is attached to the central tendon of the perineum, but some fibers are continued into the bulbocavernosus. The *deep portion* forms a heavy ring above the superficial part. It is distinctly, though not completely, separated from the pubo-rectal portion of the levator and by fascial tissue containing the inferior hemorrhoidal vessels. Some of the fiber bundles of the deep portion may be traced in front of the anus across the midline to the ascending ramus of the opposite side and form part of the superficial transverse perineal muscle.

Nerve-supply.—From the inferior hemorrhoidal branches of the pudendal (internal pudic) and frequently also by a perineal branch from the fourth sacral.

Action.—To keep the anus closed.

Relations.—Externally it is surrounded by the fat of the ischiorectal fossa, internally near the skin it surrounds the sphincter ani internus, composed of smooth muscle, deeper it lies next to the mucous membrane, for a distance of two centimeters from the skin.

Variations.—The muscle shows considerable individual variation in structure.

The *rectococcygeus* or muscle of Treitz, is a triangular bundle of smooth muscle-fibers. The origin of the muscle is from the second and third coccygeal vertebræ. It is inserted by its apex into the posterior wall of the rectum and the perirectal fascia. It retracts and elevates the rectum.

B. Muscles of the Urogenital Diaphragm

The urogenital diaphragm (or trigone) is composed of two closely united muscles, the deep transverse perineal muscle and the urogenital sphincter.

The **transversus perinei profundus** (fig. 467) is a flat muscle which *arises* from the inner side of the inferior ischial ramus and is *inserted* into the median raphé. Many of the fiber-bundles interdigitate with those of the opposite side and some may be followed into the external sphincter of the anus and into the urogenital spincter and other perineal muscles.

Nerve-supply.—By the perineal branch of the pudendal (pudic).

Action.—The pair of muscles draw back and fix the central tendon of the perineum and thus give firm support for the action of the urogenital sphincter.

Relations.—The inferior surface is separated (often incompletely) by the inferior layer of the urogenital trigone from the superficial transverse perineal muscle. The superior surface

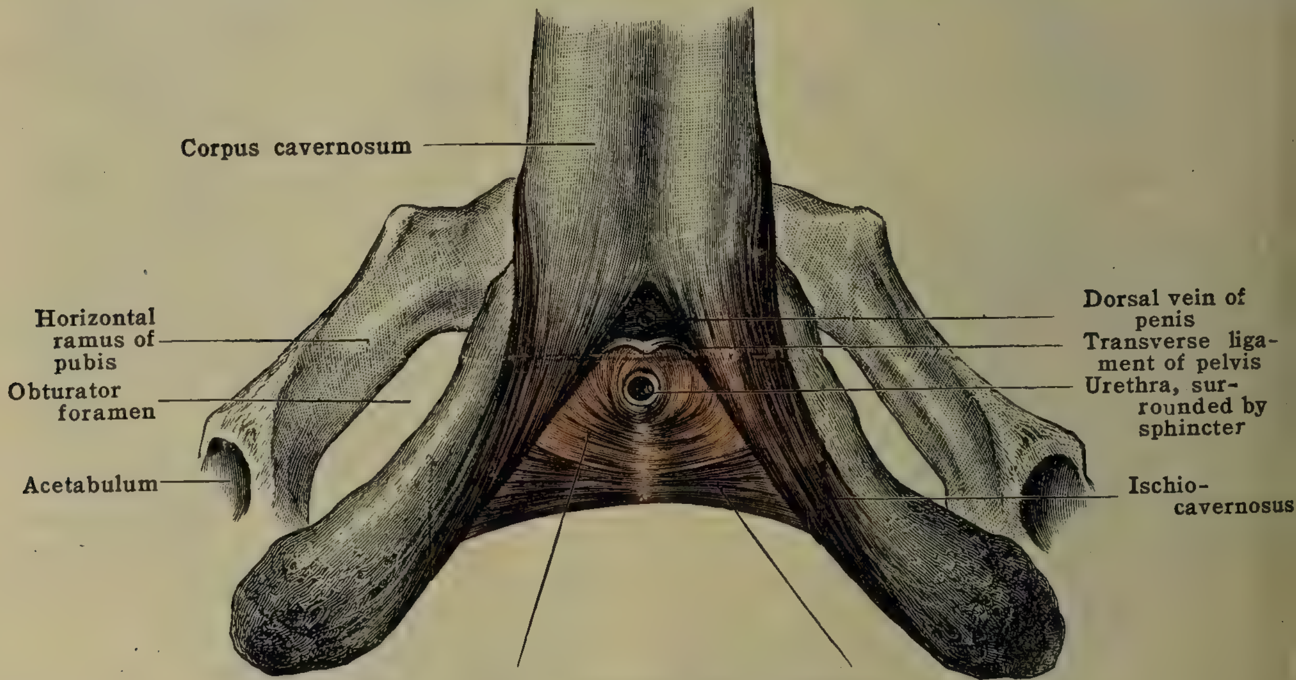


Fig. 467.—Muscles of the Urogenital Diaphragm (Male).

is covered by the deep layer of the urogenital trigone, into which the superficial layer is reflected about the anal margin of the muscle.

Variations.—The muscle is variable in structure and may be absent. It is more frequently absent in the female than in the male.

The **sphincter urogenitalis** differs in the male and female owing to the passage of the vagina through the perineum in the latter. In each sex it is convenient to consider the muscle as divided into two parts, a periurethral and an infraurethral (vaginal).

In the male (fig. 467) the periurethral part, the *m. sphincter urethrae membranaceæ* is composed of fiber-bundles which are circularly placed about the membraneous urethra. The more external fiber-bundles are attached to the crura of the penis near their junction, to the transverse ligament of the pubis and to the fasciae of the trigone. Some of them partially ensheath the lower part of the prostate, and others envelop the bulbourethral (Cowper's) glands. Some of the fiber-bundles take a longitudinal course along the urethra. Bundles of smooth muscle fibers are intermingled with the striated, and the fibrous framework of the musculature is marked by the large amount of elastic tissue which it contains. The infraurethral part, the *m. transverus urethræ* is closely associated with the urethral part. The fiber-bundles arise on each side from the inferior ramus of the pubis. They pass for the greater part beneath the urethra and interdigitate with those of the opposite side or are inserted into a median raphe. A few fiber-bundles may pass above instead of below the urethra. The transverse urethral muscle, first described by Guthrie (On the anatomy and diseases of the neck of the bladder, London, 1834) is inconstant. Its existence as a normal constituent of the male perineal musculature has been disputed by Delbet (Poirier and Charpy) and others.

In the *female* the periurethral part, *sphincter urethrae*, differs in no essential respects from the corresponding muscle in the male. Some of the fiber-bundles form a true sphincter about the urethra. The *infraurethral* part, on the other hand, seems to vary greatly in different individuals so that the descriptions given by different authors are somewhat contradictory. It is better developed in women who have not borne children than in those who have. It may be looked upon as composed of two portions, a *m. transversus vaginae* and an *m. constrictor vaginae*. The *transversus vaginæ* arises from the ischiopubic rami and is inserted into the lateral wall of

the vagina. Some of the fiber-bundles pass above and some below the vagina. This muscle corresponds with the transversus urethræ of the male but is, apparently, seldom fully developed. The *m. constrictor vaginæ*, on the other hand, seems to be more constant. It is composed of fiber-bundles which embrace the lateral wall of the vagina and are inserted above into the peri-urethral framework, below into the raphe between the two deep transverse perineal muscles. Some of the fiber-bundles are attached to the vaginal wall. Some interdigitate with the sphincter urethræ, others with the deep transverse perineal muscle and with the transversus vaginæ.

Nerve-supply.—By a branch from the perineal nerve.

Action.—To compress or close the urethra and in the male to compress the prostate and Cowper's glands, in the female to compress the vagina and Bartholin's glands.

Relations.—On the pelvic side it is separated from the levator ani by the deep layer of the uorgenital diaphragm, and on the perineal side it is separated from the superficial muscles by the superficial layer of the fascia. Toward the anus it is closely associated with the deep transverse perineal muscle. Venous plexuses are well developed near the sphincter urethræ in both sexes, but especially in the female.

Variations.—It has already been pointed out that there is considerable variation in the muscles composing urogenital sphincter. Occasionally a rudimentary *ischiopubicus* is found arising from the ischiopubic ramus and terminating in a tendon which unites with that of the opposite side beneath the dorsal vein of the penis (clitoris). The tendon may be present as the transverse ligament of the pelvis when the muscle itself is absent. It represents the compressor of the dorsal vein found in lower mammals.

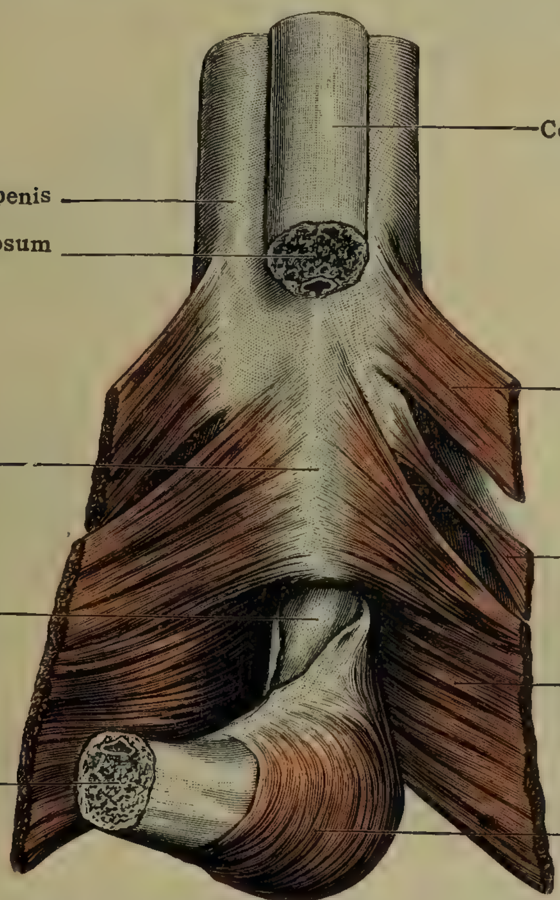


FIG. 468.—BULBOCAVERNOSUS IN THE MALE.

The two halves have been reflected from the median raphé, and the bulb turned downward after division of the corpus spongiosum. (The ischiobulbosus is not present on the right side.)

C. EXTERNAL GENITAL MUSCLES

The **bulbocavernosus** (figs. 456, 468) in the male ensheaths the bulb. The fiber-bundles *arise* from the dense tissue covering the corpus cavernosum at the root of the penis and from the subpubic connective tissue dorsal to the bulbar part of the urethra and are *inserted* into its median raphé on the ventral side of the bulb and into the central tendon of the perineum. Several parts may be more or less clearly distinguished.

1. *The constrictor radicis penis arises* usually from the lateral surface of the corpus cavernosum penis at the base of the penis, but may arise from the under surface or from the dorsal surface, or even from the suspensory ligament of the penis. The fiber-bundles pass obliquely backward and medialward and are *inserted* into the median raphé on the perineal surface of the bulb.

2. The *compressor bulbi proprius arises* (1) from a strong fibrous aponeurosis situated between the corpus spongiosum and the united crura of the penis and firmly adherent to the former, and (2) from the superficial layer of the trigone. The fiber-bundles ensheath the bulb and are *inserted* into the posterior part of the median raphé and into the central tendon of the perineum. To a greater or less extent, depending on the development of the two muscles, the compressor covers the more posterior part of the constrictor.

3. The *compressor hemispherium bulbi arises* from a tendon common to the muscles of the two sides on the dorsum of the bulbous part of the urethra near the membranous part. The fiber-bundles embrace the hemisphere of the bulb and are inserted into the median raphé. This

muscle is covered by the preceding. It not only compresses the bulb, but also is a sphincter of the urethra.

4. The *ischiobulbosus* is placed by Holl in this group. It *arises* from the pelvic surface of the tuberosity and of the inferior ramus of the ischium and when well developed is inserted into he median raphé, superficial to the compressor bulbi proprius or the constrictor radicis prourfas. Frequently, however, it does not extend over the bulb but is *inserted* into the inferior surface of the corpus cavernosum. It is more frequently absent than present. (See fig. 468.)

Nerve-supply.—The perineal division of the pudendal nerve sends several branches to the bulbocavernosus.

Action.—It compresses the bulb and at the same time the bulbous portion of the urethra. The turgescence of the penis is thus increased and urine or semen is expelled from this portion of the urethra.

Relations.—It lies beneath the skin and subcutaneous tissue.

Variations.—The muscle is variable in structure as is indicated by the different description given by different authors. The *compressor venæ dorsalis* described by Houston is composed of a few fasciculi which arise from the sheath of the corpus cavernosum urethræ, and from the median raphé and are united to those of the opposite side by a tendon which passes over the dorsal vein.

The *bulbocavernosus* (*sphincter vaginæ*) (figs. 457, 469) in the female arises (1) from fibrous tissue dorsal to the clitoris, (2) from the tunica fibrosa of the corpus cavernosum and from the superficial layer of the urogenital diaphragm in the angle between the crura of the clitoris. The fiber-bundles form a band of tissue about two centimeters wide at the side of the vagina and are inserted into the posterior part of the superficial (inferior) layer of the trigonum and into the central tendon of the perineum where some of the fiber-bundles interdigitate with those of other muscles attached here. The fiber-bundles arising from the back of the clitoris correspond with

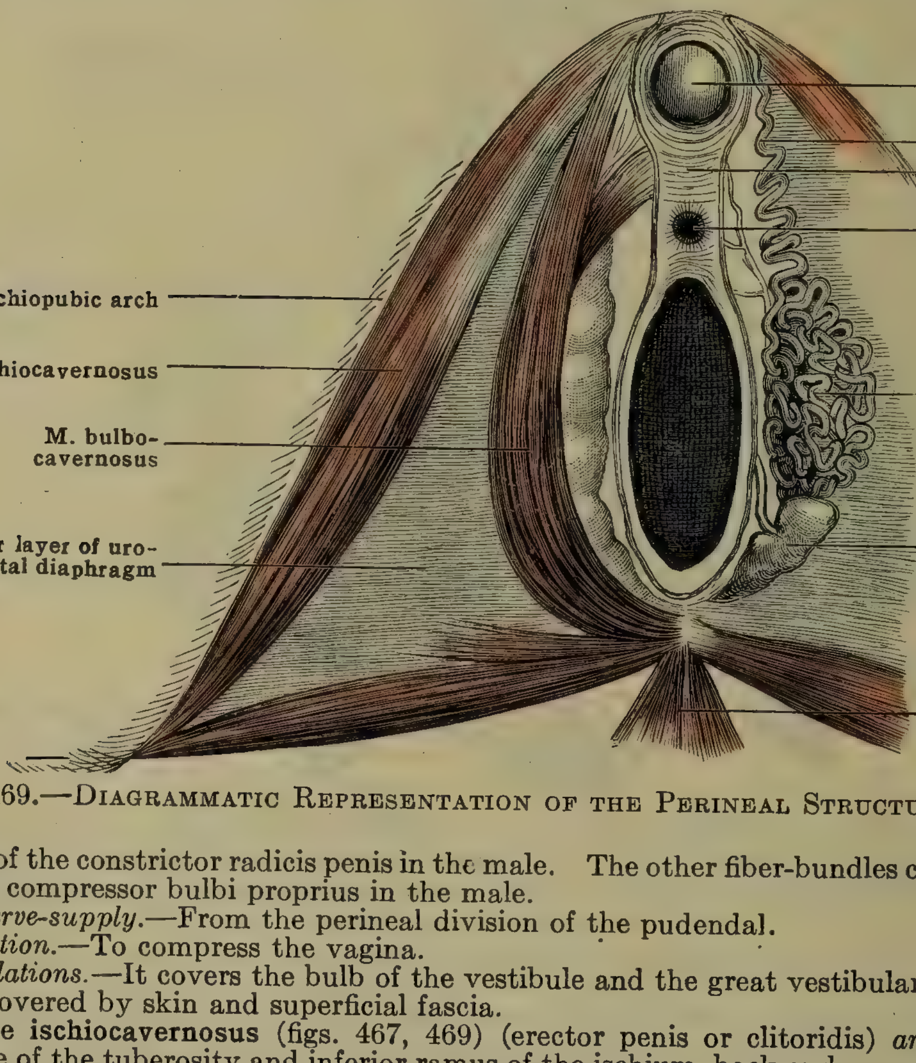


Fig. 469.—Diagrammatic Representation of the Perineal Structures in the Female.

those of the constrictor radicis penis in the male. The other fiber-bundles correspond with those of the compressor bulbi proprius in the male.

Nerve-supply.—From the perineal division of the pudendal.

Action.—To compress the vagina.

Relations.—It covers the bulb of the vestibule and the great vestibular gland (Bartholin's). It is covered by skin and superficial fascia.

The **ischiocavernosus** (figs. 467, 469) (erector penis or clitoridis) *arises* from the pelvic surface of the tuberosity and inferior ramus of the ischium, back and on each side of the attachment of the crus. The fiber-bundles form a thin sheet which is spread over the crus into the medial and inferior surfaces of which it is *inserted* near the symphysis pubis. It is better developed in the male than in the female.

Nerve-supply.—By branches of the perineal nerve.

Action.—By constricting the crus to maintain turgescence of the penis or clitoris.

Relations.—Superficially it is covered by skin and subcutaneous tissue. Laterally it lies next the ischiopubic ramus. Medially it bounds a space lying between the crus and the bulb and filled with fat.

Variations.—The muscle in the male is much larger than in the female. Some of the more anterior fiber-bundles may extend to the dorsal surface of the penis (clitoris) and form a *pubocavernosus* or levator penis muscle.

The **transversus perinei superficialis** (figs. 456, 457, 469) arises from the inferior ischial ramus. The fiber-bundles extend in front of the rectum superficial to the deep transverse muscle and are inserted into the central tendon of the perineum. Some cross to the opposite side. Some of the fiber-bundles are continuous with those of the external sphincter or of the puborectalis of the opposite side.

Action.—It acts with the deep transverse muscle in fixing the central part of the perineum.
Nerve-supply.—By a branch from the perineal division of the pudendal.
Variations.—It is frequently absent or poorly developed.

VI. MUSCULATURE OF THE LOWER LIMB

The lower limbs are used chiefly for the support and propulsion of the body. Variety of movement is subordinated to strength and precision. In contrast with the upper limbs, which perform a vast variety of complex movements under conscious control, the lower limbs are called upon to perform chiefly the relatively simple movements which are used in walking or running, without our paying much attention to them.

The contrast between the two extremities is best marked in the girdles, the relations of which to the trunk have already been described, p. 510. The shoulder-girdle is constantly called upon for movements in various directions which increase the freedom of action of the whole extremity. The sternoclavicular and acromioclavicular joints are movable so that the scapula can be carried in various directions over the thorax. The bones of the hip-girdle on each side, on the other hand, are ossified into a single hip-bone (os innominatum). The two hip-bones are almost immovably united to one another in front by the symphysis pubis and behind each is united to the sacrum by a joint which, although a diarthrosis, likewise permits but slight movement. The sacrum in turn is composed of vertebræ firmly ossified together. The pelvis, composed of the two hip-bones and the sacrum forms a strong support for the trunk. Such movements as it makes are due chiefly to the lumbosacral joint and to the joints between the lumbar vertebræ. These joints permit the pelvis, in a limited manner, to be flexed and extended, abducted, adducted, and rotated. Flexion is produced by the rectus and the oblique muscles of the abdomen (fig. 451) and by the psoas muscles (fig. 470), extension is produced by the quadratus lumborum (fig. 470) and the sacrospinalis (fig. 446). Rotation and abduction are produced when these muscles act on one side only. The weight of the body in the sitting posture is transmitted through the sacrum and hip-bones to the ischial tuberosities. In this position the pelvis is flexed. The weight of the body in the standing position is transmitted to the femora through the acetabulum on each side. In this position the pelvis is extended. In walking the pelvis is rotated forward toward the limb that is being advanced.

The hip-joint is a true ball-and-socket joint, but freedom of movement is greatly limited by the powerful musculature which surrounds it, as well as by the ligaments. Movements here, however, are freer than at the shoulder-joint, if the shoulder girdle be left out of consideration. At the hip-joint the most frequent and most free movements are those of flexion and extension, the main movements in walking or running; but abduction, adduction, circumduction, and rotation are of the greatest importance in balancing the body.

At the knee-joint the main movements are also those of flexion and extension and the musculature is so arranged that the chief flexors of the knee which lie at the back of the thigh are extensors of the hip (fig. 472) while the extensor musculature of the knee which lies at the front of the thigh flexes the hip (fig. 475). Flexion of the hip, however, through the action of gravity on the foot passively brings about flexion at the knee, while flexion of the knee likewise passively brings about flexion of the hip, since the flexed knee tends to swing forward. These passive movements, due to gravity, are of importance in walking. The gastrocnemius (fig. 477), the most powerful extensor of the ankle-joint, is also a powerful flexor of the knee-joint. At the knee-joint, in addition to flexion and extension, some rotation is possible, best marked when the knee is flexed. This rotation is of value in walking over rough ground in that it helps to accommodate the limb to the ground. It is also of value in sitting on a flat surface. While there is thus some rotation at the knee-joint not found at the elbow-joint, the free movement of the radius about the ulna which accompanies pronation and supination in the forearm, is unrepresented in the leg where the fibula is firmly united to the tibia at each end.

The joint between the bones of the leg and the tarsus permits merely of flexion and extension in contrast to the wrist-joint which also permits of adduction and abduction. Flexion and extension are also more limited at the ankle than at the wrist. On the other hand, the movements of inversion and eversion which take

place in the intertarsal joints are not needed in the wrist because of the pronation and supination of the forearm. Inversion and eversion of the foot are of value in walking on rough ground.

The movements of the toes resemble those of the fingers except that they are, in most individuals, far more restricted. The greatest restriction is seen at the joint between the metatarsal of the big toe and the tarsus, as compared with that between the metacarpal of the thumb and the carpus.

The musculature of the inferior extremity, like that of the superior, can be divided according to its development and innervation into two great subdivisions which correspond with the musculature on the dorsal and ventral sides of the shark's fin. The dorsal musculature is supplied by nerve branches which arise from the back of the lumbosacral plexus (femoral, gluteal, and peroneal nerves), the ventral musculature by branches which arise from the front of the plexus (obturator and tibial nerves). Owing, however, to the rotation which the limb makes during embryonic development, the musculature which primitively lies on the dorsal side of the limb-bud comes to lie on the front and lateral side of the extremity and the musculature of the ventral side of the limb-bud comes to lie on the back and medial side of the extremity or in the sole of the foot. The side of the limb which primitively was toward the head becomes the medial side of the limb, and that which faced caudalward comes to lie laterally. While this makes the primitive relations of the musculature of the limb at first somewhat confusing, it is possible to approximate these primitive conditions by abducting the limb and rotating it so that the sole of the foot faces forward. An understanding of the innervation of the limb is thus greatly facilitated.

In the region of the hip the musculature of the **dorsal division** is that which arises from the spinal column and ilium and is inserted into the upper part of the femur and into the fascia of the thigh. It includes the chief flexor of the thigh, the *iliopsoas* (fig. 470), and the most powerful extensor, the *gluteus maximus* (fig. 477), as well as several important rotators and abductors, *gluteus medius* and *minimus*, *piriformis* and *tensor fasciæ latæ* (fig. 472). The iliopsoas is innervated by nerves from the back of the lumbar, the other muscles by nerves from the back of the sacral plexus. The musculature of the **ventral division** arises from the pubis and ischium, is inserted into the femur near the great trochanter and serves to adduct the thigh and rotate it lateralward, *obturator internus*, *gemelli*, *quadratus femoris* (fig. 472) and *obturator externus* (fig. 470). The obturator externus is innervated by the obturator nerve from the front of the lumbar plexus, the other muscles by special branches from the front of the sacral plexus.

In the thigh there are three groups of muscles, an **anterior** or **extensor group** (fig. 475), a **medial** or **adductor group** (fig. 475), and a **posterior** or **flexor group** (fig. 472). The anterior group belongs to the primitive dorsal division, the other two groups to the ventral division.

In the leg there are also three groups of muscles, an **anterior**, a **lateral** and a **posterior.** The two former belong to the dorsal division and are innervated by the peroneal nerve. The last belongs to the ventral division and is innervated by the tibial nerve.

In the foot one muscle on the dorsum represents the primitive dorsal division, the *extensor digitorum brevis* (fig. 486), supplied by a branch from the peroneal nerve. On the other hand the primitive ventral division is well represented in the sole of the foot, not only by the muscles associated with the long flexor tendons, quadratus plantæ, lumbricales (fig. 488), but also by the short flexor of the toes (fig. 488), by the special musculature of the big and little toes (fig. 489) and by the interosseous muscles (fig. 490).

The **muscle-fasciæ** of the inferior extremity are well developed. The *fascia lata*, which encloses the musculature of the back of the hip and the musculature of the thigh, is especially strong on the lateral side where it includes the longitudinal bundles of fibers which compose the iliotibial band [tractus iliotibialis]. From the fascia lata strong intermuscular septa extend on each side of the quadriceps group of muscles to the femur. Medially beneath the sartorius muscle (fig. 474), septa help to bound Hunter's canal in which lies the femoral artery on its way to the popliteal space behind the knee. In the leg there is likewise a strong cylindrical fascial sheath which encloses the musculature and sends septa on each side of the peroneal group to the fibula. A transverse septum also separates the deep from the superficial muscles of the calf. The fascia of the leg is especially well developed near the ankle where it helps to hold in place the tendons which pass from the muscles of the leg into the foot. Muscle-fasciæ are well developed both on the dorsum and in the sole of the foot.

A. MUSCULATURE OF THE HIP

1. Iliofemoral Musculature

The iliac blade divides these muscles into an **anterior group** (iliopsoas), supplied by nerves from the lumbar plexus, and a **posterior group** (the gluteal muscles, piriformis, and tensor fasciæ latæ), supplied by nerves from the sacral plexus.

In most of the limbed vertebrates these two groups of muscles are represented, but they present marked specific variations in the different forms. Primitively, the iliacus group lies on the proximal portion of the lateral surface of the ilium.

(a) Anterior Group

(Figs. 470, 478)

The fan-shaped **iliacus** muscle arises from the iliac fossa. The fusiform **psoas major** muscle arises from the sides of the last thoracic and of the lumbar vertebræ and extends along the medial margin of the iliacus muscle. The two muscles are inserted by a common tendon into the lesser trochanter of the femur. Together they constitute the **iliopsoas** muscle. The small, flat, fusiform **psoas minor** lies on the medial surface of the psoas major and extends from the twelfth thoracic vertebra to the iliopectineal eminence. The iliopsoas flexes the thigh at the hip and the pelvis on the trunk. The psoas minor aids in flexing the pelvis.

The iliopsoas muscle arises in the human embryo from a blastema which at first surrounds the femoral nerve and later extends proximally over the ilium (iliacus) and toward the lumbar vertebræ (psoas). The iliacus is phylogenetically the more primitive. In the shoulder it is probably represented by the infraspinatus. The psoas minor is much better developed in many of the lower mammals than in man.

FASCIÆ

The **fasciæ** and the relations of these muscles are shown in figs. 448 and 471.

The iliac and psoas muscles are covered by a dense fascia which is but slightly adherent to the underlying muscles. It is best developed in the pelvic region, where it extends from the iliac crest and iliolumbar ligament to the iliac portion of the linea arcuata and is called the **iliac fascia.** Superiorly it is continued over the psoas muscle as the **psoas fascia** and is attached medially to the sacrum and the lumbar region of the spinal column. Laterally it unites with the lumbar fascia and superiorly it is strengthened to form the medial lumbocostal arch (fig. 455). Inferiorly the **iliopectinal fascia** extends over the iliopsoas muscle to its femoral insertion. It is firmly united on each side of the muscle to the capsule of the hip-joint and to the femur. As it passes beneath the inguinal ligament it is united to this by tendinous processes. Beyond the ligament it is less dense than in the pelvic region.

A **psoas abscess** descending below the inguinal ligament usually does so on the lateral aspect of the femoral vessels; if the sheath gives way, or if the abscess follows the profunda artery, it will pass beneath the adductor longus and point toward the medial side of the thigh. (Taylor.) If it simulate a femoral hernia, examination of the back and the fact that the swelling is below the fossa ovalis will prevent mistakes.

MUSCLES

The psoas major (figs. 470, 475).—*Origin.*—(1) By a series of thick fasciculi from the intervertebral disks between the twelfth thoracic and the fifth lumbar vertebra, from the adjacent parts of the bodies of these vertebræ and from tendinous arches which bridge over the middle of the sides of the first four lumbar vertebræ; and (2) by a series of more slender fasciculi from the lower borders and ventral surfaces of the transverse processes of the lumbar vertebræ.

Structure and insertion.—From these origins parallel fiber-bundles descend nearly vertically and give rise to a fusiform muscle which lies at the side of the vertebral bodies and extends along the border of the true pelvis toward its insertion. A tendon arises deep in the muscle near the last lumbar vertebra, and becomes free on its dorsolateral surface slightly above the inguinal (Poupart's) ligament. On the medial side the attachment of fiber-bundles continues to the insertion of the muscle into the small trochanter. The iliacus muscle is attached to the lateral side of the tendon from near the iliopectineal eminence downward.

Nerve-supply.—Delicate branches pass into the psoas muscle from the trunks which unite to form the femoral (anterior crural) nerve, i.e., from the fourth, third, second, and often the first lumbar nerves.

The iliacus (figs. 470, 475).—*Origin.*—(1) From the iliac crest, the iliolumbar ligament, and the greater part of the iliac fossa, the anterior sacroiliac ligaments, and often from the sacrum, and (2) from the ventral border of the ilium between the two anterior spines.

Structure and insertion.—From these areas of origin the fiber-bundles pass to be inserted—(1) in a penniform manner on the lateral surface of the tendon which emerges from the psoas above the inguinal (Poupart's) ligament, and (2) directly on the femur immediately distal to the small trochanter. The lateral portion of the muscle arises from the ventral border of the ilium

and is adherent to the direct tendon of the rectus femoris and the capsule of the hip-joint. It is sometimes more or less isolated (*m. iliacus minor, ilio-capsulo-trochantericus*, etc.).

Nerve-supply.—Nerve branches, often united in a plexiform manner, arise from the femoral anterior crural) nerve and pass across the surface of the iliacus muscle about midway between the crest of the ilium and the combined iliopsoas tendon. Special nerve branches are usually likewise distributed from the main trunk of the femoral nerve to the fleshy portion of the muscle which extends over the acetabulum and the head of the femur.

Relations.—The psoas major lies lateral to the lumbar vertebræ and in front of the quadratus lumborum and intertransverse muscles. The psoas minor passes downward across its ventral surface. Both psoas muscles are crossed by the crura of the diaphragm. The kidney with its adipose capsule lies lateral to them opposite the first two lumbar vertebræ. For the rest, their fascia is covered ventrolaterally by retrointestinal and retroperitoneal tissue in which the vena cava inferior runs in front of them on the right side, the inferior mesenteric vein in front of them on the left side, and the ureter, the spermatic or ovarian, and the renal and colic vessels on each side. The external iliac artery lies medial to the psoas major in the pelvis, and beyond the inguinal (Poupart's) ligament the femoral artery lies ventral to it. The lumbar plexus arises

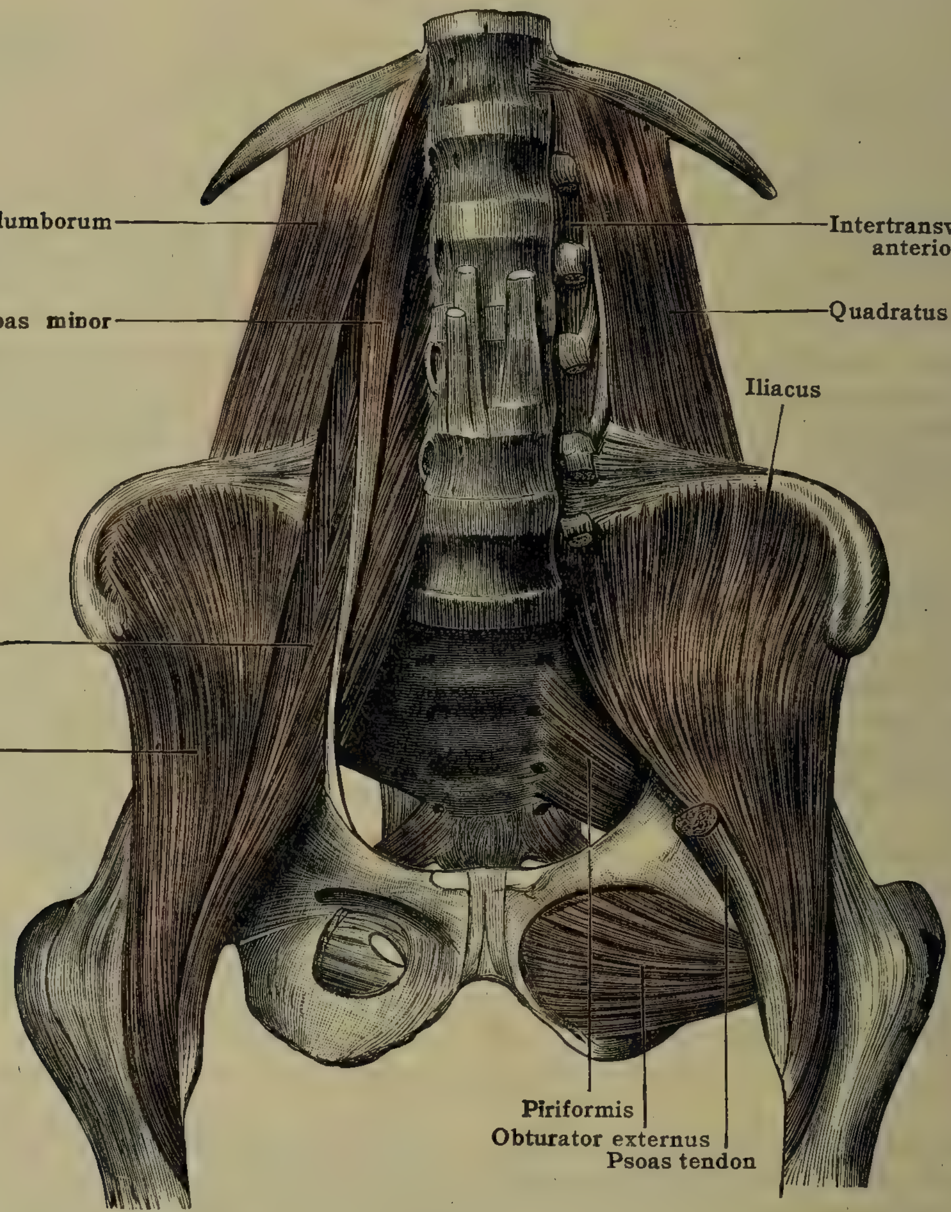


Fig. 470.—Psoas, Iliacus, and Quadratus Lumborum.

between its origins from the vertebral bodies and disks and those from the transverse processes. The nerves springing from the lumbar plexus take courses subject to much individual variation through the muscle on the way to their destinations. Fasciculi of the muscle may thus be separated by the femoral (anterior crural) nerve or other branches of the lumbar plexus.

The iliacus muscle in the region of the pelvis is covered by retroperitoneal fat. The psoas muscle crosses its medial margin and from between the two muscles the femoral nerve usually emerges to pass into the thigh above the iliacus. Beyond the inguinal ligament the iliacus lies in front of the capsule of the hip-joint and the straight tendon of the rectus femoris, and is crossed by the sartorius.

Action.—The iliopsoas is a powerful flexor of the thigh at the hip and a weak medial rotator and adductor. It also serves to flex and abduct the lumbar region of the spine.

Variations.—The psoas muscle may be separated from the iliacus as far as the femoral insertion. The part of the psoas arising from the distal lumbar vertebræ may form a distinct muscle. Slips may pass from the psoas major to the psoas minor. A separate lamina of the iliacus muscle may be attached to the iliac fascia. From the anterior inferior iliac spine a small muscle slip may run to the intertrochanteric line or the iliofemoral ligament. To this slip the term iliacus minor has been applied as well as to the larger fasciculus mentioned above.

The psoas minor (fig. 470).—*Origin.*—From the twelfth thoracic and first lumbar vertebræ and the intervening disk.

Structure and insertion.—The fiber-bundles pass to be attached as far as the level of the fifth lumbar vertebra to a flat tendon which appears about the midlumbar region and is inserted into the iliopectineal eminence. It is intimately united to the iliac fascia.

Nerve-supply.—The branch to the psoas minor arises usually from the first and second lumbar nerves, often in company with the genitofemoral (genitocrural).

Action.—To flex the pelvis.

Relations.—It is closely applied to the ventral surface of the psoas major.

Variations.—The muscle is inconstant in development and is frequently absent. Gruber has found it absent on both sides in 183 out of 450 bodies, on one side in 69.

Bursæ

B. iliopectinea.—A large bursa between the iliopsoas muscle, the iliopectineal eminence, and the capsule of the hip-joint. **B. iliaca subtendinea.**—A small bursa between the tendon of insertion of the iliopsoas and the lesser trochanter.

(*b*) Posterior Group

(Figs. 451, 471, 472, 477)

The muscles of this group arise from the ilium and and sacrum, cover the dorsolateral surface of the hip, and are inserted into the great trochanter and shaft of the femur and into the iliotibial band. They lie in three planes. In the **first layer** (fig. 451) are the flat, quadrilateral **tensor fasciæ latæ,** which arises from the front of the crest of the ilium and is inserted into the iliotibial band, and the thick, rhomboid **gluteus maximus,** which arises from the dorsal portion of the iliac ala, the lumbodorsal fascia, the sacrum and coccyx, and the sacrotuberous (great sacrosciatic) ligament, and is inserted in part into the iliotibial band and in part into the back of the upper part of the shaft of the femur. The **iliotibial** band (tract) is a flat tendon which descends, closely fused with the fascia lata, to the lateral side of the upper extremity of the tibia. In the **second layer** (fig. 472) are the flat, thick, triangular **gluteus medius** and the 'pear-shaped' **piriformis.** The former arises from the upper and back part of the outer surface of the ala of the ilium, the latter from the ventral surface of the sacrum and the posterior border of the great sciatic notch. Both are inserted into the top of the great trochanter. The **third layer** (fig. 473) is composed of the triangular **gluteus minimus,** which arises from the inferior ventral portion of the outer surface of the ala of the ilium, and is inserted into the front of the great trochanter of the femur.

The muscles of this group extend, flex, abduct, and rotate the thigh at the hip. The gluteus maximus and medius are in part extensors, the gluteus minimus and the tensor fasciæ latæ are flexors of the hip-joint. All the muscles serve to abduct, the gluteus maximus acting thus when the hip is flexed. When the thigh is extended the lower part of the gluteus maximus is an adductor. The gluteus maximus and posterior part of the gluteus medius and the piriformis act as lateral, the anterior part of the gluteus medius, the gluteus minimus, and the tensor fasciæ latæ as medial, rotators. The gluteus maximus and the tensor fasciæ latæ through the iliotibial band keep the extended knee-joint firm. The gluteus maximus is supplied by the inferior gluteal nerve, the piriformis by special nerves, and the other muscles of the group by the superior gluteal nerve. All these nerves arise from the upper part of the back of the sacral plexus.

The gluteus medius, gluteus minimus, and piriformis form a group of muscles which in the embryo have a common origin and are more or less fused in the adult. The gluteus maximus arises in two distinct, though associated, portions, and the tensor fasciæ latæ as another distinct portion. The two muscles, however, are probably to be considered as parts of a primitive caudo-pelvo-tibial musculature, while the gluteus medius group is represented in the lower forms by an iliofemoral musculature. The former group is often closely associated with the extensor muscles of the thigh in the lower forms (frog), and in some of the lower mammals extends its insertion to the plantar fascia (ornithorhynchus). In the arm this group is perhaps represented by the deltoid, the latissimus dorsi, and the teres major, while the gluteus medius group is represented by the subscapularis.

FASCIÆ

The **tela subcutanea** of the gluteal region is very thick, contains much fat, and is often divisible into two layers, of which the deeper is closely adherent to the fascia lata and through this to the gluteus maximus. Over the great trochanter a subcutaneous bursa is usually found (**bursa trochanterica subcutanea**).

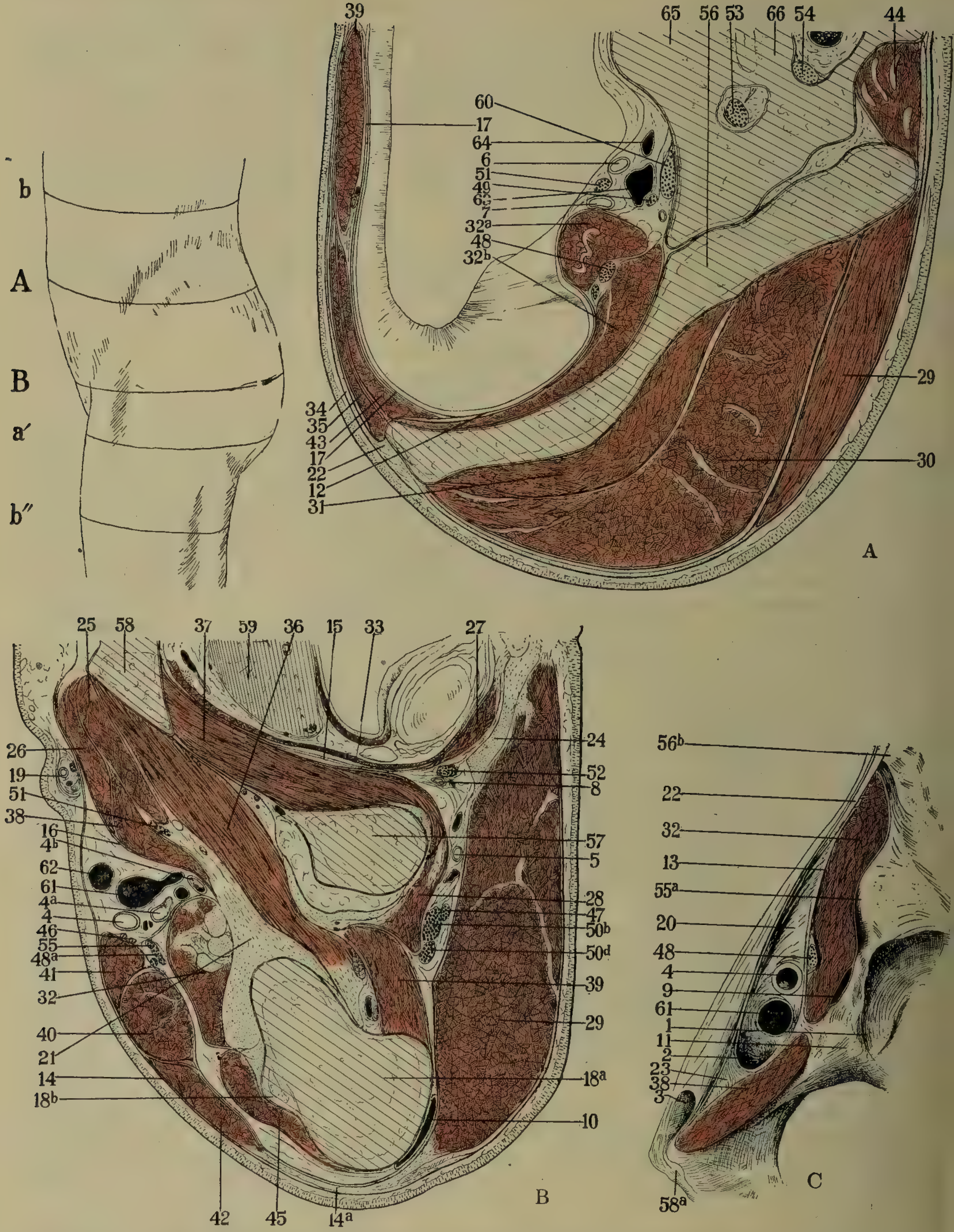


FIG. 471, A and B.—TRANSVERSE SECTIONS THROUGH THE LEFT SIDE OF THE PELVIS IN THE REGIONS INDICATED IN THE DIAGRAM.

C. Section through the muscles of the left inguinal region parallel to the inguinal (Poupart's) ligament (after Spalteholz). *b* in the diagram indicates Section *B*, fig. 448; *a′* and *b′* indicate sections *A* and *B*, fig. 474. (For legends, see p. 533.)

1. Acetabulum. 2. Annulus femoralis. 3. Annulus inguinalis subcutaneus (ext. abdominal ring). 4. Arteria femoralis. 4*a*. A. profunda femoris. 4*b*. A. circumflexa femoris medialis. 5. A. glutea inferior. 6. A. hypogastrica (internal iliac). 7. A. iliaca externa. 8. A. pudena interna (pudic). 9. Bursa iliopectinea. 10. B. trochanterica m. glutæi maximi. 11. Eminentia iliopectinea. 12. Fascia iliaca. 13. F. iliopectinea. 14. F. lata—*a*, iliotibial band. 15. F. obturatoria. 16. F. pectinea. 17. F. transversalis. 18. Femur—*a*, trochanter major; *b*, trochanter minor. 19. Funiculus spermaticus (spermatic cord). 20.—Lacuna vasorum. 21. Ligamentum iliofemorale. 22. L. inguinale (Poupart's ligament). 23. L. lacunare (Gimbernat's). 24. L. sacrotuberosum (great

Muscle-fascia.—The muscles of the hip and thigh are enclosed in a dense fascia, the **fascia lata** (figs. 451, 471). This arises from the tuber ischii, the sacrotuberous (great sacrosciatic) ligament, the back of the sacrum and the coccyx, the crest of the ilium, the inguinal (Poupart's) ligament, and the pubic and ischial rami, and extends to the tibia and the fascia covering the muscles of the leg. It is composed mainly of bundles of fibers running transversely to the long axis of the limb. In the region of the gluteal groove it is strengthened by a transverse fibrous band which arises from the tuberosity of the ischium and arches upward over the lower border of the gluteus maximus muscle.

In the region of the hip the fascia lata invests both surfaces of the tensor fasciæ latæ and the gluteus maximus, and is closely bound to these muscles through intramuscular septa. Between these two muscles the fascia covers the fascia of the gluteus medius, to which it is adherent near the iliac crest, but from which it is separated by loose tissue more distally. Anteriorly the fascia is fused with the iliopectineal fascia and the inguinal (Poupart's) ligament.

More distally the tendons of the tensor fasciæ latæ and of the superficial portion of the gluteus maximus become incorporated with the deep surface of the fascia lata and give rise to the **iliotibial band** [tractus iliotibialis] (fig. 475).

The gluteus medius and minimus muscles are invested by adherent fascial sheets which, ventrally between the two muscles, may be combined into an intermuscular septum or be so slightly developed that the muscles are fused. The fascial sheet covering the gluteus medius toward the iliac crest is fused with the deep surface of the fascia lata. This fusion results in the formation of septa between the gluteus medius and the gluteus maximus and tensor fasciæ latæ.

The piriformis in the pelvic cavity is covered on the anterior surface by a special slightly developed fascia. This fascia also covers the pelvic surface of the sacral plexus. Outside the pelvis the piriformis is covered by an adherent membrane which usually is separated by loose tissue from the surrounding structures.

MUSCLES

I. First Layer

The tensor fasciæ latæ (figs. 451, 475).—*Origin.*—(1) By a tendinous band from the external lip of the iliac crest, and the upper part of the notch between the anterior superior and anterior inferior spines of the ilium, and (2) from the septum between it and the gluteus medius.

Structure and insertion.—The nearly parallel fiber-bundles pass distally and laterally and are united to tendon fasciculi which become incorporated with the iliotibial band [tractus iliotibialis] about one-third of the way down the thigh.

Nerve-supply.—The superior gluteal nerve sends a branch through the ventral margin of the gluteus minimus to terminate in the middle third of the deep surface of the tensor fasciæ latæ near its dorsal border.

Action.—To rotate medially, flex, and abduct the thigh, and to make tense the fascia lata. It rotates the tibia lateralward at the knee-joint after medial rotation.

Relations.—It lies over the gluteus medius, the proximal part of the rectus femoris, and the vastus lateralis.

Variations.—It may be divided into two parts, one rising from the anterior superior spine, the other from the iliac crest. Accessory slips may arise from the inguinal ligament, the crest of the ilium, or the fascia over the lower part of the abdominal wall. Union of the muscle with the gluteus maximus has been observed, thus making a muscle much resembling the deltoid of the shoulder. By some the fascia lata between the tensor and the gluteus maximus is considered an atrophied part of a deltoid of the hip.

The gluteus maximus (or superficialis NK) (figs. 451, 477).—*Origin.*—(1) From the dorsal fifth of the outer lip of the iliac crest, the outer surface of the ilium dorsal to the posterior gluteal line, the lumbodorsal fascia between the posterior superior spine of the ilium, and the side of the sacrum, and (2) from the lateral portions of the fourth and fifth sacral and the coccygeal vertebræ and from the back of the sacrotuberous (great sacrosciatic) ligament.

Insertion.—Into (1) the iliotibial band; (2) the gluteal tuberosity of the femur and the adjacent part of the tendinous origin of the vastus lateralis (fig. 472).

Structure.—The large fiber-bundles of which the muscle is composed take a somewhat parallel course from origin to insertion. From the areas of origin and the enveloping fascia fibrous bands extend into the muscle. The belly is divisible into two portions, a superficial and a deep. The division may be much more clearly recognized in the embryo than in the adult. The superficial portion is the larger, and includes all of that part of the muscle which springs from the ilium and the more superficial portion of that arising from the sacrum and the upper

---

sciatic). 25. Musculus adductor brevis. 26. M. adductor longus. 27. M. coccygeus. 28. M. gemellus inferior. 29. M. gluteus maximus. 30. M. gluteus medius. 31. M. gluteus minimus. 32. M. iliopsoas—*a*, psoas; *b*. iliacus. 33. M. levator ani. 34. M. obliquus abdominis externus, aponeurosis. 35. M. obliquus abdominis internus. 36. M. obturator externus. 37. M. obturator internus. 38. M. pectineus. 39. M. quadratus femoris. 40. M. rectus femoris. 41. M. sartorius. 42. M. tensor fasciæ latæ. 43. M. transversus abdominis. 44. M. transversospinales (multifidus). 45. M. vastus lateralis. 46. N. cutaneus femoris anterior (middle cutaneous). 47. N. cutaneous femoris posterior (small sciatic). 48. N. femoralis (anterior crural). 49. N. gluteus superior. 50. N. ischiadicus (great sciatic)—*a*, peronæus communis (external popliteal); *b*, tibialis (internal popliteal). 51. N. obturatorius. 52. N. pudendus. 53. N. sacralis I. 54. N. sacralis II. 55. N. saphenus. 56. Os ilium—*a*, spina anterior superior; *b*, spina anterior inferior. 57. Os ischium. 58. Os pubis—*a*, spina (tubercle). 59. Prostata. 60. Truncus lumbosacralis. 61. Vena femoralis. 62. V. saphena magna. 63. V. iliaca externa. 64. V. hypogastrica (internal iliac). 65. Vertebra sacralis I. 66. Vertebra sacralis II.

part of the coccyx. The deep portion includes that part of the muscle attached to the side of the sacrum and the coccyx, and to the sacrotuberous ligament. The superficial portion and some of the fiber-bundles of the deep portion terminate in the iliotibial band along a line extending from the great trochanter to the end of the upper third of the femur. The deep portion is inserted chiefly by a flat tendon into the gluteal tuberosity, and also directly into the adjacent portion of the origin of the vastus lateralis.

Nerve-supply.—Two branches (inferior gluteal) arising from the sacral plexus either separately or united, are usually given to the muscle. One of these curves anteriorly across the deep surface of the proximal superficial portion of the muscle in the middle third between the tendons

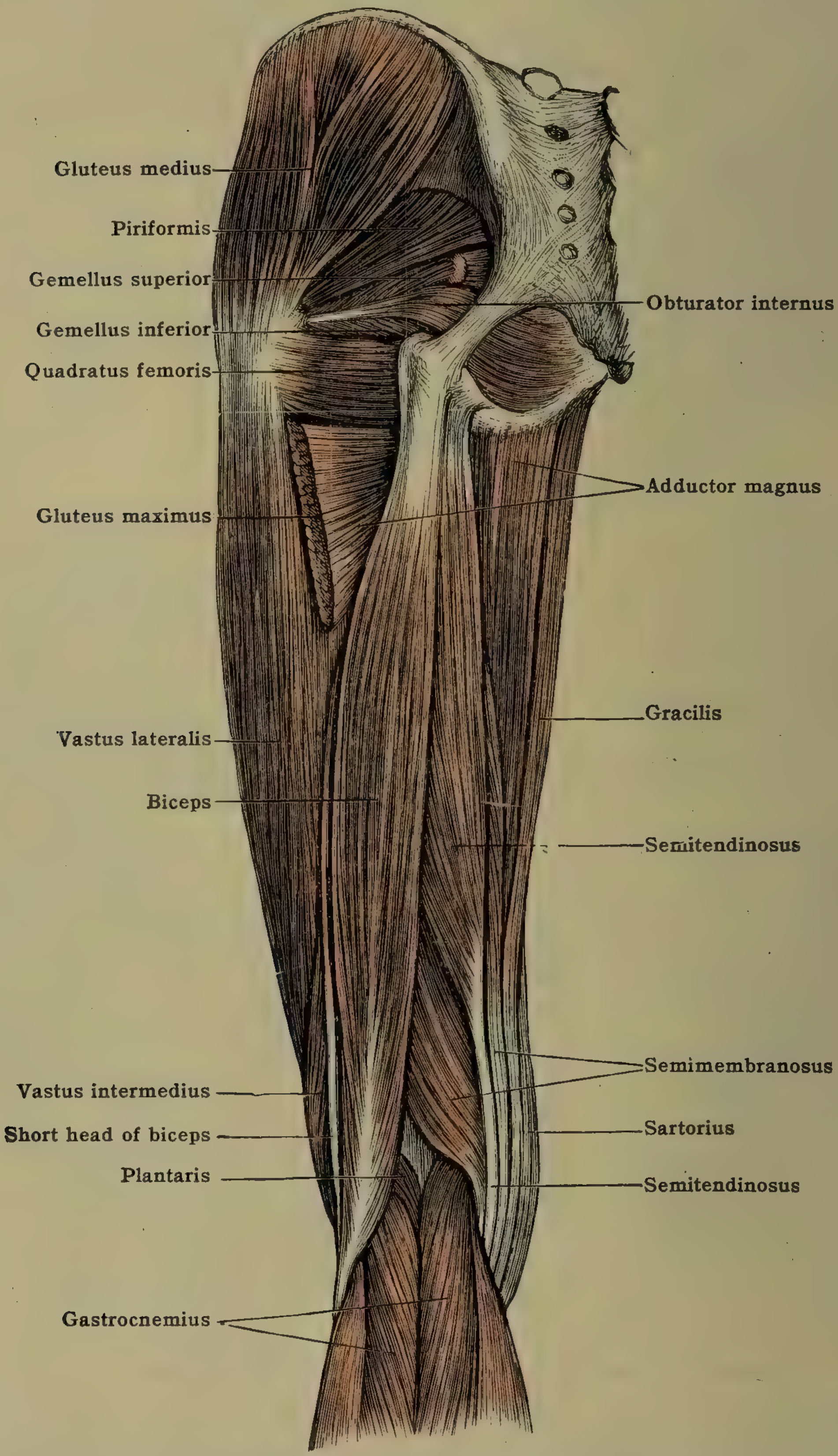


FIG. 472.—THE LATERAL ROTATORS AND THE HAMSTRING MUSCLES.

of origin and insertion, the other descends to enter the middle third of the distal deep portion of the muscle.

Action.—It is the most powerful extensor of the thigh. It also rotates the limb lateralward and to make tense the fascia lata, and through the iliotibial band to keep the extended knee-joint steady. When the thigh is extended the major part of the muscle is an adductor but the upper part is a weak abductor. The whole muscle is an abductor when the thigh is flexed. It is brought powerfully into play in climbing and in walking up hill.

Relations.—It is covered by the fatty superficial tissue of the buttock. It extends over the posterior portion of the ilium, the lateral surface of the sacrum and coccyx, the sacrotuberous

ligament, and the great trochanter. It covers the tuber of the ischium in the standing but not in the sitting position. Immediately beneath the muscle lie portions of the gluteus medius, piriformis, obturator internus, gemelli, quadratus femoris, obturator externus, and hamstring muscles, and of the gluteal vessels and nerves and the sciatic nerve.

Variations.—Few anomalies are recorded. The deep distal portion of the muscle may be more isolated than normal in the adult. A special coccygeofemoral muscle may run from the coccyx to the linea aspera, or from the sacrotuberous ligament to the fascia of the leg. A special fasciculus, the ischiofemoralis, may arise from the tuberosity of the ischium and become inserted into the lower border of the muscle near the great trochanter. The sacral, ischial, or coccygeal origin may be lacking, or the origin of the muscle may be from the sacrum only.

II. Second Layer

The muscles of this layer are the gluteus medius and the piriformis.

The gluteus medius (fig. 472).—*Origin.*—From (1) the ventral three-fourths of the iliac crest, and the outer surface of the ilium between the anterior and posterior gluteal lines and (2) the investing fascia.

Structure and insertion.—The fiber-bundles converge upon both surfaces of a broad tendon nearly to its insertion on an oblong impression on the posterosuperior angle and the external surface of the great trochanter. The more posterior fiber-bundles of the superficial stratum of the ventral portion of the muscle cross obliquely those of the deeper dorsal portion near the tendon of insertion. From the tendon an aponeurotic extension is usually continued into the tendon of the vastus lateralis.

Nerve-supply.—From the superior gluteal nerve a branch passes to the dorsal portion of the muscle and one or more twigs of the branch to the tensor fasciæ latæ enter the ventral portion of the muscle. The branches enter the middle third of the muscle between its tendons of origin and insertion. The nerve-fibers arise usually from the fourth and fifth lumbar and first sacral nerves. The branch to the dorsal portion of the muscle has a lower spinal origin than those to the ventral portion.

Action.—To abduct the thigh. The anterior portion of the muscle is a flexor and a medial rotator, the posterior a lateral rotator and an extensor. When the muscle acts as a whole, it is a medial rotator.

Relations.—Upon the muscle lie the tensor fasciæ latæ and gluteus maximus muscles and the fascia lata; beneath it lie the gluteus minimus muscle, the superior gluteal nerve and vessels, and the great trochanter.

Variations.—It may be divided into two distinct portions, or it may be fused with the piriformis or the gluteus minimus or both. A special fasciculus may extend to the superior portion of the great trochanter.

The piriformis (fig. 472).—*Origin.*—From (1) the lateral part of the ventral surface of the second, third, and fourth sacral vertebræ; (2) the posterior border of the great sciatic notch; and (3) the deep surface of the sacro-tuberous (great sacrosciatic) ligament near the sacrum.

Structure and insertion.—The fiber-bundles converge upon a tendon which is inserted upon the anterior and inner portion of the upper border of the great trochanter. The insertion of fiber-bundles continues nearly to the great trochanter. An accessory slip of insertion may pass to the gluteus minimus.

Nerve-supply.—From a nerve which arises either directly from the first or second sacral nerve or from a loop between them. The nerve enters the deep surface of the muscle in its middle third. There may be two or more nerves.

Action.—It is an extensor, abductor, and lateral rotator of the thigh. It causes medial rotation when the hip is flexed.

Relations.—Its ventral surface faces the sacral plexus, the rectum, and the hip-joint. It is covered dorsally by the gluteus maximus. It lies between the gluteus medius and the superior gemellus. Between the piriformis and the superior gemellus the sciatic nerve usually passes into the thigh. The superior gluteal nerve and vessels pass dorsally above its superior margin; the inferior nerve and vessels beneath its inferior margin.

Variations.—It is rarely absent. The origin may extend to the first sacral or to the fifth sacral vertebra and the coccyx. It may be fused with the gluteus medius or minimus or more rarely with the superior gemellus. Its tendon of insertion may be fused with that of the gluteus medius or the obturator internus. In about 20 per cent. of bodies it is divided partly or completely into two portions, between which the sciatic nerve or its peroneal (external popliteal) division usually passes. Rarely the tibial instead of the peroneal portion may pass between the two fasciculi, or the muscle may be divided into three or more fasciculi, between which the branches of the sciatic nerve pass.

III. Third Layer

The gluteus minimus (or profundus NK) (fig. 473).—*Origin.*—From the outer surface of the ilium between the anterior and inferior gluteal lines; (2) from the septum between it and the gluteus medius near the anterior superior iliac spine; and (3) from the capsule of the hip-joint.

Structure and insertion.—The fiber-bundles converge upon a tendon which appears on the middle of the ventral border and gradually spreads over the lateral surface. The muscle is thickest in front, where it is usually bound by an intermuscular septum to the gluteus medius. The tendon is inserted into the ventral surface of the great trochanter of the femur.

Nerve-supply.—From twigs of the branch of the superior gluteal nerve which goes to the tensor fasciæ latæ. These twigs enter the middle third of the muscle as the tensor branch passes across it.

Action.—To abduct the thigh and rotate it medialward. The anterior part of the muscle is a flexor, the posterior an extensor.

Relations.—It is covered by the gluteus medius and piriformis muscles. Beneath it lie the inferior part of the iliac ala, the hip-joint (to the capsular ligament of which it is bound), and the direct tendon of the rectus femoris muscle.

Variations.—It may be fused with the gluteus medius or the piriformis. It may send a slip to the fascia lata or the vastus lateralis. It may be divided into two distinct divisions, an anterior and a posterior. Very frequently from the anterior margin of the muscle a special fasciculus is more or less isolated (the **scansorius, invertor femoris, small anterior gluteal, etc.**). The **accessorius of the gluteus minimus** is a small muscle fasciculus which may lie under cover of the gluteus minimus and extend to be inserted into the capsule of the hip-joint.

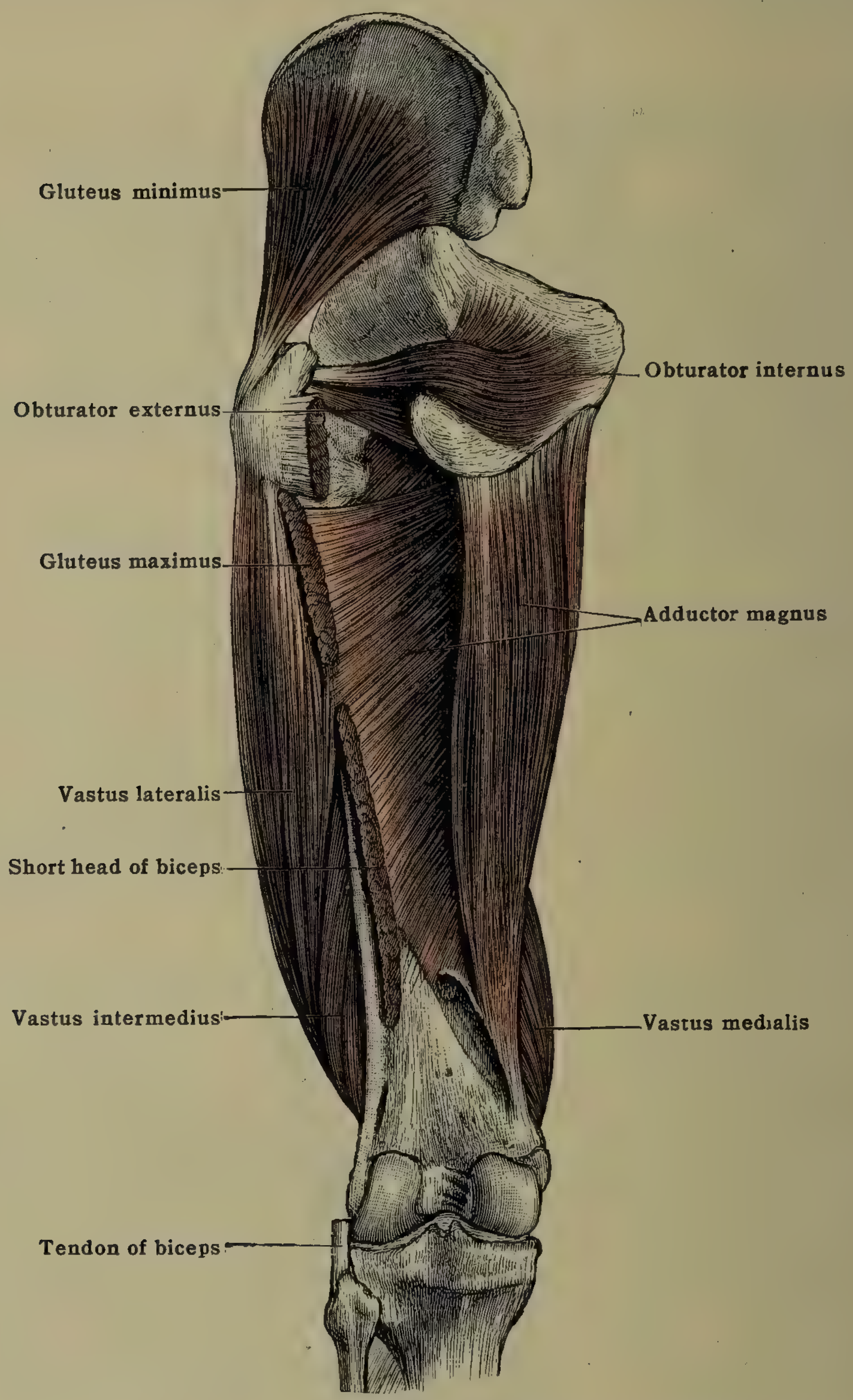


Fig. 473.—The Deep Muscles of the Back of the Thigh.

Bursæ

B. ischiadica m. glutei maximi.—A small inconstant bursa between the tuber ischii and the gluteus maximus muscle. **B. trochanterica m. glutei maximi.**—A large bursa constantly present between the fascial tendon of the gluteus maximus and the posterior lateral surface of the great trochanter and the origin of the vastus lateralis muscle. **B. gluteofemorales.**—Two or three small bursæ on each side of the tendon of attachment of the gluteus maximus to the femur. **B. trochanterica m. glutei medii anterior.**—A small bursa constantly present between the tendon of the gluteus medius muscle and the lateral surface of the great trochanter. **B. trochanterica m. glutei medii posterior.**—A small bursa frequently present between the tendons of the piriformis and the gluteus medius. **B. trochanterica m. glutei minimi.**—A fairly large bursa generally present between the margin of the great trochanter and the tendon of this muscle. **B. m. piriformis.**—A small bursa frequently present between the tendons of the piriformis and superior gemellus muscles and the femur.

2. Ischio-pubo-femoral Musculature of the Hip

The muscles belonging to this group, the obturator internus, the two gemelli, the quadratus femoris and the obturator externus, extend from the pubis and ischium across the back of the hip-joint to the great trochanter and the neighboring part of the shaft of the femur. They are powerful lateral rotators of the thigh. The **obturator internus** (fig. 473), a large, flat, triangular muscle, arises from the pelvic surface of the innominate bone and from the obturator membrane. At the lesser sciatic notch its tendon is joined by the two **gemelli** (fig. 472), one of which arises on each side from the bony projections which make the notch, and the combined tendon is inserted into the trochanteric (digital) fossa. The **quadratus femoris** (fig. 472) passes from the tuber of the ischium to the femur behind and below the great trochanter. These muscles are supplied by special nerves which arise from the front of the sacral plexus and enter the deep surfaces of the muscles. A fifth muscle, attached to the greater trochanter and associated with this group, the **obturator externus,** is differentiated near the adductor muscles of the thigh and is supplied by a branch from the obturator nerve. It arises from the outer surface of the bones bounding the ventral two-thirds of the obturator foramen and is inserted by a tendon into the trochanteric (digital) fossa.

These muscles seem to have no certain representatives in the arm, where the shoulder-joint is entirely ensheathed by the dorsal musculature. It is possible that the pectoral group has a corresponding embryonic origin. The group is represented, with marked variations, in the lower extremities of amphibia and all higher vertebrates.

FASCIÆ

Within the pelvis the obturator internus lies on the obturator membrane. It is covered by the **obturator fascia,** which is attached to the body of the pubis, to the iliac portion of the arcuate line, to the ventral margin of the great sciatic notch, to the ischial spine, to the sacrotuberous (great sacrosciatic) ligament, and with the falciform process of that ligament, to the ischial and pubic rami. Near the upper part of the obturator foramen the fascia instead of being attached to bone is reflected over the muscle and attached to the obturator membrane. It here helps to bound the canal for the obturator vessels and nerve. The upper part of the fascia lies beneath the pelvic peritoneum and the levator ani. The lower part forms the outer boundary of the ischiorectal fossa. The fascia is continued as a thin, adherent membrane over the obturator internus and the gemellus muscles to their attachment. The quadratus femoris is invested by a thin adherent fascial sheet.

MUSCLES

The obturator internus (fig. 473).—*Origin.*—From (1) the pelvic surface of the pubic rami near the obturator foramen; (2) the pelvic surface of the ischium between the foramen and the great sciatic notch; (3) the deep surface of the obturator internus fascia; (4) the fibrous arch which bounds the canal for the obturator vessels and nerve; and (5) the pelvic surface of the obturator membrane except in the lower part.

Structure and insertion.—From this extensive area of origin the fiber-bundles converge toward the lesser sciatic notch and become applied to the broad tendon of insertion. At the notch the muscle curves laterally and extends outward and upward to its insertion into the fore part of the trochanteric fossa of the femur. The tendon is formed of five or six bands which begin high in the muscle and converge into a common tendon situated on the deep surface of the muscles as the latter curves about the ischium. The tendon bands at first throw the tendon into folds which run in ridges in the fibrocartilage which lines the notch. The attachment of fiber-bundles continues upon the dorsal surface of the tendon to half way between the lesser sciatic notch and the great trochanter.

Nerve-supply.—A special nerve to the obturator internus arises from the front of the sacral plexus, usually from the lumbosacral cord and the first and second sacral nerves. This nerve passes lateral to the sacrospinous (lesser sciatic) ligament, then re-enters the pelvis through the lesser sciatic notch and sends out branches of distribution on the pelvic surface of the obturator internus.

Action.—This muscle with its two companions, the gemelli, is a powerful lateral rotator of the thigh. It is also an extensor and abductor when the thigh is bent at a right angle

Relations.—The chief pelvic relations have been described in connections with the obturator fascia which completely covers the medial surface of the muscle. The muscle passes out between the two sacroischial (sacrosciatic) ligaments. Outside the pelvis the gemellus muscles run on each side of the tendon, which is here closely applied to the capsule of the joint. Dorsal to it lie the gluteus maximus, the sacrotuberous (great sacrosciatic) ligament, the inferior gluteal (sciatic) vessels, and the sciatic and posterior cutaneous nerves. The nerve of the quadratus femoris runs beneath the obturator internus and gemellus muscles.

Variations.—It varies in the extent of its insertions. It may be divided into two parts, a pubic and an ischial. Fasciculi may be sent to the posteroinferior part of the iliopectineal eminence, the tendon of the psoas minor, the tuber ischii, the sacrotuberous (great sacrosciatic) ligament, the ischial spine, etc.

The gemellus superior (gemellus spinalis NK) (fig. 472).—*Origin.*—From the outer surface of the ischial spine and the neighboring edge of the lesser sciatic notch.

Structure and insertion.—The fiber-bundles encircle the upper border and ventral aspect of the tendon of the obturator internus. They are inserted into the upper border of this tendon, and sometimes also into the trochanteric fossa.

Nerve-supply.—From a small nerve which arises either directly from the plexus or as a branch of the nerve to the obturator internus or of that to the quadratus femoris. This nerve usually enters the deep surface of the muscle near the junction of its ischial and middle thirds.

Action.—It is essentially a part of the obturator internus.

Relations.—It lies between the piriformis and the tendon of the obturator internus. Proximally it adjoins its fellow beneath this tendon; distally, the two gemelli enclose the tendon in a musculotendinous sheath.

Variations.—It may be wanting or may have a more extensive origin than usual. It may be joined to the piriformis or to the gluteus minimus or be joined more closely than usual to the obturator tendon.

The gemellus inferior (gemellus tuberalis NK).—*Origin.*—From the upper part of the inner border of the tuberosity of the ischium, the sacrotuberous (great sacrosciatic) ligament and from the neighboring edge of the lesser sciatic notch.

Structure and insertion.—The fiber-bundles converge upon the inferior border of the tendon of the obturator internus, and are inserted by tendon-fibers into this or into the great trochanter below the obturator internus tendon.

Nerve-supply.—From a branch of the nerve to the quadratus femoris. This branch enters the deep surface of the muscle near the junction of the ischial with the middle third.

Action.—It is essentially a part of the obturator internus.

Relations.—It lies between the quadratus femoris and the tendon of the obturator internus.

Variations.—It is rarely absent. It may be joined to the quadratus femoris. It is frequently closely bound up with the obturator internus. It may be doubled.

The quadratus femoris (fig. 472).—*Origin.*—From the upper part of the outer border of the tuber of the ischium.

Structure and insertion.—The fiber-bundles take a nearly parallel course and are inserted into the vertical ridge which terminates above on the inferior dorsal angle of the great trochanter.

Nerve supply.—From a nerve which arises usually from the lumbosacral cord and the first sacral nerve and passes under the gemelli and the tendon of the obturator internus. The nerve enters the deep surface of the muscle near the junction of the ischial and middle thirds.

Action.—It is a powerful lateral rotator and a weak adductor of the thigh.

Relations.—It is covered by the gluteus maximus. Between this muscle and the quadratus femoris runs the sciatic nerve. The obturator externus muscle lies in front. The inferior gemellus extends along its superior border. The adductor minimus adjoins it distally.

Variations.—It is absent in from 1 to 2 per cent. of instances. (Schwalbe and Pfitzner.) It may be double near its femoral insertion. It may be fused with the inferior gemellus or the adductor magnus. It may send a fasciculus to the semimembranosus.

The obturator externus (figs. 471, 473, 476).—*Origin.*—From the lateral surface of the pubic and ischial rami, where they bound the obturator foramen, and from the surface of the obturator membrane.

Structure and insertion.—Often the muscle is distally divided into three fasciculi, a superior from the superior pubic ramus, a middle from the inferior pubic ramus and the obturator membrane, and an inferior from the ischium. The fiber-bundles converge upon a tendon which is at first deeply buried, then appears on the lateral surface of the muscle and is continued as a rounded tendon over the capsule of the joint to its insertion into the dorsal part of the trochanteric fossa.

Nerve-supply.—The obturator nerve gives rise, usually in the obturator canal, to a branch which bifurcates to enter the superior border and ventral surface of the muscle in its middle third.

Action.—It is a powerful lateral rotator of the thigh and is also a weak adductor.

Relations.—It is covered by the pectineus, the iliopsoas, and the adductor magnus muscles in front, and by the quadratus femoris behind near its insertion. It covers over the obturator membrane. The obturator nerve passes either above the muscle or through its upper portion.

Variations.—The reported variations are few. It may be joined by a slip from the adductor brevis.

Bursæ

B. m. obturatoris interni.—A fairly large bursa constantly present between the tendon of the obturator internus muscle and the lesser sciatic notch. It may extend on each side beneath the gemellus muscles. **B. m. quadrati femoris.**—A small bursa frequently found between this muscle and the small trochanter. **B. m. obturatoris externi.**—A bursa is sometimes found between the tendon of this muscle and the capsule of the joint.

B. MUSCLES OF THE THIGH

In the thigh three groups of muscles may be recognized, an anterior or extensor (figs. 475, 476), a medial or adductor (figs. 473, 475, 476), and a posterior, flexor or hamstring group (figs. 462, 477).

In the proximal part of the thigh the anterior group of muscles is separated from the medial group by the iliopsoas muscle (fig. 475) and by the femoral blood-vessels and nerve, and from the posterior group by the gluteus maximus (fig. 477). More distally it is separated from the medial group by the medial

intermuscular septum and from the posterior by the lateral intermuscular septum (see below). The medial and posterior groups are closely associated. The adductor magnus belongs ontogenetically to both.

The three groups of muscles, with numerous modifications, are represented in the thighs of amphibia and all higher vertebrates. In the human arm they are likewise represented, the adductor group in a much reduced form by the coracobrachialis. The quadriceps is represented by the triceps in the arm, the long head of the triceps corresponding with the rectus femoris. The hamstring muscles are represented by the biceps and the brachialis.

FASCIÆ

The **fasciæ** and the relations of the musculature of the thigh may be followed in the cross-sections, figs. 471, 474, 478.

The **tela subcutanea** of the thigh varies considerably in thickness in different regions, but is well developed throughout and contains a considerable amount of fat. Over the front of the thigh, especially in the upper medial region, one or more deeper membranous layers may usually be separated from the superficial adipose layer. Between the former and the latter are situated the inguinal lymphatic nodes and the saphenous vein. The deepest layer near the inguinal (Poupart's) ligament is fused with the fascia lata (see below). Medially it is attached to the pubic arch. Thus fluids beneath the tela subcutanea of the abdomen and perineum do not readily pass into the region of the thigh.

Over the lower half of the patella a subcutaneous bursa (**b. præpatellaris subcutanea**) is found. Another is usually found over the upper end of the patellar ligament (**b. infrapatellaris subcutanea**).

The muscles of the thigh are enclosed in a dense fascial sheet, the **fascia lata** (figs. 451, 474). The gluteal portion of this and the iliotibial band have already been described (p. 525). The ventral portion of the fascia, composed chiefly of transverse fibers, is a dense, fibrous membrane. Above it is attached to the inguinal ligament from the anterior superior spine to the pubic tubercle. Below it extends over the knee, where it is united to the capsule of the joint and is strengthened by expansions from the vastus lateralis and medialis. Between the front of the patella and the fascia is a bursa (**b. prepatellaris subfascialis**). Above the knee the fascia is strengthened by an *arciform process* which extends obliquely distally across the fascia from the iliotibial band to the capsule of the knee. This gives rise to a fold in the skin when the leg is extended and the muscles are not tense. Over the medial and posterior regions of the thigh the fascia is less dense. It extends from the body and inferior ramus of the pubis, the inferior ramus and tuber of the ischium, and the sacrotuberous ligament into the fascia of the back of the leg. Above the popliteal space it is strengthened by a transverse band of fibers. Near the knee the tendons of the quadriceps, sartorius, gracilis, and semitendinosus become bound to the fascia by membranous laminæ. The density of the fascia lata is of clinical importance in causing pus to burrow, especially downward, and in rendering difficult the diagnosis of swellings beneath the fascia.

The relations of the fascia lata to the inguinal ligament and the iliac fascia are somewhat complex. The fascia of the iliopsoas muscle extends over the muscle to its femoral insertion. Above the inguinal ligament this fascia is called the **fascia iliaca**; below the ligament, the **fascia iliopectinea.** This fascia is firmly united to the lateral extremity of the inguinal ligament. The pectineus muscle is likewise invested with a fascial membrane which extends over the muscle from the pubis to the femur and is fused laterally with that of the iliopsoas. This combined fascia is firmly bound between the muscles to the iliopectineal eminence. The iliopectineal fascia divides the space beneath the inguinal ligament into a lateral **lacuna musculorum,** which contains the iliopsoas muscle and the femoral (anterior crural) nerve, and a medial **lacuna vasorum,** which contains the femoral artery and vein. Medial to the vein is the **femoral ring,** bounded medially by the **lacunar** (**Gimbernat's**) **ligament.** This is closed off from the abdominal cavity by a septum derived from the transversalis fascia, the **femoral septum,** but offers passage for lymph-vessels.

Beyond the inguinal ligament the fasciæ of the iliopsoas and pectineal muscles line **Scarpa's triangle** [trigonum femorale], a space bounded by the inguinal (Poupart's) ligament superiorly, the sartorius laterally and long adductor muscles medially. Within this triangle is a depression, the **iliopectineal fossa,** through which run the femoral vessels (fig. 471). The sartorius muscle partly overlies the distal lateral margin of this fossa. The fascia lata is here reflected from the surface of the sartorius to the iliopsoas fascia, and becomes fused with it. From the medial margin of the sartorius a process of the fascia is continued over the lateral and upper part of the fossa, and is attached to the inguinal and lacunar (Gimbernat's) ligaments (fig. 453). Over the lower extremity of the fossa a process is continued medially into the pectineal fascia. On the medial margin of the fossa the fascia lata is continued directly into the pectineal fascia. The lateral concave margin of the fascia overlying the fossa is called the **falciform margin;** the upper extremity of this, the **superior cornu;** the distal extremity, the **inferior cornu.** The oval space bounded by the margo falciformis is called the **fossa ovalis** (saphenous opening) This is covered by the **fascia cribrosa,** which some consider a deep layer of the tela subcutanea and others a portion of the fascia lata. This fascia cribrosa contains many openings for the passage of blood-vessels and lymphatics. The space which lies medial to the femoral vessels between the femoral ring and the fossa ovalis is called the **femoral canal** (crural canal), through which femoral hernia descends.

From the fascia intermuscular septa descend in between the underlying muscles. Of these, the medial and lateral intermuscular septa are the best marked (fig. 474).

The **lateral intermuscular septum** separates the extensor muscles from the hamstring group. It extends from the tendon of the gluteus maximus to the lateral epicondyle. It is

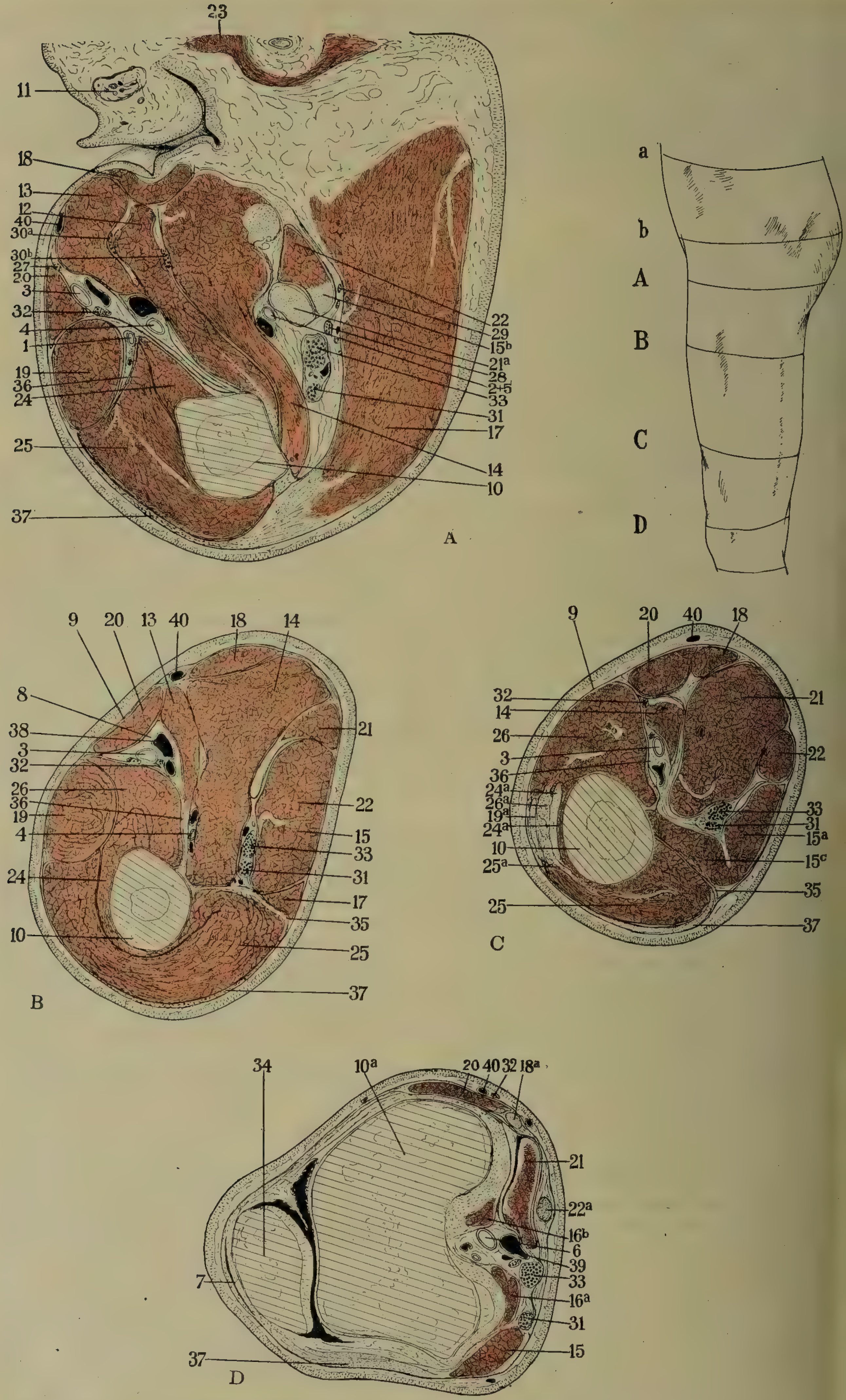


Fig. 474, A–D.—Transverse Sections through the Left Thigh in the Regions indicated in the Diagram.

a and *b* in the diagram indicate the regions through which pass sections A and B, fig. 471.

composed chiefly of longitudinal fibers and is thickest distally. The vastus lateralis is united to its ventrolateral surface; the short head of the biceps, to its dorsomedial surface.

It will be noted that this septum serves to divide primarily ventral from primarily dorsal musculature, with the exception of the short head of the biceps, which, though primarily dorsal, occupies a position, perhaps secondarily acquired, with the primarily ventral muscles.

The **medial intermuscular septum** serves to divide the anterior extensor from the medial adductor musculature. It is perhaps simplest in the region immediately distal to the iliopectineal fossa (fig. 474B). Here a well-marked septum may be seen extending to the femur between the sartorius and quadriceps on the one side, and the adductor longus and brevis on the other. The septum here, next the muscles, has on each side a membranous lamina. Between the two laminæ there is a looser tissue in which run blood-vessels and nerves. A fibrous membrane extends between the rectus and sartorius to the septum.

More distally the sartorius comes to overlie the septum (fig. 474C). The sheath of the sartorius on the lateral margin becomes fused with the fascia of the vastus medialis, and on the medial margin to a membrane that covers the ventral surfaces of the adductor longus and magnus. Beneath the sartorius and between the adductor longus and the vastus medialis is a three-sided space bounded by the sheaths of these muscles, and filled with a loose areolar tissue in which run the femoral vessels and the saphenous nerve. This space, first described by John Hunter, is known as **Hunter's canal,** or the **adductor canal.** Still more distally the vessels with their surrouding fibrous tissue pass through the hiatus tendineus, between the long tendon of the adductor magnus and the femur, to the back of the thigh. The septum here passes behind the posterior surface of the vastus medialis to the femur. Hunter's canal therefore extends from the apex of the femoral triangle to the upper end of the popliteal space.

1. The Anterior Group

(Figs. 475, 476)

This group, which forms a semiconical mass pointed upward, is composed of the quadriceps femoris and the sartorius muscles, innervated by the femoral nerve.

The **sartorius** is a long, ribbon-like muscle which arises from the anterior superior spine of the ilium and extends along the medial margin of the quadriceps, passing obliquely across the upper part of the thigh, and then descending to the dorsomedial side of the knee, whence its tendon curves forward to be inserted into the ventromedial surface of the superior extremity of the tibia.

The **quadriceps femoris** is composed of four muscles differentiated from a common embryonic origin. Of these, the **rectus femoris,** which arises from the ventrolateral margin of the ilium by two tendons, is the most superficial and the most completely differentiated. The **vastus lateralis,** which arises from the superior extremity of the ventral surface of the shaft of the femur and from the lateral lip of the linea aspera; the **vastus medialis,** which arises from the medial lip of the linea aspera and from the intertrochanteric line; and the **vastus intermedius** (crureus), which arises between these two and beneath the rectus from the surface of the femur, are less distinctly differentiated from one another. The vastus intermedius and vastus lateralis are partly fused at the insertion, the intermedius and medialis at their origins. From the four muscles arises a tendon which is inserted into the tuberosity of the tibia. In this tendon, which is closely applied to the capsule of the knee-joint, lies a sesamoid bone, the patella.

The sartorius flexes, abducts, and rotates the thigh lateralward; it extends and medially rotates the leg. The quadriceps extends the leg; the rectus portion in addition flexes the thigh.

In the embryo the sartorius has an origin distinct from that of the quadriceps. In the anthropoid apes it is much more developed than in man.

---

1. Arteria circumflexa femoris lateralis. 2. A. circumflexa femoris medialis. 3. A. femoralis. 4. A. femoralis profunda. 5. A. glutea inferior (sciatic). 6. A. poplitea. 7. Bursa præpatellaris subfascialis. 8. Adductor (Hunter's) canal. 9. Fascia lata. 10. Femur—a, distal extremity. 11. Funiculus spermaticus (spermatic cord). 12. Musculus adductor brevis. 13. M. adductor longus. 14. M. adductor magnus. 15. M. biceps femoris—a, long head; b, tendon of origin; c, short head. 16. M. gastrocnemius—a, lateral head; b, medial head. 17. M. gluteus maximus. 18. M. gracilis—a, tendon. 19. M. rectus femoris—a, tendon. 20. M. sartorius. 21. M. semimembranosus—a, tendon. 22. M. semitendinosus —a, tendon. 23. M. sphincter ani. 24. M. vastus intermedius (crureus)—a, tendon. 25. M. vastus lateralis—a, tendon. 26. M. vastus medialis—a, tendon. 27. Nervus cutaneous femoris anterior. 28. N. cutaneous femoris posterior (small sciatic). 29. N. gluteus inferior. 30. N. obturatorius—a, superficial branch; b, deep branch. 31. N. peroneus communis (external popliteal). 32. N. saphenus (great saphenous). 33. N. tibialis (internal popliteal). 34. Patella. 35. Septum intermusculare laterale. 36. Septum intermuscular mediale. 37. Tractus iliotibialis (iliotibial band). 38. Vena femoralis. 39. Vena poplitea. 40. V. saphena magna (great saphenous vein).

In addition to supplying the muscles of this group, the femoral nerve also gives branche to the iliacus muscle (p. 522) and the pectineus muscle (p. 538).

The sartorius (fig. 475).—*Origin.*—From the anterior superior spine of the ilium and th area immediately below this.

Insertion.—Into the medial surface of the tibia near the tuberosity and into the neighborin ascia of the leg.

Structure.—The muscle arises by short tendinous strands. The fiber-bundles take a nearl parallel course. The component muscle-fibers are said to be the longest in the body. Near th

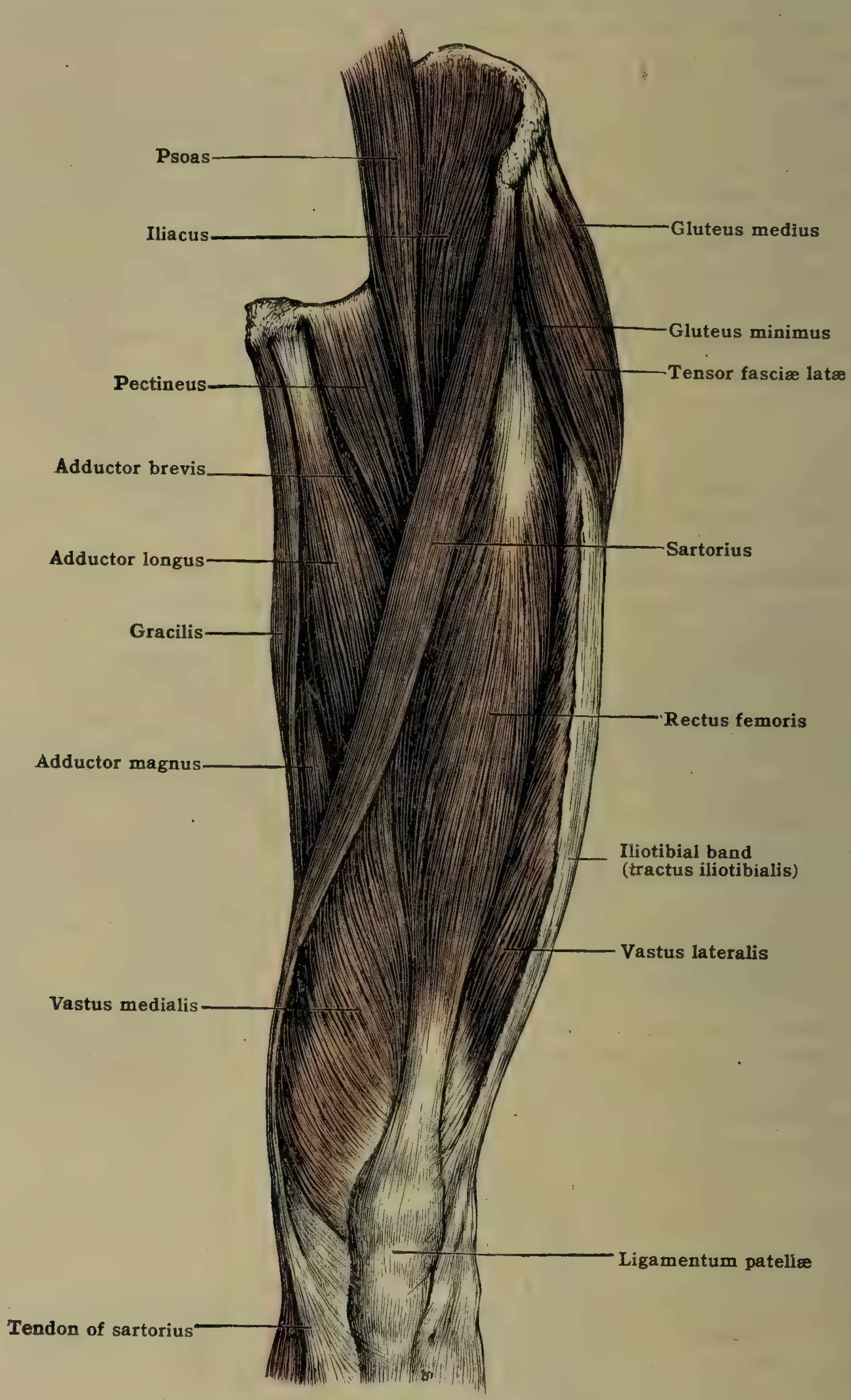


Fig. 475.—Muscles on the Front of the Thigh.

medial epicondyle of the femur the tendon of insertion makes its appearance on the deep aspect of the muscle. On the superficial surface of the tendon the muscle-fibers are inserted as far as the distal margin of the knee-joint. From there the tendon turns forward to its insertion.

Nerve-supply.—Usually two branches enter the deep surface of the proximal third of the sartorius. One or both of them may be bound up with an anterior cutaneous nerve passing through the muscle. The first of the branches is distributed chiefly to the lateral and proximal, the second to the medial and distal, portions of the muscle. Within the muscle is a complex plexus.

Action.—(1) To flex the thigh at the hip, abduct and rotate it lateralward; (2) to flex the leg and rotate it slightly medialward; (3) to make tense the medial part of the fascia lata.

Relations.—The sartorius lies in a fascial canal bounded by the fascia lata and by intermuscular septa which descend from this. It crosses the rectus femoris, iliopsoas, the adductor longus and magnus, and the vastus medialis muscles, the femoral vessels and nerve, and the knee-joint. At its insertion its tendon covers the gracilis and semitendinosus.

Variations.—It may arise from the inguinal ligament or be inserted into the fascia lata, the medial epicondyle, or the capsule of the knee-joint. It may be longitudinally divided into two parts. The tendon of the secondary slip is in such instances usually attached to the capsule of the knee-joint, but sometimes is attached to the fascia over the vastus medialis or to the anterior wall of the adductor canal. More frequently the muscle is partly divided proximally or distally. The secondary tendon of origin may arise from the anterior inferior spine, the iliopectineal eminence, etc. The muscle is very rarely absent. It may be crossed by a tendinous inscription, or more rarely it is rendered digastric by an intervening tendon.

The quadriceps femoris (figs. 475, 476).—This, as pointed out above, is composed of the rectus femoris and the vastus lateralis, intermedius, and medialis.

The rectus femoris (fig. 475).—*Origin.*—By two tendons. The anterior 'straight' tendon is attached to the anterior inferior spine of the ilium; the posterior 'reflected' tendon to the posterosuperior surface of the rim of the acetabulum. The two tendons unite so as to form a small arch above the capsule of the joint.

Structure and insertion.—From this arch an aponeurotic expansion descends upon the front of the muscle nearly to the middle of the thigh. This expansion is broad above, becomes narrower as it descends, and is continued a short distance as a narrow intramuscular tendon after it disappears from the surface. The tendon of insertion begins on the back of the muscle above the middle of the thigh, expands into a broad aponeurosis, and finally becomes a strong band which is attached to the proximal border of the patella, with ultimate insertion into the tuberosity of the tibia, as explained later; through the patellar ligament. The fiber-bundles pass in a bipenniform manner from the back and sides of the tendon of origin to the front and sides of the tendon of insertion.

Nerve-supply.—As a rule, two branches enter the muscle. One of these enters the deep surface of the muscle in its upper fourth, and is distributed mainly to the proximal part of the lateral half. The other enters the medial margin of the muscle near the junction of the proximal and middle thirds, and is distributed chiefly to the medial half and distal portion of the muscle.

The vastus lateralis (vastus externus) (fig. 476).—*Origin.*—From—(1) the shaft of the femur along the anteroinferior margin of the great trochanter and in front of the gluteal tuberosity; and (2) the lateral intermuscular septum along the upper half of the linea aspera.

Insertion.—By a flat tendon into—(1) the proximolateral border of the patella; and (2) the front of the lateral condyle of the tibia and the fascia of the leg. See also patellar ligament.

Structure.—The fiber-bundles arise partly from the bone, partly from an aponeurosis which covers the proximal two-thirds of the muscle, and from the lateral intermuscular septum. They take a parallel course distally in a ventromedial direction, and are inserted into an aponeurosis which lies on the deep surface of the muscle and receives fibers until within a few centimeters of the patella. Ventrally this aponeurosis fuses with the rectus tendon, medially with that of the vastus medialis, and dorsally it receives some of the fiber-bundles of the vastus intermedius. Commonly the muscle is distinctly divisible for the greater part of its course into two sheets, a superficial and a deep. The deep sheet is often subdivided into two laminæ.

Nerve-supply.—Usually there are three nerves, one of which, accompanied by blood-vessels, runs on the inner surface of the superficial sheet midway between the tendons of origin and insertion, the second between the two laminæ of the deep layer, and the third passes through the innermost lamina to be distributed in part to the vastus intermedius (crureus) muscle.

The vastus medialis (vastus internus) (fig. 476).—*Origin.*—From the whole extent of the medial lip of the linea aspera and from the distal half of the intertrochanteric line. The origin takes place by means of an aponeurosis which is adherent to the tendons of insertion of the adductor muscles.

Structure and insertion.—The fiber-bundles arise from the deep surface of this aponeurosis and are inserted on the medial surface and margin of a tendon which begins on the deep surface of the muscle about its middle near the lateral margin. On the distal lateral border of the muscle it is inserted into the medial half of the proximal margin of the patella and into the medial condyle of the tibia and the fascia of the leg. For some distance near the knee the lateral margin of the tendon is united to the tendons of the vastus intermedius (crureus), lateralis (externus) and the rectus. For the ultimate insertion, see patellar ligament.

Nerve-supply.—The nerve to this muscle descends on its medial surface, often bound up with the saphenous nerve for a part of its course. It gives off successive branches and finally sinks into the muscle substance. These branches enter about midway between the origin and insertion of the fiber-bundles of the muscle.

The vastus intermedius (medius NK) (crureus) (figs. 474, 476).—*Origin.*—From (1) the distal half of the lateral margin of the linea aspera and its lateral bifurcation; (2) the anterolateral surface of the shaft of the femur. Between the origin of the vastus intermedius (crureus) and that of the vastus medialis the shaft of the femur is free from muscle attachment.

Structure and insertion.—On the ventral surface of the muscle lies an aponeurosis which extends from its proximal fourth to the proximal margin of the patella. The fiber-bundles of the muscle are inserted into the deep surface of this and into the deep surface of the aponeurosis of insertion of the vastus lateralis. The proximal fiber-bundles descend vertically, the medial and lateral, especially the latter, obliquely to their insertion. Medially the tendon is more or less fused with that of the vastus medialis, and laterally with that of the vastus lateralis. The muscle is composed of muscle lamellæ superimposed concentrically about the shaft of the femur. The deepest, most distal of these is called the **articularis genus** (subcrureus). The fiber-bundles

of this layer are inserted into the capsule of the joint or into the superior margin of the patella and ultimately, through the ligamentum patellae, into the tuberosity of the tibia.

Nerve-supply.—Several branches are usually distributed to this muscle. To the latera region a branch from the nerve to the vastus lateralis is usually given; to the middle of th muscle another branch descends from the femoral (anterior crural) nerve; to the medial portio there extend several twigs from the nerve to the vastus medialis.

Tendon of the quadriceps.—The quadriceps tendon may be more or less distinctly divide into layers, of which the superficial layer belongs to the rectus, the deep to the vastu

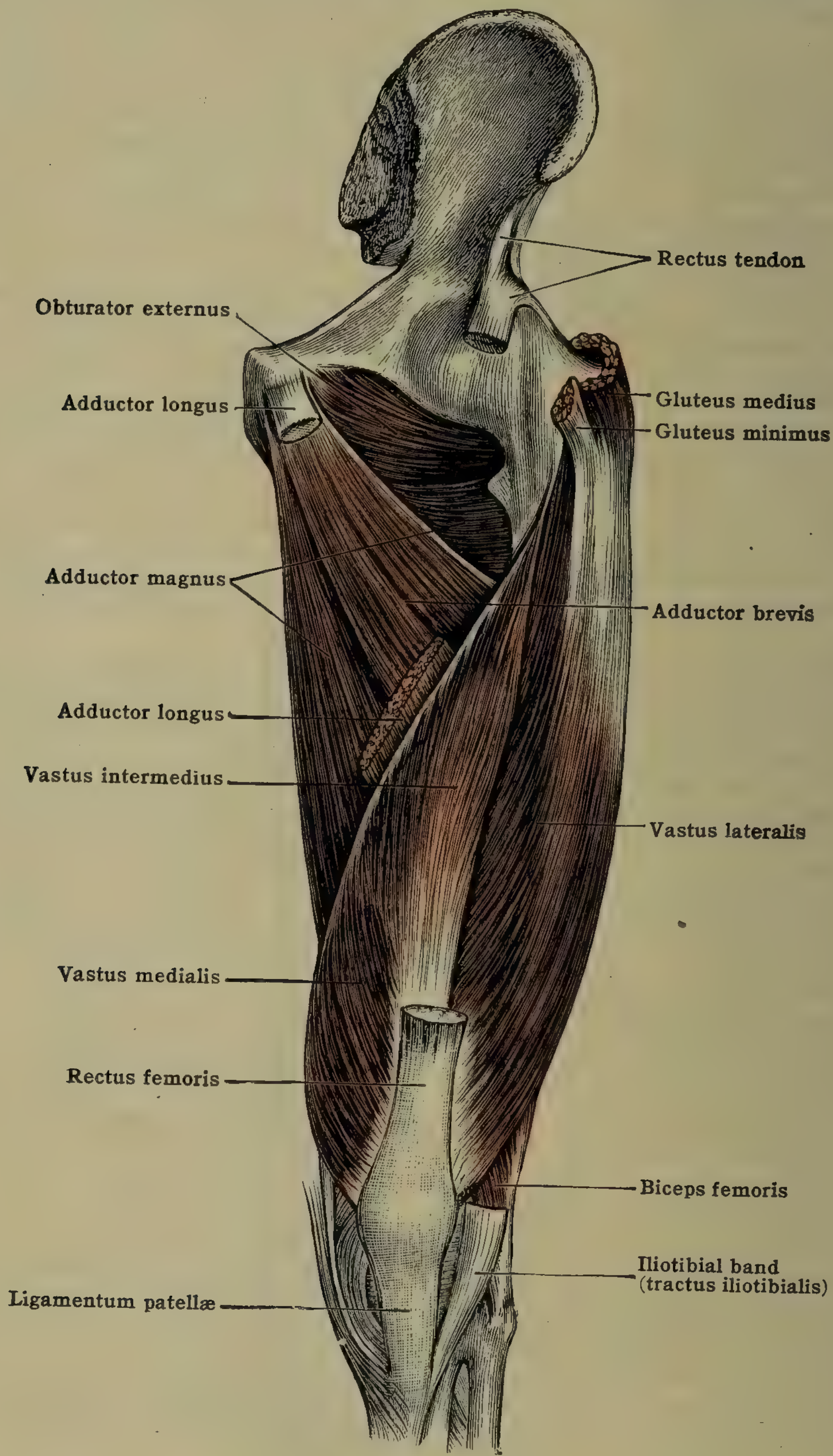


FIG. 476.—THE DEEP MUSCLES OF THE FRONT OF THE THIGH.

intermedius, and the intermediate to the vastus lateralis and medialis. Some of the more superficial fibers of the tendons of the two vasti, however, cross in front of the rectus tendon. The combined tendon of the quadriceps is in part attached to the superior and lateral margins of the patella, and in part extends over the patella into the patellar ligament. A part of the tendon fibers of the vastus lateralis and medialis run on each side of the patella to the ventral surface of the condyles of the tibia. These form the **retinacula patellæ mediale and laterale.** The medial is the broader and better developed. With the retinacula are included bundles of fibers which run from the epicondyles to the patella and into which some muscle fiber-bundles are inserted. From the apex of the patella to the tuberosity of the tibia the quadriceps tendon is continued as the **patellar ligament** (fig. 479).

Nerve-supply.—The relations of the branches of distribution to the various parts of the muscle have been pointed out above in connection with each head. The general relations of these branches of the femoral nerve are as follows:—From the femoral nerve near the proximal end of the vastus medialis the branches for the vastus lateralis, vastus intermedius (crureus), and rectus pass distally and laterally between the rectus and vastus intermedius (crureus) to be distributed to the muscles named, while the chief nerve for the vastus medialis descends on the medial side of this muscle in company with the saphenous nerve. The branches to the vastus lateralis and intermedius are commonly bound up in a single nerve-trunk for some distance. The branches to the rectus are usually bound up with this trunk for a shorter distance. The nerve to the vastus medialis may be united to this trunk for a slight distance, but more frequently it is more or less bound up with the saphenous nerve.

Action.—The quadriceps is the extensor of the leg. The rectus femoris also flexes the thigh at the hip and is a weak abductor of the thigh. The articularis genu makes tense the capsule of the knee-joint.

Relations.—The quadriceps is covered ventrally immediately by the fascia lata. The sartorius runs along its medial margin; the tensor fasciæ latæ lies over the proximal quarter of its lateral surface. Dorsal to the vastus lateralis lie the gluteus maximus and biceps; dorso-medial to the vastus medialis, the three adductor muscles and the semimembranous. Next to vastus medialis lies the adductor canal with the femoral vessels and the saphenous nerve.

Variations.—The variations of this muscle, aside from a greater or less fusion of its parts, are not marked. The attachment of the rectus femoris to the anterior inferior spine, which takes place in the embryo later than its insertion above the acetabulum, may be wanting. On the other hand, this tendon may extend to the anterior superior spine. Occasionally the deep reflected tendon may be wanting. The **rectus accessorius** is a fasciculus rarely found, which arises by a tendon from the rim of the acetabulum and is inserted into the ventral edge of the vastus lateralis. It is innervated by a twig from the branch to the rectus.

Bursæ

B. m. recti femoris (superior).—A small bursa between the deep tendon of the rectus femoris and the edge of the acetabulum. Rare. **B. m. recti femoris (inferior).**—Between the tendon of the rectus and combined tendon of the vastus lateralis and medialis. Occasional. **B. præpatellaris subtendinea.**—A bursa between the tendon of the quadriceps and the periosteum of the patella. Of the three præpatellar bursæ—the subcutaneous, subfascial, and subtendinous—as a rule only one occurs. When two or three exist, they usually communicate freely with one another. **B. suprapatellaris.**—A bursa between the anterior surface of the lower end of the femur and the tendon of the quadriceps. It usually communicates with the joint cavity. **B. infrapatellaris profunda.**—A bursa between the patellar ligament and the tibia. It seldom communicates with the joint cavity. **B. m. sartorii propria.**—A bursa, fairly large, between the tendon of the sartorius and the tendons of the semitendinosus and gracilis muscles. This usually communicates with the bursa anserina (see p. 539).

2. The Medial (Adductor) Group

(Figs. 473, 475, 476)

To this group of muscles belong the gracilis, the pectineus, the adductors brevis, longus, and magnus, and the obturator externus. The most superficial of the group is the **gracilis** (figs. 472, 475). This ribbon-shaped muscle arises from the inferior pubic and ischial rami, extends along the medial side of the thigh, and gives rise to a tendon which curves forward from behind the medial condyle of the femur to be inserted under the tendon of the sartorius into the medial side of the upper extremity of the tibia. The quadrilateral **pectineus** arises from the body and superior ramus of the pubis; the triangular **adductor longus** from the superior ramus medial to this (fig. 475). The pectineus is inserted into the pectineal line of the femur; the adductor longus into the middle third of the linea aspera. The triangular **adductor brevis** (fig. 476) arises from the inferior pubic ramus below the adductor longus. It is inserted into the pectineal line and the upper third of the linea aspera. The large, triangular **adductor magnus** (figs. 473, 476) arises from the inferior ramus and the tuber of the ischium and is inserted behind the short and long adductors into the whole length of the linea aspera, and by a special tendon into the adductor tubercle of the femur. The deepest muscle of the group, the **obturator externus,** which arises from the outer surface of the bones bounding the ventral two-thirds of the obturator foramen, and is inserted by a tendon into the trochanteric (digital) fossa, has been described in connection with the ischio-pubo-femoral muscles of the hip.

All the muscles of this group adduct the thigh. The gracilis, obturator externus, adductor brevis and the lower part of the adductor magnus (when the thigh is extended) rotate it lateralward. The pectineus, adductor longus, and the adductor magnus rotate it medialward. Those attached to the pubis flex the thigh. The gracilis flexes the leg and rotates it medialward. The inferior part of the adductor magnus extends the thigh.

The muscles of this group are supplied by the obturator nerve, except the pectineus, which usually gets its whole supply from the femoral (anterior crural) nerve, and the adductor magnus, which gets a part of its supply from the sciatic nerve.

In embryonic development the pectineus arises in close conjunction with the obturator group, and in the adult it may get the whole or a part of its nerve-supply from the obturator nerve or from the accessory obturator nerve. In the lower mammals the nerve-supply may come from the femoral (anterior crural) or the obturator nerve or from both. It is not certain whether the innervation from the femoral nerve indicates that the muscle belongs phylogenetically, if not ontogenetically, with the primitive dorsal musculature of the limb. By some it is considered to be derived in part from the primitive dorsal, in part from the primitive ventral, musculature. The adductor magnus arises in the embryo as two distinct portions, one connected with the flexor group of muscles, the other with the adductor group. These two portions later become fused. Primitively the sciatic portion of the adductor magnus and the semimembranosus constitute a single medial flexor muscle.

The gracilis (figs. 472, 475).—*Origin.*—By a flat tendon from the medial margin of the inferior ramus of the pubis and the pubic extremity of the inferior ramus of the ischium.

Structure and insertion.—The nearly parallel fiber-bundles which arise between two laminæ of the tendon form a thin band of muscle which is narrower and thicker distally than proximally. They are inserted on a tendon which begins as an aponeurosis on the posterior border and medial surface of the muscle in the distal third of the thigh, becomes free as a rounded cord a little proximal to the medial condyle of the femur, runs behind the condyle, and then turns forward to be inserted by an expanded process into the tibia below the medial condyle.

Nerve-supply.—The nerve enters the deep surface of the muscle near the junction of the superior and middle thirds.

Action.—To adduct, flex and (slightly) rotate the thigh lateralward, and flex the leg. With the knee flexed, it acts as a medial rotator of the leg.

Relations.—It occupies a position beneath the fascia lata and superficial to the adductor brevis, longus, and magnus muscles. Distally the sartorius lies in front, the semimembranosus behind. Its tendon crosses the tibial collateral ligament of the knee-joint and the tendons of the semitendinosus and the semimembranosus, and is overlapped by that of the sartorius.

Variations.—The pubic origin of the muscle may be much reduced or may be double. Its tendon of insertion may give rise to an accessory fasciculus which extends distally in the leg. In some of the apes the tendon descends normally much farther down the leg than in man.

The pectineus (fig. 475).—*Origin.*—(1) From the pecten (crest) of the os pubis, the bone in front of this, and the pectineal fascia near this origin; and (2) from the anterior margin of the obturator sulcus and from the pubocapsular ligament. Laterally the two areas of origin are usually separated by most of the superior surface of the body of the pubis. Medially they come together.

Structure and insertion.—From each area of origin a separate lamina arises. The fiber-bundles of each layer take a nearly parallel course and terminate between two tendinous lamellæ which fuse to be inserted into the upper half of the pectineal line behind the small trochanter. The fiber-bundles of the superficial layer cross those of the deep slightly obliquely. The muscle faces ventrally at its origin, laterally at its insertion.

Nerve-supply.—From a branch of the femoral (anterior crural) nerve, which passes behind the femoral artery and vein and through the pectineal fascia to enter the ventral surface of the muscle. It may also be supplied by the accessory obturator nerve, when present, or by a branch from the obturator. When both the femoral (anterior crural) and obturator nerves supply this muscle, the femoral supplies the superficial, the obturator, the deep lamina (Paterson).

Action.—To flex and adduct the thigh (as in crossing the legs).

Relations.—It is covered by the pectineal fascia, lies between the iliopsoas and the adductor longus muscles, and crosses the obturator externus and adductor brevis muscles. The medial circumflex artery runs between it and the iliopsoas, the deep femoral artery between it and the adductor longus.

Variations.—The extent of the division of the pectineus into superficial and deep portions varies considerably. It may also be divided into a lateral and a medial division. Often the pectineus is fused with the adductor longus. It may receive an accessory fasciculus from the capsule of the hip-joint, the iliacus muscle, the obturator externus, or the adductor brevis muscles, or the small trochanter. It may send a fasciculus to the sartorius.

The adductor longus (fig. 475).—*Origin.*—From the medial corner of the superior ramus of the pubis by a strong tendon which extends for some distance on the medial border of the muscle.

Structure and insertion.—From this tendon the fiber-bundles diverge toward their insertion. This takes place between two lamellæ of a short tendon attached to the middle third of the linea aspera. The tendon is usually fused to the medial intermuscular septum and sends an expansion to the long tendon of the adductor magnus.

Nerve-supply.—A branch from the anterior division of the main obturator trunk gives off several twigs which enter the middle third of the deep surface of the muscle. Occasionally a small branch from the femoral (anterior crural) nerve enters the muscle. This is probably sensory in nature.

Action.—To adduct and flex the thigh, and rotate it medialward.

Relations.—The sartorius, the vastus medialis, and the femoral vessels lie anterolateral to it. Behind it lie the adductor brevis and adductor magnus muscles. Between these and the longus run the profunda vessels. Its lateral border touches the pectineus above, but is separated from it toward the insertion.

Variations.—It may be fused with the other adductors, including the pectineus. It may be doubled. The femoral insertion may extend to the medial epicondyle.

The adductor brevis (fig. 476).—*Origin.*—From the medial part of the outer surface of the inferior ramus of the pubis directly, and by means of short tendinous processes or a short flat tendon.

Structure and insertion.—From their origin the fiber-bundles diverge into a sheet which is inserted by short tendinous bands into the distal two-thirds of the pectineal line and the upper third of the linea aspera. The muscle is more or less completely divided into two fasciculi near its insertion. The place of division is near where the intertrochanteric line curves away from the linea aspera.

Nerve-supply.—Usually from the anterior but also sometimes from the posterior branch of the main obturator trunk. The rami enter the middle third of the muscle near the proximal border.

Action.—It is chiefly an adductor and to a less extent a flexor and a lateral rotator of the thigh.

Relations.—In front lie tbe pectineus and adductor longus; behind, the obturator externus quadratus femoris and adductor magnus. It is crossed by the profunda artery. The first perforating artery passes usually between the two fasciculi of the insertion.

Variations.—It may be fused with other members of the group. It may be divided completely into two fasciculi, rarely into three.

The **adductor magnus** (figs. 473, 476).—The *origin* of this muscle begins on the inferior ramus of the pubis posterior to the origins of the adductor brevis and gracilis muscles. From here it extends backward along the inferior margin of the ventrolateral surface of the ischium to the tuberosity. The muscle in passing from this curved origin to its extensive femoral insertion presents posteriorly a longitudinal groove in which rest the hamstring muscles. The adductor magnus is composed of three superimposed fasciculi, of which the first is frequently fairly distinct and is called the **adductor minimus,** while the other two are normally fused, but are occasionally distinct.

The **superior fasciculus (adductor minimis)** *arises* directly from the inferior rami of the pubis and ischium. From here the fibers diverge to form a thin sheet *inserted* by tendinous bands to the medial side of the gluteal ridge and the superior part of the linea aspera. The **middle fasciculus** *arises* directly from the inferior margin of the ventrolateral surface of the inferior ramus and the tuber of the ischium, and from a tendon which descends along the dorsomedial margin of the muscle from the tuber ischii. The fiber-bundles diverge to be *inserted* between the lamellæ of a narrow flat tendon attached to the distal three-fourths of the linea aspera. This tendon is pierced by the perforating vessels. The **inferior fasciculus** *arises* dorsal to and in common with the middle fasciculus. The fiber-bundles converge toward a strong tendon which begins in the distal third of the thigh and is *inserted* into a tubercle at the distal end of the medial supracondylar ridge.

Nerve-supply.—The chief nerve-supply is from the posterior ramus of the obturator. This enters by one or more branches the proximal portion of the ventral surface of the muscle about midway between its pubic and femoral attachments. It also receives a branch from the sciatic which enters the dorsal surface of the muscle in the middle third of the thigh. To the adductor minimus a branch may be sent from the nerve to the quadratus femoris.

Action.—It is the strongest of the adductors. The superior and middle fasciculi rotate the thigh medialward and flex it; the inferior rotate it lateralward when the thigh is extended, but medialward when the thigh is flexed. The latter also extend the thigh.

Relations.—In front are the pectineus, the short and long adductor and the vastus medialis muscles, and the profunda artery. Behind lie the hamstring muscles and the gluteus maximus. Medially lies the gracilis muscle. The femoral and perforating arteries pass through its attachment to the shaft of the femur.

Variations.—The divisions of the muscle may be more or less distinct. It may be partly fused or exchange fasciculi with neighboring muscles—the semimembranosus, quadratus femoris, adductor brevis, and adductor longus.

Bursæ

B. m. pectinei.—A small bursa frequently present between this muscle and the iliopsoas and small trochanter. **B. anserina.**—A fairly large bursa which lies between the tendons of the sartorius, gracilis, and semitendinosus muscles and the tibial collateral ligament of the knee-joint. (See also B. M. Sartorii Propria, p. 537.)

3. The Posterior (Hamstring) Group

(Figs. 472, 477)

The muscles of this group are the semitendinosus, semimembranosus, and biceps. They flex the leg and extend and adduct the thigh. The semitendinosus and semimembranosus rotate the thigh and the leg medialward; the biceps, lateralward. The semitendinosus and the long head of the biceps constitute a superficial layer; the semimembranosus and the short head of the biceps a deep layer. The **semitendinosus** and the **long head of the biceps** arise by a common tendon from the tuber of the ischium. The somewhat fusiform semitendinosus gives rise to a tendon in the lower half of the thigh. The tendon curves forward behind the knee to be inserted under that of the sartorius into the medial side of the tibia. The penniform **short head of the biceps** arises from the linea aspera in the lower part of the thigh, and is inserted, together with the fusiform long head, into a tendon that passes over the lateral side of the knee and is attached

to the head of the fibula. The **semimembranosus** arises from the tuber ischi through a long, flat, triangular tendon. The belly of the muscle increases ir thickness toward the knee. It is inserted by a strong tendon on the back of the

Fig. 477.—Superficial Muscles of the Back of the Thigh and Leg.

medial condyle of the tibia. From the tendons of all the hamstring muscles expansions are sent into the crural fascia.

The muscles of this group are all supplied by the tibial portion of the sciatic, except the short head of the biceps, which is supplied from the peroneal portion.

The femoral head of the biceps is characteristic of the anthropoid apes and man. In many mammals its place is taken by a slender muscle, the **tenuissimus**, which extends from the caudal vertebræ, the sacrotuberous (great sacrosciatic) ligament, or the gluteal fascia to the fascia of the back of the leg. In some forms this muscle is broad instead of slender. According to Testut, the long head of the biceps may be looked upon as arising by two fasciculi, one primitively attached to the posterior part of the ilium, the other to the caudal vertebræ or coccyx. The sacrotuberous (great sacrosciatic) ligament represents the reduced upper portion of this muscle. In the fetus the origin of the muscle extends higher on the sacrotuberous ligament than in the adult. In many of the lower mammals the origins of the semimembranosus and semitendinosus take place in part from the sacrocaudal vertebræ.

In the mammals below man the insertion of the biceps, gracilis, and semitendinosus takes place chiefly into the fascia of the back of the leg, and extends more distally than in man. This insertion of these flexor muscle is associated with a permanent position of flexion of the leg at the knee. In the human embryo likewise these muscles are inserted more distally than in the adult. In the lower primates the semimembranosus is chiefly a medial rotator of the leg.

Biceps femoris (figs. 472, 477).—**Long head** [caput longum].—*Origin.*—From a tendon common to it and the semitendinosus. This tendon arises from the more medial of the two facets on the back of the tuber of the ischium and from the sacrotuberous (great sacrosciatic) ligament. It is continued for a third of the distance to the knee as a septum between the biceps and the semitendinosus, and for a short distance as an aponeurotic sheath on the deep surface of the biceps.

Structure and insertion.—The fiber-bundles begin to arise from the tendon some distance from the ischium. They form a thick fusiform belly which is inserted into the deep surface of a tendon that begins laterally on the back of the muscle about the middle of the thigh. The insertion of the fiber-bundles of the long head continues on the medial margin of the deep surface of the tendon nearly as far as the lateral condyle of the femur.

Short head [caput breve].—*Origin.*—By short tendinous fibers from the lateral lip of the linea aspera of the femur from the middle of the shaft to the bifurcation of this line, the proximal two-thirds of the supracondylar ridge, and the lateral intermuscular septum.

Structure and insertion.—The fiber-bundles take a nearly parallel course, to be inserted on the deep surface of the common tendon of insertion. The most distal fibers are inserted nearly to the skeletal attachment of the tendon. The tendon is inserted into the superior extremity of the head of the fibula, into the lateral condyle of the tibia, and into the fascia of the leg.

Nerve-supply.—Commonly two branches are given to the long head of the biceps. One of these branches is given off proximal to the ischium, and enters the proximal third of the deep surface of the muscle. The other is given off more distally and usually enters the middle third. Either or both branches may be doubled or the two may be combined for some distance in a common trunk. The nerve-fibers arise usually from the first, second, and third sacral nerves. The branch to the short head arises from the peroneal (external popliteal) portion of the sciatic nerve about the middle of the thigh. It enters the posterior surface near the lateral margin of origin and insertion. The nerve-fibers come chiefly from the fifth lumbar, first and second sacral nerves.

Action.—To extend and adduct the thigh and flex the leg. The short head acts only on the leg. The long head acts as a lateral rotator of the thigh, and of the leg when flexed.

Relations.—The upper extremity of the muscle is covered by the gluteus maximus. Below this the long head and tendon of insertion lie beneath the fascia lata and overlie the short head. Ventral to the muscle lie the tendon of origin of the semimembranosus, the adductor magnus and vastus lateralis muscles, and the lateral head of the gastrocnemius. The medial border is in contact with the semitendinosus and semimembranosus. Distally it forms the upper lateral border of the popliteal space. The sciatic nerve runs between it and the adductor magnus.

Variations.—The short head is rarely absent. It may be more isolated from the long head than usual, and at times has a separate tendon of insertion. It may itself be divided into two distinct laminæ. Its origin may take place higher up on the femur than usual or from the fascia lata. Variations of this sort suggest the tenuissimus muscle of some of the lower mammals (see above). The long head of the biceps may receive accessory fasciculi from the coccyx, sacrum, sacrotuberous (great sacrosciatic) ligament, tuber of the ischium, or the deep surface of the gluteus maximus. These fasciculi suggest the iliac and sacrococcygeal origin of the muscle found in lower vertebrates (see above). Inferiorly, a muscle fasciculus may take the place of the fibrous prolongations from the tendon of the biceps into the sural fascia (the **tensores fasciæ suralis**). This may extend to the tendon of Achilles. The long head may have a tendinous inscription similar to that of the semitendinosus.

The semitendinosus (figs. 472, 477).—*Origin.*—Partly from a mediodorsal facet on the distal margin of the tuber of the ischium by direct implantation of the fiber-bundles, and partly from the medial surface of the tendon common to it and the long head of the biceps.

Structure and insertion.—The fiber-bundles spread out to form a flat, fusiform belly which, about the middle of the thigh, again contracts toward the tendon of insertion. This begins on the medial margin and dorsal surface of the muscle, becomes free from the muscle slightly above the medial condyle of the femur, passes behind this and curves forward to be inserted by a triangular expansion into the proximal part of the medial surface of the tibia behind and distal to the insertion of the gracilis. An aponeurotic expansion is continued into the fascia of the leg. About the middle of the muscle a narrow irregular tendinous inscription more or less completely divides the belly into proximal and distal divisions.

Nerve-supply.—To the muscle two nerves are commonly given. One arises from the sciatic nerve or directly from the plexus, proximal to the tuber of the ischium, sometimes in com-

pany with a branch to the long head of the biceps. It enters the middle third of the deep surfac of the proximal portion of the muscle. The other branch arises from the sciatic nerve, usuall distal to the ischial tuber, sometimes in common with a nerve to the biceps or the semimem branosus. It enters about the middle of the deep surface of the distal half of the muscl Either or both branches may be represented by two nerves. The nerve fibers of the firs branch arise chiefly from the first and second sacral nerves, those of the second from the fift lumbar and first sacral nerves.

Action.—To extend and adduct the thigh and rotate it medialward and to flex the leg and with knee flexed, to rotate the leg medialward.

Relations.—It is covered by the gluteus maximus and fascia lata; on the lateral side lie the biceps; and in front, the semimembranosus and adductor magnus.

Variations.—It may be completely separated from the biceps at its origin. It may b fused with neighboring muscles. There may be two tendinous inscriptions. It may have femoral head (a condition characteristic of many birds). A muscle fasciculus may extend fron the body of the muscle to the fascia of the back of the leg.

The **semimembranosus** (figs. 472, 477).—*Origin.*—By a long, flat tendon which lies beneatl the proximal half of the semitendinosus, and which arises from the more lateral of the two facet on the back of the tuber of the ischium, between the tendons of the biceps and the quadratu femoris. The tendon is at first adherent to the tendon of the adductor magnus in front an to that of the biceps and semitendinosus behind. It descends to the middle of the muscle.

Structure and insertion.—From both surfaces of the medial side and distal extremity o the tendon of origin fiber-bundles arise which take an oblique course to their insertion on th aponeurosis of the tendon of insertion. This appears on the deep surface and medial margi of the muscle opposite the end of the tendon of origin and descends on the medial side and dee surface of the muscle. Near the back of the medial condyle of the femur the insertion of muscle fibers ceases and the tendon is inserted directly on the back of the medial condyle of the tibia and by aponeurotic expansions into the capsule of the joint, into the lateral condyle of the femur into the tibial collateral ligament, and into the fascia of the popliteus muscle.

Nerve-supply.—By several branches from the sciatic nerve, which usually arise from a common trunk in company with the branches to the adductor magnus. These branches ente the deep surface of the muscle about midway between the origin and insertion of the constituen fiber-bundles.

Action.—To flex the leg and rotate it medialward and to extend and adduct the thigh and rotate it medialward.

Relations.—It is covered by the gluteus maximus, the long head of the biceps, the semi-tendinosus, and the fascia lata. It lies dorsal to the quadratus femoris, the adductor magnus, and the knee-joint.

Variations.—It may be fused with the semitendinosus or the adductor magnus. It may be doubled. Its tendons may have a more extensive attachment than usual. The extent of the belly of the muscle varies considerably. A muscle fasciculus may be sent into the popliteal space. An extra head may arise from the ischial spine.

Bursæ

B. m. bicipitis femoris superior.—A fair-sized bursa which frequently lies between the tendon of origin of the long head of the biceps and semitendinosus and the tendon of the semi-membranosus and the ischial tuber. **B. m. bicipitis femoris inferior.**—A small bursa which separates the tendon of insertion from the fibular collateral ligament of the knee-joint. **B. m. bicipitis gastrocnemialis.**—A bursa infrequently found between the tendon of the biceps and the tendons of origin of the lateral head of the gastrocnemius and the plantaris muscles. **B. m. semimembranosi.**—This is a large double bursa constantly present. One part extends between the semimembranosus, the medial head of the gastrocnemius, and the knee-joint. With the cavity of the joint it frequently communicates. The other part extends between the tendon of the semimembranosus and the medial condyle of the tibia.

POPLITEAL SPACE

The diamond-shaped popliteal space or fossa behind the knee is shown in fig. 477. It is bounded above by the biceps laterally and the semitendinosus and semimembranosus medially; below by the two heads of the gastrocnemius. In flexion, the hollow of this space appears; in extension it is obliterated and its boundaries are ill-defined, the only ones now to be made out being the semitendinosus and the biceps. Its *roof* is formed by the popliteal fascia; its *floor* by the planum popliteum of the femur above, by the popliteus muscle (fascia) below, and between these by the oblique popliteal ligament of the knee-joint. Its chief *contents* are the popliteal vessels, the termination of the small saphenous vein, the tibial and common peroneal nerves, and a few popliteal lymph nodes,—all embedded in a mass of fatty tissue.

Landmarks.—When the knee is a little bent and the foot rests on the ground, the following can be made out:—on the *lateral aspect*, behind the iliotibial band, and descending to the prominence on the lateral side of the head of the fibula, is the tendon of the biceps. This prominence also gives attachment to the fibular collateral ligament, which splits the tendon into two parts. Behind is the apex (styloid process) from which the posterior part of the fibular collateral ligament arises. Parallel and close to the medial border of the tendon, the peroneal nerve descends, as a rounded cord, to cross the neck of the fibula and enter the peroneus longus. In tenotomy of the biceps an open incision should be employed to avoid injury to the nerve and insure the division of any contracted fascial bands. On the *medial side* the tendons are thus arranged: Nearest to the middle of the popliteal space is the long and more slender tendon of the semi-tendinosus; next, the thicker tendon of the semimembranosus; this and the gracilis, which comes next, appear as one tendon, but by a little manipulation the finger can be made to sink into the interval between the semimembranosus, with its thick rounded border laterally and the

gracilis medially. The sartorius can easily be thrown into relief on the medial side of the joint by telling the patient to raise the leg extended, the limb being rotated laterally and one leg crosses over the other.

C. MUSCULATURE OF THE LEG

(Figs. 477, 479, 480)

The musculature of the leg arises in part from the distal end of the femur, but in the main from the tibia and fibula. The muscle-bellies are best developed in the proximal half of the leg, where they give rise to the 'calf' behind and to less well-marked ventral and lateral protrusions. Toward the ankle the muscle-bellies give way to tendons which attach the muscles of the leg to the skeleton of the foot.

The musculature is divisible into **anterior,** a **lateral** and a **posterior group** of muscles. The anterior and lateral groups are separated from one another by an intermuscular septum. The anterolateral groups are separated from the posterior group by the tibia and fibula, the interosseous membrane, and by an intermuscular septum which extends from the lateral margin of the shaft of the fibula to the fascia enveloping the leg. Medially the separation is well marked by the broad medial surface of the tibia. Laterally the line of division is not so clearly marked externally. In the proximal part of the leg the dorsal musculature protrudes somewhat ventrally; in the distal part the lateral musculature passes dorsal to the lower end of the fibula. The posterior group is divided by a transverse septum into superficial and deep divisions.

The anterior group of muscles flexes the ankle dorsally, everts the foot and extends the toes. The lateral group extends the ankle (plantar flexion) and everts the foot. The posterior group flexes the knee, extends the ankle, inverts the foot and flexes the toes.

While in the forearm the extensor-supinator muscles extend proximally on the radial side of the arm to the humerus, and the flexor-pronator muscles on the ulnar side, in the leg both of the corresponding sets of muscles extend primitively on the fibular side of the leg to the femur. In the higher vertebrates the superficial layer of the flexor musculature of the leg takes origin from both sides of the distal extremity of the femur, and the origin of the extensor musculature ceases to extend to the femur. The crural musculature is primitively inserted into the bones of the leg, the tarsus, and the aponeuroses of the foot. On the extensor side of the leg the musculature ultimately becomes attached wholly to the foot by means of tendons differentiated, in part at least, from the dorsal aponeurosis. The lateral portion of the extensor musculature, which primitively extends from the femur to the fibula, in the higher vertebrates extends from the fibula to the tarsus and metatarsus (peroneal musculature). On the flexor side of the leg the more superficial musculature maintains a tarsal attachment through the tendon of Achilles. The deeper musculature in part extends from the femur to the tibia, and in part arises from the fibula and tibia, and is inserted into the metatarsus and the digits through tendons differentiated from the plantar aponeuroses. The musculature of the sole of the foot is highly developed in five-toed vertebrates, but in those which walk on the toes, and especially in hoofed animals, it is very greatly reduced.

FASCIÆ OF THE LEG

(Fig. 478)

The **tela subcutanea** of the leg contains a considerable amount of fat where it overlies the muscles, but less where it overlies the bones and joints. Subcutaneous bursæ are found over the tuberosity of the tibia (**b. subcutanea tuberositatis tibiæ**) and over each of the malleoli (**b. subcutanea malleoli medialis et lateralis**). Over the dorsum of the foot the tela contains comparatively little fat, but on the sole of the foot and plantar surface of the toes it contains much fat interposed between dense fibrous tissue. The **b. subcutanea calcanea** lies beneath the tuber calcanei.

The **crural fascia,** or external layer of fascia of the leg, extends from the knee to the ankle. It forms an enveloping cone-like sheath for the muscles and is adherent to the periosteum of the medial surface of the tibia. It is formed of transverse, oblique, and longitudinal fibers and is thickest in front.

Ventrally the fascia of the thigh, to which the tendons of the quadriceps, sartorius, gracilis, semitendinosus, and biceps muscles and the iliotibial band are closely united, becomes attached with these tendons to the tibia and fibula. From these attachments, therefore, the fascia of the front of the leg may be said to arise. Into it extend processes from the tendons mentioned. Dorsally the fascia of the thigh is continued uninterruptedly into that of the leg. Distally the crural fascia is attached to the two malleoli and to the posterior surface of the calcaneus.

In the proximal part of the leg in front the underlying muscles in part take origin from the fascia; in other places the fascia is separated from the underlying muscles by loose tissue.

From the fascia two main intermuscular septa arise. One, the **anterior intermuscular septum,** extends between the extensor digitorum longus and peroneal muscles to the anterior

crest of the fibula; the other, the **posterior intermuscular septum,** between the peroneal muscle and the soleus to the lateral crest of the fibula. These septa separate compartments for th anterior, lateral, and posterior groups of muscles.

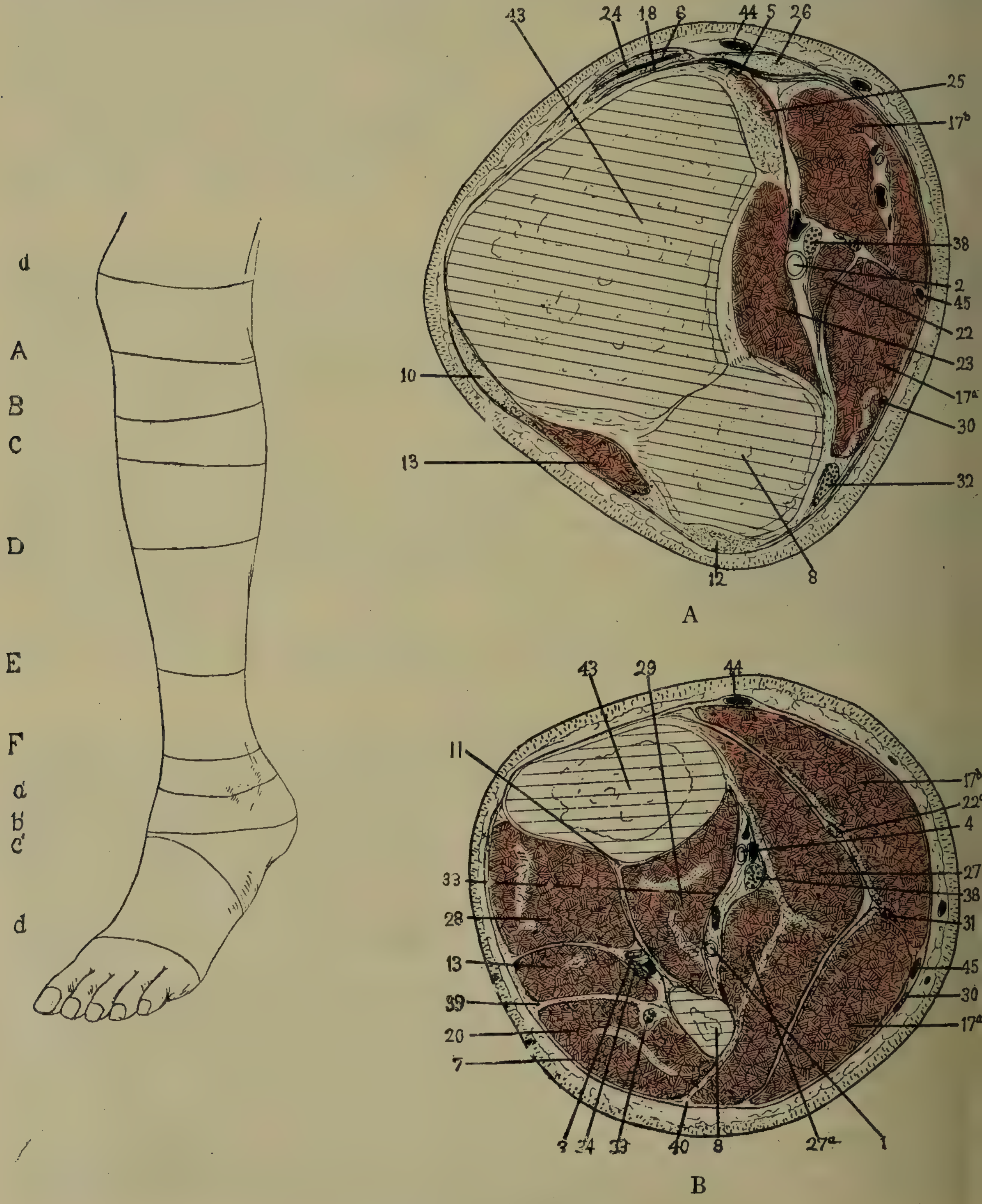
As the heads of the gastrocnemius pass over the back of the knee they are held in place by special deep lamina of the fascia lata, which distally becomes fused with the crural fascia (fig 478 A).

The semimembranosus has a special fascial investment which, on the back of the kne becomes bound on each side of the muscle and its tendon to the capsule of the joint. Thi fascia extends into a transverse septal membrane which is continued over the deep muscles o the back of the leg to the ankle. It is united on one side to the tibia, on the other to the fibula Proximally the fibers are continued into it from the tendon of the semimembranosus. Ove the back of the tibia the septum is interrupted by the attachment of the soleus to the poplitea line. Beyond the tibial origin of the soleus it is fused on the medial side of the flexor digitorun longus to the crural fascia.

In addition to the two intermuscular septa and the longitudinal transverse septum, othe septa serve to separate the individual muscles of the different groups.

Above the ankle the fascia is reinforced by bands of tissue so that ligaments are forme which serve to retain in position the various tendons which pass from the leg into the foot.

The **transverse crural ligament** (upper part of anterior annular ligament) (fig. 479) lie on the front of the lower part of the leg above the ankle. It is composed of fascia strengthene by transverse bundles which pass from the medial side of the tibia to the ventral margin of th fibula. From its deep surface a strong, broad septum descends to the tibia and divides th underlying space into two osteofibrous canals, a medial for the tibialis anterior and a latera



For Legend See Page 545.

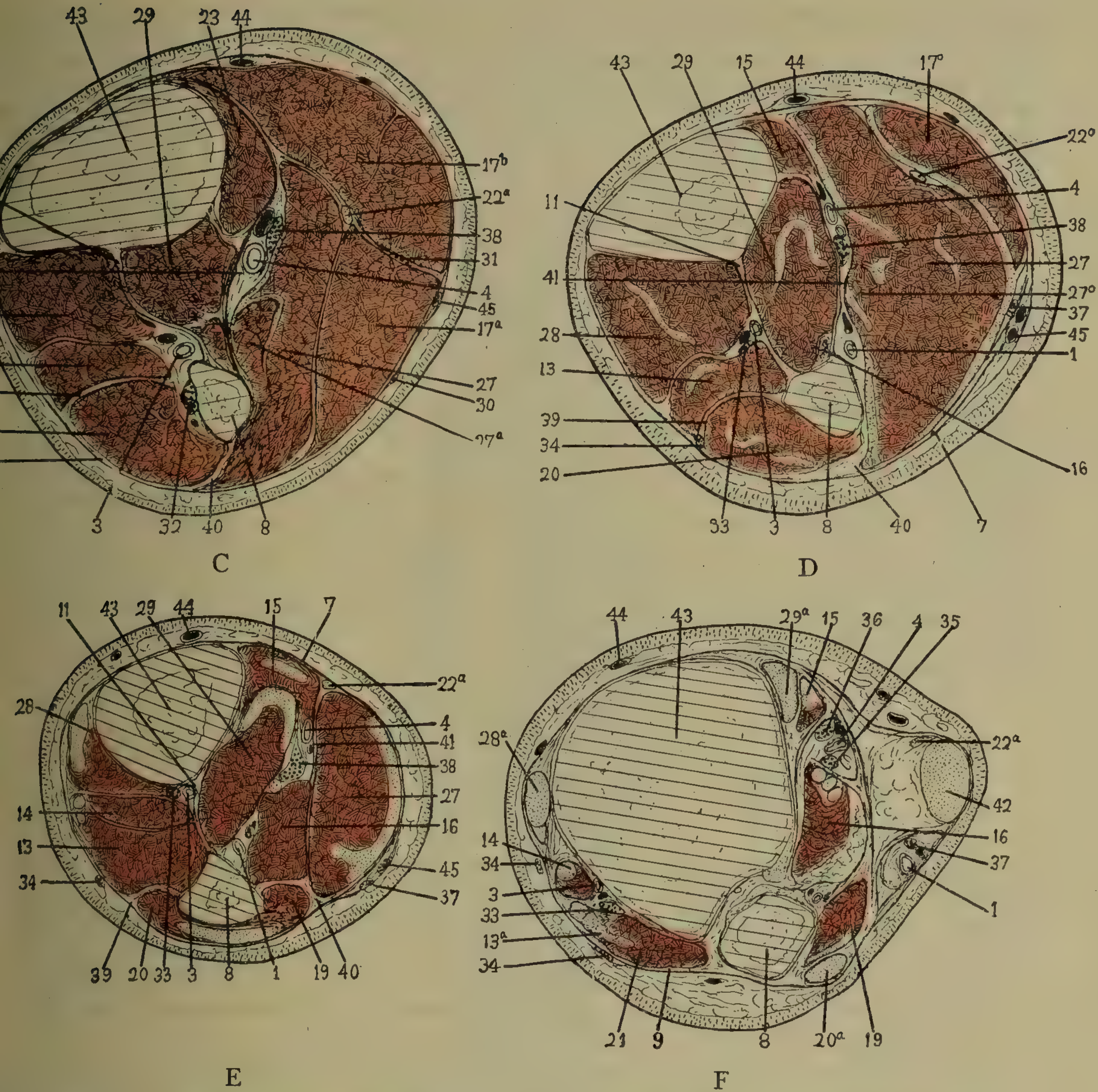


Fig. 478, A–F.—Transverse Sections through the Left Leg in the Regions shown in the Diagram.

d In the diagram indicates the region through which passes section D, fig. 474; *a′*, *b′*, *c′*, *d′*, the regions through which pass sections A, B, C, D, fig. 481.

1. Arteria peronea. 2. A. poplitea. 3. A. tibialis anterior. 4. A. tibialis posterior. 5. Bursa anserina. 6. Bursa m. sartorii propria. 7. Fascia cruralis. 8. Fibula. 9. Ligamentum crurale transversum. 10. Lig. patellæ. 11. Membrana interossea. 12. Musculus biceps femoris—tendon. 13. M. extensor digitorum longus—a, tendon. 14. M. extensor hallucis longus. 15. M. flexor digitorum longus. 16. M. flexor hallucis longus. 17. M. gastrocnemius—a, lateral head; b, medial head. 18. M. gracilis, tendon. 19. M. peroneus brevis. 20. M. peroneus longus—a, tendon. 21. M. peroneus tertius. 22. M. plantaris—a, tendon. 23. M. popliteus. 24. M. sartorius, tendon. 25. M. semimembranosus, tendon. 26. M. semitendinosus, tendon. 27. M. soleus—a, fasciculus accessorius. 28. M. tibialis anterior—a, tendon. 29. M. tibialis posterior—a, tendon. 30. N. cutaneus suræ lateralis. 31. N. cutaneus suræ medialis. 32. N. peroneus communis (external popliteal). 33. N. peroneus profundus (anterior tibial). 34. N. peroneus superficiales (musculocutaneus). 35. N. plantaris lateralis (external plantar). 36. N. plantaris medialis (internal plantar). 37. N. suralis (external saphenous). 38. N. tibialis (posterior tibial). 39. Septum intermusculare (anterior). 40. S. intermusculare (posterior). 41. S. suræ transversum. 42. Tendo Achillis (calcaneus). 43. Tibia. 44. Vena saphena magna. 45. V. saphena parva.

for the long extensor muscles. The lateral compartment is further subdivided by a slightly marked septum into a medial division for the extensor hallucis longus and a lateral for the extensor digitorum longus and the peroneus tertius.

The **cruciate ligament** (lower part of anterior annular ligament) (figs. 479, 482, 483) holds the tendons of the anterior muscle group in place as they pass to the dorsum of the foot. In part it is formed by a dense fibrous band lying in the fascia over the ankle, in part of a ligament which passes from the bones of the ankle to the deep surface of this band. The superficial band is V-shaped. It arises from the lateral surface of the body of the calcaneus and passes

across the dorsum of the foot, one arm of the V going to the medial malleolus, the other to th side of the foot, where it terminates in the fascia over the first cuneiform bone. The apex o the V lies over the tendons of the extensor digitorum longus and peroneus tertius muscles The distal arm extends over the tendons of the extensor hallucis longus and tibialis anterio muscles. The proximal arm passes over the tendon of the extensor hallucis longus and the divides into two layers, between which the tendon of the tibialis anterior passes. The deepe ligament mentioned above arises from deep within the tarsal sinus, some of its fibers eve from the sustentaculum tali. It then passes forward and medially beneath the long extenso tendons, and divides into two parts, one of which curves about the medial margin of the tendon of the extensor digitorum longus, the other about the extensor hallucis longus tendon to the under surface of the proximal arm of the V-shaped band.

The **peroneal retinacula** are strengthened regions in the fascia which serve to hold the tendons of the peroneal muscles in place. The **superior** extends from the lateral malleolus into the fascia on the back of the leg, and to the lateral surface of the calcaneus. The **inferio** overlies the tendons on the lateral surface of the calcaneus, and is attached to this bone on each side of them. Between the tendons it sends a septum to the bone. It is connected with the superficial layer of the cruciate ligament (figs. 482, 483).

The **laciniate ligament** (internal annular) (figs. 480, 482) is on the medial side of the ankle Here the fascia is strengthened by fiber-bands which form a well-marked ligament that holds in place the tendons of the deep dorsal cruropedal muscles. This ligament extends from the dorsal and distal margins of the medial malleolus to the calcaneus. It is closely bound to the tibia and the talotibial (tibioastragaloid) ligament until the tendon of the tibialis posterior is reached. It passes over this and becomes bound to the bony structures on the posterior margin of the tendon. From this attachment two layers, a deep and a superficial, extend backward. The superficial layer extends to the tuber calcanei, and is connected superiorly with the crural fascia. The deep layer, which represents a continuation distally of the transverse septum, extends over the tendons of the flexor digitorum longus and flexor hallucis longus to the medial surface of the calcaneus, and is closely united to the underlying bone on each side of these tendons, thus giving rise to osteofibrous canals.

MUSCLES

1. Muscles of the Front of the Leg

(Figs. 479, 486)

The anterior musculature of the leg consists of four muscles, the tibialis anterior, extensor digitorum longus, peroneus tertius, and extensor hallucis longus. The **tibialis anterior** has a quadrangular prismatic belly which arises from the lateral side of the tibia and adjacent interosseous membrane in the proximal half of the leg. The tendon passes over the front of the tibia to the first metatarsal. The **extensor digitorum longus** is a transversely flattened, fusiform muscle, which arises from the superior extremity of the tibia, the anterior crest of the fibula, and the adjacent interosseous membrane, and gives rise to a tendon which passes over the front of the distal extremity of the tibia and sends tendons to the terminal phalanges of the four more lateral toes. The **peroneus tertius** represents a more or less completely differentiated portion of the preceding muscle. Its tendon passes laterally through the same osteofibrous canal in the same synovial sheath and terminates on the fifth metatarsal. The **extensor hallucis longus** is a narrow muscle which arises from the distal half of the medial surface of the fibula and the interosseous membrane. Its tendon extends over the ankle to the great toe. The tendons of these muscles are held in place by the transverse and cruciate ligaments described above.

All the muscles of this group flex the foot. The extensors extend the toes; the peroneus tertius and the extensor digitorum longus evert the foot. The nerve supply is from the deep peroneal (anterior tibial) nerve.

The tibialis anterior is represented in the arm probably by the brachioradialis and the two radial extensors; the extensor digitorum longus by the extensor digitorum communis and extensor digiti quinti proprius; and the extensor hallucis longus by the extensor pollicis longus. Two abnormal muscles not infrequently found, the abductor hallucis longus and extensor primi internodii hallucis, represent probably the corresponding normal muscles of the hand.

The **tibialis anterior** (or dorsalis NK) (fig. 479). *Origin.*—From the distal surface of the lateral condyle of the tibia, and the lateral surface of the proximal half of the shaft of the tibia, the adjacent interosseous membrane, the overlying fascia near the condyle (tuberosity) of the tibia, and the intermuscular septum between it and the extensor digitorum longus.

Structure.—Bipenniform. The fiber-bundles converge upon a flat tendon which begins high in the muscle and emerges on the anterior margin of the muscle about the middle of the leg. On the deep surface the implantation of fiber-bundles continues to the transverse crural (anterior annular) ligament.

Insertion.—The tendon passes over the front of the tibia to the medial side of the foot, where it is inserted into the medial surface of the first cuneiform and the base of the first metatarsal.

Nerve-supply.—As a rule, a branch from the common peroneal (external popliteal) nerve enters the proximal portion of the muscle by several twigs, and another from the deep peroneal (anterior tibial) enters near the middle of the belly on the lateral edge.

Relations.—In the proximal half of the leg the extensor digitorum longus lies lateral to it; and between the two muscles, the anterior tibial artery and vein. It is covered by the crural fascia and rests on the interosseous membrane. Distally it lies over the extensor hallucis longus. The tendon passes in special compartments beneath the transverse and the cruciate (anterior annular) ligaments.

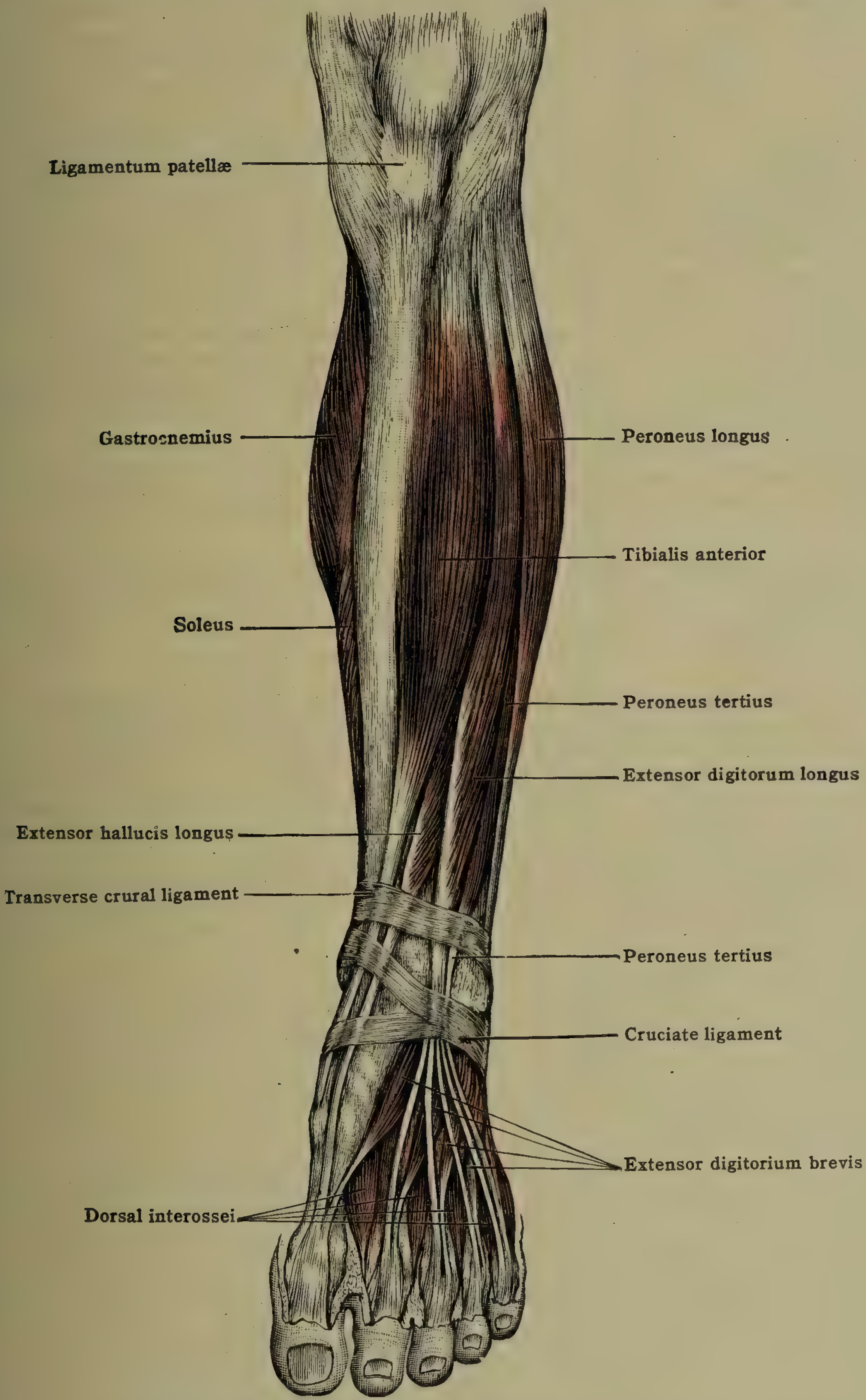


FIG. 479.—THE MUSCLES OF THE FRONT OF THE LEG.

The extensor digitorum longus (fig. 479).—*Origin.*—From the lateral condyle of the tibia, the anterior crest (surface) of the fibula, the intermuscular membrane between it and the tibialis anterior, the lateral margin of the interosseous membrane, the septum between it and the peroneus longus, and the fascia of the leg near the tibial origin.

Structure.—Penniform. The fiber-bundles converge upon the posterior surface of a tendon which begins at the middle of the leg. The implantation of fibers continues nearly to the

ankle. Usually at the distal margin of the transverse (anterior annular) ligament the tendo divides into two parts which pass between the two layers of the cruciate (lower part of an terior annular) ligament, and then each divides again into two parts, thus giving rise to fou slips, one for each of the four lateral toes.

Insertion.—Each tendon on the dorsal surface of the toe to which it goes divides into thre fasciculi: an intermediate, which is attached to the dorsum of the base of the second phalanx and two lateral, which converge to the dorsum of the base of the third phalanx. The margin of the tendon are also bound by fibrous tissue to the sides of the back of the first phalanx.

Nerve-supply.—Most frequently two branches of the deep peroneal (anterior tibial) ente the deep surface of the muscle, one near its tibial origin, one about the center of the belly.

Relations.—In the proximal half of the leg it lies on the interosseous membrane, and beneatl the fascia of the leg, and adjoins medially the tibialis anterior, laterally the peroneus longus Distally it lies over the extensor hallucis longus and adjoins laterally the peroneus brevis. Th tendon passes beneath the transverse crural and the superficial layer of the cruciate (anterio annular) ligaments and over the extensor digitorum brevis muscle. The superficial peronea (musculocutaneous) nerve runs in the septum between it and the peroneal muscles; the anterio tibial artery and deep peroneal nerve pass beneath the head of the muscle, and then betwee it and the tibialis anterior.

The peroneus tertius (fibularis tertius NK) (fig. 479).—*Origin.*—From the distal third of th medial surface of the fibula, the neighboring interosseous membrane, and the anterior inter muscular septum.

Structure.—It is essentially a fasciculus of the extensor digitorum longus, from which it i seldom completely differentiated. The fiber-bundles descend obliquely forward to be insertec in a penniform manner on a tendon which runs along the lateral margin of the tendons of th extensor digitorum. The attachment of fiber-bundles continues to the cruciate ligament (lowe part of anterior annular ligament).

Insertion.—On the base of the fifth metatarsal and often also on the base of the fourth.

Nerve-supply.—The more distal nerve to the extensor digitorum continues into this muscle

Relations.—It lies lateral to the extensor digitorum longus. Its tendon passes into the foo beneath the transverse crural and the superficial layer of the cruciate ligament in the sam compartments with those of the extensor longus.

The extensor hallucis longus (fig. 479).—*Origin.*—From the middle two-fourths of th medial surface of the fibula near the interosseous crest, and from the distal half of the inteos seous membrane.

Structure.—Penniform. The fiber-bundles are attached as far as the cruciate ligament to the back and sides of a tendon which begins on the anteromedial margin of the distal third of the muscle.

Insertion.—On the base of the second phalanx of the big toe. On the back of the first phalanx the margins of the tendon are attached to the bone by bands of fibers.

Nerve-supply.—As a rule, a branch from the deep peroneal (anterior tibial) nerve enters the deep surface of the muscle near the junction of the upper and middle thirds, and passes distally across the middle of the obliquely running muscle fiber-bundles.

Relations.—It lies on the distal half of the interosseous membrane, partly covered by the extensor digitorum longus and the tibialis anterior muscles. Its tendon passes over the front of the distal extremity of the tibia and the medial side of the dorsum of the foot and is held in place by the transverse and cruciate ligaments and by a strengthening band in the fascia over the base of the first metatarsal. In the distal part of the leg the anterior tibial artery and the deep peroneal (anterior tibial) nerve pass beneath the muscle to enter the foot at the lateral side of its tendon.

Actions of the muscles of this group.—All flex the ankle. The tibialis anterior and extensor hallucis longus evert the foot at the talocalcaneonavicular joint, and invert it at the talonavicular and calcaneocuboid joints. The peroneus tertius and the long extensor of the toes evert the foot. The force of the extensor hallucis longus is exerted powerfully on the first phalanx and weakly on the second. The short muscles of the big toe aid in extending the second phalanx. The extensor digitorum longus extends the first phalanx of each toe powerfully, but exerts less force on the second and third. The lumbrical muscles assist in extending the last two phalanges.

Variations.—The origin of the tibialis anterior may extend to the femur. Its tendon of insertion may give accessory slips to the cuneiforms, metatarsals, and phalanges. More rarely its belly is divided into two portions, one of which sends a tendon to the first cuneiform and one to the first metatarsal. A slip, the **tensor fasciæ dorsalis pedis** (Wood), may pass to the dorsal fascia of the foot. Another, the **tibioastragalus anticus** (Gruber), to the talus (astragalus) or calcaneus. The bellies or the tendons of the extensor hallucis and extensor digitorum may be more or less completely fused, or tendon slips may pass from the tendon of one muscle to that of the other. Tendon slips may pass to the metatarsal bones or from the tendon of one toe to that of a neighboring toe. The tendon to each toe may be doubled. The belly of the extensor digitorum longus may be more or less completely subdivided to correspond with the tendons to individual toes. The peroneus tertius is frequently fused with the long extensor. It may be doubled. More often its tendon may bifurcate or trifurcate and be inserted into the extensor tendons of the fifth toe or into the fourth or third metatarsal. It is absent in about 8.5 per cent. of bodies (Le Double).

Abnormal Muscles.—The **abductor hallucis longus** is rarely found as a completely independent muscle. It usually arises as a fasciculus of the extensor digitorum longus, extensor hallucis longus, or the tibialis anterior. It is inserted into the base of the first metatarsal. The **extensor primi internodii hallucis** (extensor hallucis brevis) has an origin similar to that of the long abductor above described. It is inserted into the dorsum of the base of the first phalanx of the big toe. It is not to be confounded with that portion of the extensor digitorum brevis connected with the great toe and also sometimes called the extensor hallucis brevis.

B. subtendinea m. tibialis anterioris.—A small bursa between the medial surface of the first cuneiform bone and the tendon of the tibialis anterior. **B. subtendinea m. extensoris hallucis longi.**—A small bursa beneath the tendon near the tarsometatarsal articulation. It may communicate with the synovial sheath of the tendon. **B. sinus tarsi.**—A large bursa in the sinus tarsi and on the lateral surface of the neck of the talus (astragalus) beneath the tendons of the extensor digitorum longus and the fibrous bands between the talocalcaneal and the cruciate ligaments. It extends back to the talocrural, forward to the talonavicular joint, and may communicate with the joint cavity of the latter.

2. Lateral Musculature of the Leg

(Figs. 479, 480, 490)

The lateral muscles consist of the peroneus longus and the peroneus brevis. They extend and evert the foot. The thick prismatic belly of the **peroneus longus** arises from the proximal half of the lateral surface of the fibula and from neighboring structures, while the smaller belly of the **peroneus brevis** arises from the middle third of the lateral surface of this bone. The peroneus longus partly covers the peroneus brevis. The tendons of the two muscles pass behind the lateral malleolus, held in place by special retinacula (p. 546). There the tendon of the peroneus longus lies at first lateral to and then crosses behind that of the peroneus brevis and curves about the lateral side of the calcaneus and across the sole of the foot closely applied to the cuboid and to the tarsometatarsal articulations, and terminates on the base of the first metatarsal. The tendon of the peroneus brevis terminates on the lateral side of the foot at the base of the fifth metatarsal. The nerve supply is from the superficial peroneal (musculocutaneous) nerve.

The two muscles are probably represented in the arm by the extensor carpi ulnaris. In some of the lower animals the head of the peroneus longus extends to the femur. The fibular collateral ligament of the knee-joint probably represents in man the femoral head of the peroneus longus.

The peroneus longus (fibularis longus NK) (figs. 480, 490).—*Origin.*—Anterior head: tendinous from the anterior tibiofibular ligament, the neighboring part of the lateral condyle of the tibia, and the head of the fibula; fleshy from the proximal third of the anterior intermuscular septum and the crural fascia near the tibia. Posterior head: fleshy from the proximal half of the lateral surface of the shaft of the fibula and from the posterior intermuscular septum.

Structure.—Bipenniform. The fiber-bundles converge upon a tendon which begins high in the muscle. The constituent fiber-bundles of the anterior head are long and take a nearly vertical course. The fiber-bundles of the posterior head take a more oblique course and their attachment extends more distally on the tendon. The tendon emerges on the surface of the muscle in the distal half of the leg. The fiber-bundles of the posterior head extend to within a few centimeters of the lateral malleolus. The tendon passes through the retromalleolar groove, passes across the lateral face of the calcaneus, to and through the peroneal groove of the cuboid, and crosses the second and third tarsometatarsal joints. Where the tendon enters the groove in the cuboid it contains a fibrocartilaginous nodule which may become a sesamoid bone.

Insertion.—On the inferior surface of the first cuneiform and on the inferolateral border and base of the first metatarsal. From the region of the fibrocartilaginous nodule above mentioned a fibrous slip is usually sent to the base of the fifth metatarsal.

Nerve-supply.—Most often the common peroneal (external popliteal) nerve before dividing gives off two branches. One of these enters the deep surface of the middle third of the anterior head, the other passes across the middle third of the constituent bundles of the posterior head. The latter branch may arise from the superficial peroneal (musculocutaneous) nerve, and it may extend to supply the peroneus brevis.

The peroneus brevis (fibularis brevis NK) (fig. 480).—*Origin.*—From the middle third of the lateral surface of the fibula; (2) from the septa which separate it from the anterior and posterior groups of muscles.

Structure.—Penniform. The fiber-bundles converge upon a tendon which begins high in the muscle and becomes visible on the lateral surface of the distal half of the belly. Behind the lateral malleolus the tendon becomes free, then passes forward below the malleolus and across the calcaneus and cuboid.

Insertion.—Into the tip of the tuberosity of the fifth metatarsal.

Nerve-supply.—The nerve arises from the superficial peroneal (musculocutaneous) nerve, or from a branch to the peroneus longus. It enters the proximal margin of the muscle and passes distally across its constituent fiber-bundles.

Relations.—The peroneal muscles in the leg are contained in a compartment bounded by the anterior and posterior intermuscular septa, by the fibula, and by the fascia of the leg. The peroneus longus to a considerable degree overlies the peroneus brevis. Beneath the upper part of the peroneus longus the peroneal (external popliteal) nerve bifurcates into its two chief branches. The deep peroneal (anterior tibial) nerve passes medially beneath the anterior head of the muscle. The superficial peroneal (musculocutaneous) nerve extends in the interval between the areas of the attachment of the two heads of the peroneus longus, and along the anterior margin of the peroneus brevis to the anterior intermuscular septum, through which it passes to its superficial distribution. The tendon of the peroneus longus at first lies lateral to

and slightly overlaps that of the peroneus brevis. Toward the tip of the malleolus it lies almos directly posterior to this tendon. On the lateral surface of the calcaneus the tendon of th brevis lies superior to that of the longus, from which it is separated by bony spine, the processu trochlearis of the calcaneus. The tendon of the longus is separated from the deep surface of th abductor of the little toe, and is held in place in the groove in the cuboid by the long planta ligament.

Action.—The peroneus brevis everts the foot. The peroneus longus extends, abducts, an everts the foot, and supports the arch of the foot. The peroneus brevis also extends the foo when this is flexed.

Variations.—The two peroneal muscles may be more or less fused. The origin of th peroneus longus may extend to the femur. The two heads of origin may be fused. Its tendo of insertion may send slips to the second, third, and rarely to the fourth and fifth metatarsals The tendon may be united to that of the tibialis posterior (12 out of 45 bodies—Picou). Sesa moid cartilages or bones are occasionally found in the retromalleolar and calcaneal portions c the tendon. The tendon of the peroneus brevis may send a slip to the second or third phalan or to the head of the metatarsal of the fifth toe, to its extensor tendon, or to the cuboid. It ma also send a fasciculus to the fourth metatarsal or the extensor tendon of the fourth toe.

Accessory peroneals.—Poirier considers these all varieties of a muscle which in its simples form arises from the distal fourth of the fibula and is inserted by a tendon into the fifth toe. corresponding muscle is normally found in many of the monkeys (**peroneus digiti quinti**). I man in one form or another it is a frequent anomaly. It may be so fused with the peroneu brevis that only its tendon of insertion is apparent. It may appear as a special muscle fasciculu of the peroneus longus or brevis. It may be merely a tendinous band, or it may be tendinou at origin and insertion, with an intermediate belly. Instead of being attached to the fifth toe it may be inserted into the fifth metatarsal, the cuboid, the tendon of the peroneus longus, th calcaneus, lateral malleolus, or posterior talofibular ligament.

3. Musculature of the Back of the Leg

a. Superficial Group (fig. 477)

To this group belong the gastrocnemius, soleus, and plantaris muscles. The extend the foot and flex the leg. The two ovoid heads of the **gastrocnemius** aris one on each side from above the condyles of the femur, extend about to the middl of the back of the leg, and are inserted into the posterior surface of the tendon o Achilles, and through this into the back of the calcaneus. The broad, flat, ovoi **soleus** arises beneath the gastrocnemius from the tibia and fibula, and is in serted into the deep surface of the tendon of Achilles as far as the ankle. The two heads of the gastrocnemius and the soleus constitute the **triceps suræ**. The **plantaris** is a slender muscle which passes along the medial margin of the latera head of the gastrocnemius and beneath the medial head, where it gives rise to slender tendon that runs between the gastrocnemius and soleus and along the medial margin of the tendon of Achilles [tendo Achillis] to the fatty fibrou tissue of the heel. The nerve-supply is from the tibial nerve.

The muscles of this group have a common embryonic origin, and are first differentiate on the fibular side of the leg, whence they extend over the posterior tibial vessels and nerve t their medial attachments. The gastrocnemius corresponds with the flexor carpi radialis an ulnaris, the plantaris with the palmaris longus, the soleus with a portion of the flexor digitorun sublimis of the forearm. In many of the monkeys and in the prosimians the plantaris is much more developed than in man.

The gastrocnemius (fig. 477).—**Medial head.**—*Origin.*—From a facet on the back of the medial condyle of the femur above the articular surface, from an area on the back of the femu superior and lateral to this, and from the femoral margin of the capsule of the knee-joint **Lateral head.**—*Origin.*—From a facet on the proximal portion of the posterolateral surface of the lateral condyle of the femur and from a rough area situated more medially and at greater distance from the joint.

Structure and insertion.—The heads of the gastrocnemius are similar in structure. From the condylar facets there descend aponeurotic bands, one on the medial margin and the medial side of the posterior surface of the medial head, the other on the lateral margin and the lateral side of the posterior surface of the lateral head. These bands descend about two-thirds of the way down the muscle. In the tendon of the lateral head a sesamoid bone is frequently found. The fiber-bundles of the muscle pass obliquely from the supracondylar areas of origin and from the deep surface of the aponeurosis on each side to the tendon of insertion. This tendon begins as a septum between the two heads, and as a lamina on the deep surface of each head. The septum and laminæ soon fuse with the broad aponeurosis which covers the dorsal surface of the soleus. The attachment of fiber-bundles continues to about the middle of the back of the leg. The attachment of the medial head extends more distally than that of the lateral head. As a rule, the medial head is also the broader and thicker of the two.

The soleus (fig. 477).—*Origin.*—(1) By a fibular head from the back of the head and the proximal third of the posterior surface of the shaft of the fibula, and from the intermuscular septum between it and the peroneus longus; and (2) by a tibial head from the transverse septum over the distal margin of the popliteus, from the popliteal line, and from the middle third of the medial border of the tibia.

Structure and insertion.—From the fibular and tibial origins arise broad aponeuroses which unite proximally on the deep surface of the muscle so as to form a fibrous arch over the pos-

terior tibial vessels and nerves. Distally they diverge and become more narrow, but the fibular aponeurosis is continued on the fibular side and the tibial aponeurosis on the tibial side of the muscles as far as the distal quarter of the leg. The main portion of the belly of the muscle is formed by fiber-bundles which arise from the posterior surface of these aponeuroses and pass obliquely to be inserted in a bipenniform manner on the deep surface of the tendon of Achilles. This tendon begins as a broad aponeurosis which covers the greater part of the posterior surface of the muscle, and gradually converges into a heavy fibrous band that is inserted into the calcaneus. The bundles of fibers of the tendon take a slightly spiral course. Those on the posterior surface run from the medial margin toward the lateral surface of the calcaneus; those on the anterior surface in a reverse direction. The attachment of the fiber-bundles continues to within a short distance of the heel. A few of the fiber-bundles arise directly from the fibula and the posterior intermuscular septum. On the deep surface of the belly of the muscle there is an **accessory fasciculus** which is formed by fiber-bundles that spring on each side from the anterior surface of the aponeuroses of origin of the muscle and have a bipenniform insertion on each side of a thin, oblique tendinous lamina which inferiorly becomes united to the deep surface of the tendon of Achilles.

The plantaris (fig. 477).—This muscle *arises* from the distal part of the lateral line of bifurcation of the linea aspera, in close association with the lateral head of the gastrocnemius. The fiber-bundles give rise to a flat, short, fusiform belly, and are united to a narrow tendon which extends along the medial edge of the tendon of Achilles to the dorsal surface of the calcaneus, where it *terminates* in the neighboring fibrous tissue.

Nerve-supply.—From the tibial (internal popliteal) part of the sciatic nerve in the popliteal space nerves arise for each head of the gastrocnemius. Each nerve enters the middle third of the deep surface of the head near the proximal margin. The nerve-supply for the soleus is from two sources. One nerve arises in the popliteal space, often in company with the nerve to the lateral head of the gastrocnemius. It enters the posterior surface of the muscle near the proximal border and divides into two branches, one for each head of the muscle. The tibial (posterior tibial) nerve gives rise to a branch which, about half-way down the leg, enters the deep surface of the muscle and furnishes branches for the deep portion of the muscle on each side The nerve-supply of the plantaris is by a branch from the tibial (internal popliteal) portion of the sciatic. This arses in the popliteal space and enters the deep surface of the muscle.

Relations.—The semimembranosus winds about the medial margin of the medial head of the gastrocnemius to its deep surface. The biceps passes to the lateral side of the lateral head of the gastrocnemius, and the plantaris along its medial margin. The semimembranosus and biceps above, the medial head of the gastrocnemius and the plantaris below, bound the popliteal space. The peroneal (external popliteal) nerve passes from the popliteal space obliquely across the plantaris and the lateral head of the gastrocnemius. The medial sural (short saphenous) nerve and the small saphenous vein pass between the heads of the gastrocnemius to the surface and thence to the lateral side of the ankle. From the peroneal (external popliteal) nerve in the popliteal space the lateral sural (communicans peronei) nerve extends distally over the calf. The (posterior) tibial nerve and posterior tibial artery and vein run between the two heads of the gastrocnemius, and then beneath the soleus to the medal side of the ankle. In the region of the tendon of Achilles a considerable space filled with fatty tissue intervenes between the tendon and the transverse septum.

Action.—The contraction of the triceps suræ produces extension, adduction, and inversion of the foot. The gastrocnemius is also a flexor of the leg. The plantaris is a weak flexor of the leg at the knee, and extensor of the foot at the ankle.

Variations.—There is considerable variation in the extent of the separation of the different parts of the triceps suræ. The tendons of the three heads may be separate nearly to the heel. Either or both heads of the gastrocnemius or the soleus may be doubled. A slip from the biceps or semimembranosus, from the linea aspera, or popliteal space may join the triceps and give rise to a quadriceps suræ. On the other hand, one of the heads of the gastrocnemius or the tibial head of the soleus may be missing. A supernumerary fasciculus may extend from the deep surface of the soleus to the calcaneus. The plantaris is exceedingly variable in origin, structure, and insertion. The origin may be from the capsule of the knee-joint, the fascia of the leg, or from the tibia. Its tendon may terminate at almost any part of its course in neighboring structures. It may be represented by a fibrous band. It is absent in about 7 per cent. of instances (Le Double).

Bursæ

B. m. gastrocnemii lateralis.—A bursa is often found between the tendon of the lateral head of the gastrocnemius and the capsule of the joint. It may communicate with the joint cavity. **B. m. gastrocnemii medialis.**—A bursa usually lies between the tendon of origin of the medial head of the gastrocnemius, the condyle of the femur, and the capsule of the joint. Another bursa (**b. m. semimembranosi**) extends between the semimembranosus and the medial head of the gastrocnemius muscle. The two bursæ frequently communicate with one another and with the joint. **B. tendinis calcanei.**—This lies between the tendon of Achilles and the upper part of the back of the calcaneus. Between the back of the tendon and the crural fascia another bursa is frequently present.

b. Deep Group

The deep posterior musculature is separated from the superficial by the transverse septum described above (p. 544). The muscles covered by this septal fascia are the **popliteus**, the **flexor digitorum longus**, the **flexor hallucis longus**, and the **tibialis posterior.** An intermuscular septum between the popliteus and the tibialis posterior, and the attachment of the soleus to the popliteal line on the

back of the tibia serve to separate the popliteus from the other deep posteric muscles which lie distal to this region and send tendons into the sole of the foo The deep posterior musculature may thus be considered as divided into a proxima femorotibial and a distal cruropedal group. Both sets of muscles are supplie by branches of the tibial nerve.

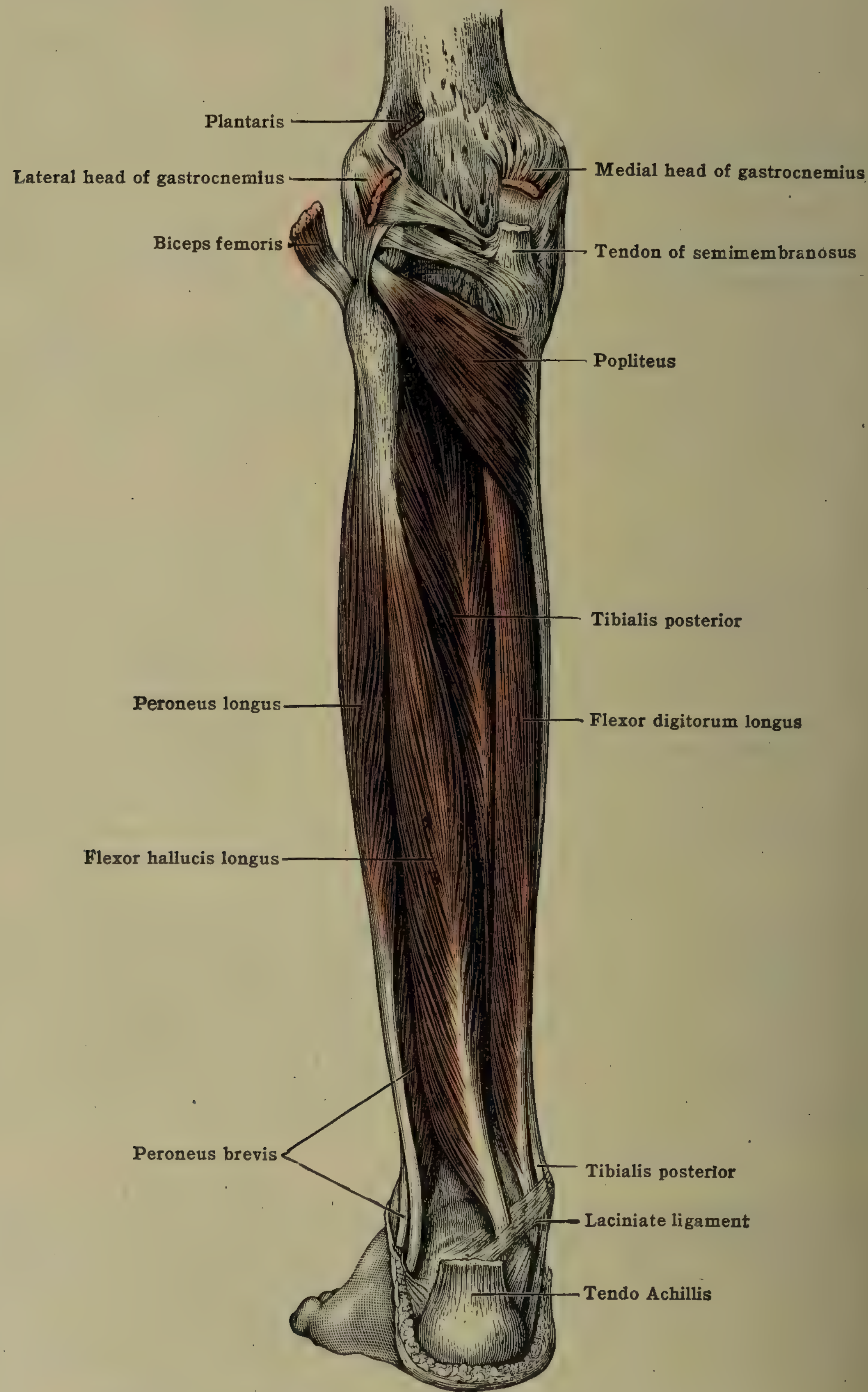


Fig. 480.—The Deep Muscles of the Back of the Leg.

Femorotibial Muscle

The popliteus (fig. 480).—A triangular muscle which *arises* from an ovoid facet at the inferior extremity of the groove on the outer side of the lateral condyle of the femur and is *inserted* into the proximal lip of the popliteal line of the tibia and the surface of the shaft of the tibia proximal to this. It rotates the leg medialward and flexes it.

Structure.—From the origin a broad tendon glides over the condyle within the capsule of the joint, then over the lateral fibrocartilage and through a groove on the back of the tibiofibular articulation. From both surfaces of this tendon, fiber-bundles diverge toward the area of insertion. The tendon is more or less intimately united to several structures with which it comes in contact about the joint. Rarely it contains a sesamoid bone. The fibers of insertion terminate in part in the fascia covering the muscle. The popliteus is homologous with the pronator teres of the arm, or, according to some investigators, with the deep portion of that muscle.

Nerve-supply.—A nerve which arises either independently or in conjunction with that to the posterior tibial muscle enters the popliteus near the middle of its distal edge. Sometimes a branch from the chief nerve to the knee-joint enters the proximal edge of the muscle.

Action.—To flex and rotate the leg medially.

Relations.—The popliteus lies within a compartment bounded by the transverse septum, the capsules of the knee and superior tibiofibular joints, the back of the tibia, and a septum extending to the popliteal line (see above). On the transverse septum run the popliteal vessels and the tibial nerve. The proximal margin of the soleus overlaps the distal margin of the popliteus. The synovial membrane of the knee-joint sends a prolongation between its tendon and the back of the lateral condyle of the tibia.

Variations.—It is rarely absent. An accessory head may arise from the medial side of the lateral condyle or from some neighboring structure. The **fibulotibialis** (peroneotibialis) is a small muscle found by Gruber in one body in seven. It arises from the medial side of the head of the fibula and is inserted into the posterior surface of the tibia beneath the popliteus.

Cruropedal Muscles (figs. 480, 488)

Of the three muscles of this group, the **flexor digitorum longus** lies on the tibial side of the leg, the **flexor hallucis longus** on the fibular side, and the **tibialis posterior** upon the interosseous membrane, partly covered by the other two muscles, beneath the former of which it crosses, distally, to the tibial side of the leg. Septa separate the flexor muscles from the tibialis. The tendons of the three muscles pass behind the medial malleolus, held in place by the transverse septum and the deep layer of the laciniate (internal annular) ligament. They lie in compartments divided by septa which descend to the tibia. The compartment for the tibialis posterior is the most medial. It is partly overlapped by that for the flexor digitorum. At the ankle the tendon of the tibialis passes above, the tendon of the flexor digitorum medial to, and that of the flexor hallucis below, the sustentaculum tali, each in a separate osteofibrous canal bounded externally by the laciniate (internal annular) ligament. In the sole the tendon of the long flexor of the big toe passes deeper than the tendon of the flexor digitorum, to which it gives a slip, and is inserted into the terminal phalanx of the big toe. The tendon of the long flexor of the toes passes obliquely across the sole, is joined by the quadratus plantæ (flexor accessorius), and gives rise to a tendon for the terminal phalanx of each of the four lateral toes. From these tendons the lumbrical muscles arise. The tibialis posterior has an extensive insertion on the plantar surface of the tarsus.

The long flexors act chiefly on the toes. Together with the tibialis posterior they invert and extend the foot.

The long flexors of the toes probably represent the flexor profundus and the flexor pollicis longus of the forearm. The tendons of the deep flexors of the forearm do not, however, cross like those of the long flexors of the toes. In the lower mammals there is much variation in the toes to which the tibial and fibular flexors are distributed. The tibialis posterior has no certain representative in the forearm. The rare ulnocarpeus may represent it.

The flexor digitorum longus (fl. dig. tibialis NK) (figs. 480, 488).—*Origin.*—From the popliteal line, the medial side of the second quarter of the dorsal surface of the tibia, the fibrous septum between the muscle and the tibialis posterior, and the fascia covering its proximal extremity.

Structure and insertion.—From these areas of origin the fiber-bundles run obliquely to be inserted in a penniform manner on a tendon which begins in the proximal quarter of the muscle as a narrow septum, and more distally becomes a strong band on the medial margin. The insertion of the fiber-bundles continues nearly to the medial malleous. From here the tendon passes behind the medial malleolus, dorsolateral to the tendon of the tibialis posterior, crosses the posterior talotibial ligament, and passes along the medial margin of the sustentaculum tali into the sole of the foot. Here it crosses the tendon of the flexor hallucis longus, from which it receives a tendinous slip, and divides into four parts, which pass to the second to the fifth toes. Each tendon is bound to the phalanges of the toe to which it passes by a fibrous sheath. Superficial to it in the sheath lies a tendon of the flexor digitorum brevis, which the flexor longus tendon perforates as it passes to the base of the terminal phalanx. The tendon is connected, like those of the fingers, by vincula tendinum, to the phalanges of the toes.

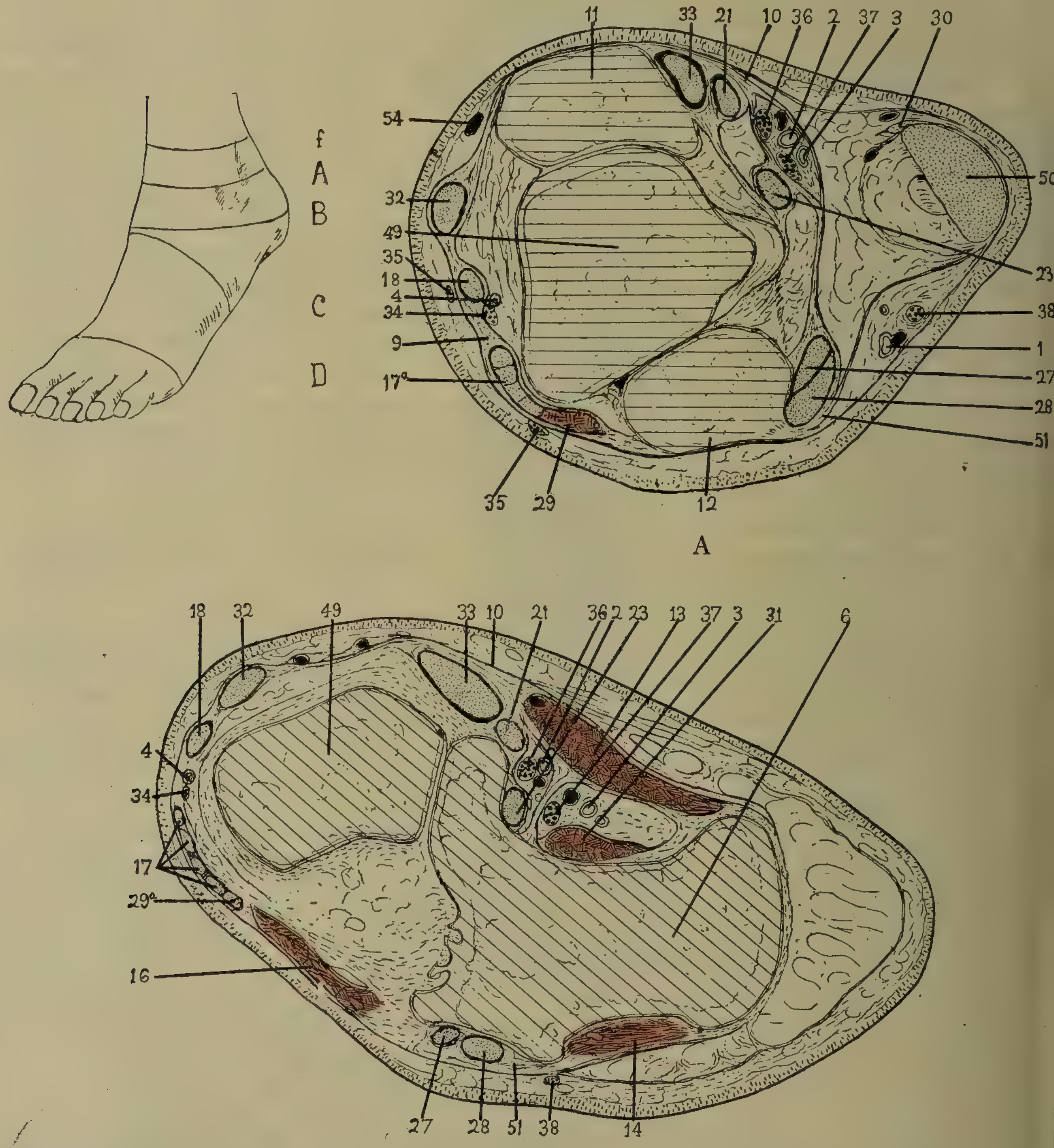
Nerve-supply.—From the tibial (posterior tibial) nerve a branch arises, often in company with nerves to some other or others of the muscles of this group. The nerve divides into two branches, one of which passes to the lateral side of the muscle, where it extends along near the middle of the fiber-bundles of that side, while the other branch passes along near the middle of the fiber-bundles of the medial side of the muscle.

Relations.—In the proximal half of the leg it lies on the tibia, in the distal half on the pos-terior tibial muscle. Between it and the flexor hallucis lie the posterior tibial vessels and nerve. Near the ankle the plantar vessels and nerves cross the tendon of the muscle, separated from it by the deep layer of the laciniate (internal annular) ligament. In the upper two-thirds of its extent it is covered by the triceps suræ. In the lower third of the leg it emerges medial to the soleus and the tendon of Achilles. The relations of its tendon at the ankle have been de-scribed above. The tendon lies beneath the origin of the abductor hallucis muscle and in the sole is covered by the flexor digitorum brevis, crosses the tendon of the long flexor and the oblique adductor of the big toe and the interosseous muscles, is joined by the quadratus plantæ (flexor accessorius), and gives origin to the lumbrical muscles.

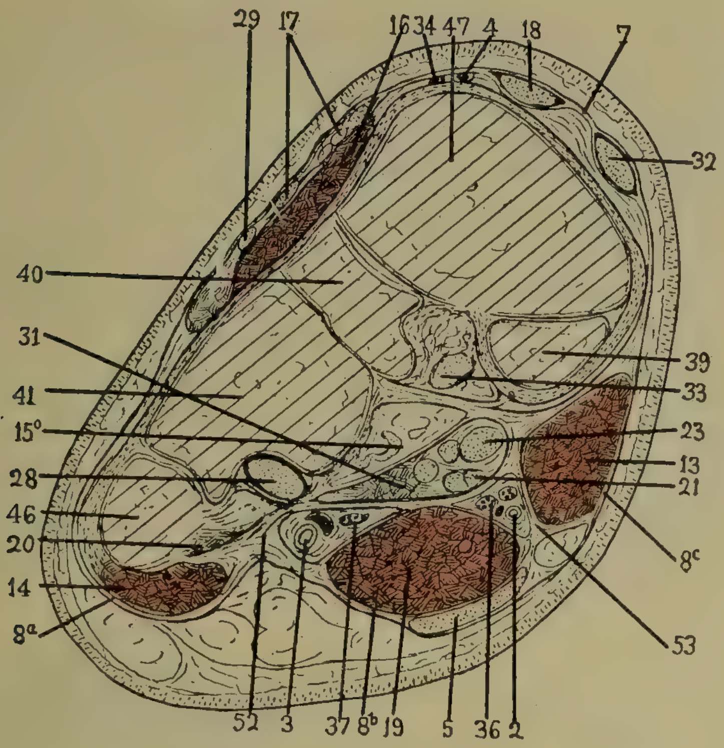
The flexor hallucis longus (flexor digitorum fibularis NK) (figs. 480, 488).—*Origin.*—From the distal two-thirds of the posterior surface of the fibula, the septa between it and the tibialis posterior and peroneal muscles, and the fascia above its proximal extremity.

Structure and insertion.—The fiber-bundles converge upon a tendon which begins in the second quarter of the muscle, within its substance, and emerges upon the posteromedial margin in its distal half. The insertion of the fiber-bundles continues to the end of the tibia. From here the tendon passes over the dorsal talotibial (tibioastragaloid) ligament, and through the groove on the posterior surface of the talus and the under surface of the sustentaculum tali, where it lies on the fibular side of the tendon of the flexor digitorum longus. It then crosses the deep surface of this tendon, to which it gives a slip, passes over the plantar surface of the medial head of the flexor hallucis brevis, and between the sesamoid bones of this muscle into the osteofibrous canal on the plantar surface of the big toe. It is inserted into the base of the terminal phalanx of the big toe.

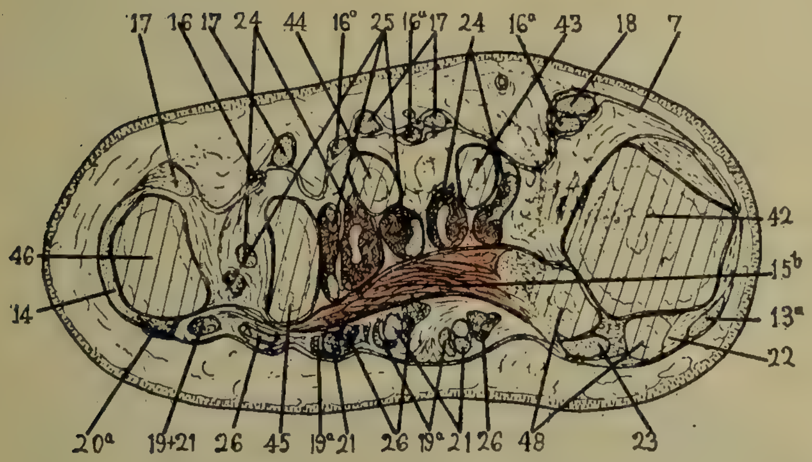
Nerve-supply.—The nerve arises from the tibial (posterior tibial) nerve, often in company with the nerve to the flexor digitorum longus or the other muscles of the group. It runs along



For Legend See Page 555.



C



D

FIG. 481. A–D.—TRANSVERSE SECTIONS THROUGH THE FOOT IN THE REGIONS SHOWN IN THE DIAGRAM.

f in the diagram indicates the region through which passes section F, fig. 478.

1. Arteria peronea. 2. A. plantaris medialis (internal). 3. A. plantaris lateralis (external). 4. A. tibialis anterior. 5. Aponeurosis plantaris. 6. Calcaneus. 7. Fascia pedis dorsalis. 8. F. plantaris—a, lateral; b, intermediate; c, medial. 9. Ligamentum cruciatum (anterior annular). 10. L. laciniatum (internal annular). 11. Malleolus lateralis (external). 12. Malleolus medialis (internal). 13. Musculus abductor hallucis—a, tendon. 14. M. abductor quinti digiti—a, insertion. 15. M. adductor hallucis—a, oblique head, origin; b, transverse head. 16. M. extensor digitorum brevis—a, tendons. 17. M. extensor digitorum longus, tendons. 18. M. extensor hallucis longus, tendon. 19. M. flexor digitorum brevis—a, tendon. 20. M. flexor digiti quinti brevis—a, tendon. 21. M. flexor digitorum longus, tendon. 22. M. flexor hallucis brevis tendon. 23. M. flexor hallucis longus. 24. M. interossei dorsales. 25. M. interossei plantares. 26. M. lumbricales. 27. M. peroneus brevis. 28. M. peroneus longus. 29. M. peroneus tertius—a, tendon. 30. M. planaris, tendon. 31. M. quadratus plantæ. 32. M. tibialis anterior, tendon. 33. M. tibialis posterior, tendon. 34. Nervus peroneus profundus. 35. N. peronæus superficialis (musculocutaneous). 36. N. plantaris medialis (internal). 37. N. plantaris lateralis (external). 38. N. suralis (external saphenous). 39. Os cuneiform I. 40. Os cuneiform III. 41. Os cuboid. 42. Os metacarpale I. 43. Os metacarpale II. 44. Os metacarpale III. 45. Os metacarpale IV. 46. Os metacarpale V 47. Os naviculare. 48. Ossa sesamoidea. 49. Os talus (astragalus). 50. Tendo Achillis. 51. Retinacula mm. peroneorum. 52. Septum intermusculare laterale. 53. S. intermusculare mediale. 54. Vena saphena magna.

the deep surface of the muscle and sends twigs into the middle third of its constituent fiber-bundles. Sometimes two nerves are furnished to the muscle.

Relations.—It lies on the fibular side of the distal two-thirds of the leg. Proximally it diverges from the preceding muscle so as to disclose the tibialis posterior, which is more deeply situated. Between it and the tibialis posterior lie the peroneal vessels. Distally its tibial margin approaches the flexor digitorum longus, but between them lie the posterior tibial vessels and nerve. Lateral to it lie the peroneal muscles. It is covered in the leg by the soleus.

In the distal part of the leg its tendon lies medial to the tendon of Achilles. On entering the foo the tendon crosses beneath the abductor hallucis muscle and the lateral plantar vessels an nerve. The other relations of the tendon have been described above.

The tibialis posterior (or tibialis plantaris NK) (figs. 480, 490).—*Origin.*—From—(1) th lateral half of the distal margin of the popliteal line and the middle third of the posterior surfac of the tibia; (2) the medial side of the head and of that part of the body of the fibula next th interosseous membrane in the proximal two-thirds; (3) from the whole of the proximal and th lateral portion of the distal part of the posterior surface of the interosseous membrane; and (4 from the septa between its proximal portion and the long flexor muscles.

Structure.—From this extensive area of origin the fiber-bundles converge upon a tendon which is at first deep seated within the muscle-belly, but about the middle of the leg emerge on the medial margin of the muscle. The fibular portion of the muscle is much more extensiv than the tibial. The proximal fibers take a nearly perpendicular, the most distal (from th fibula) a nearly transverse, course. The insertion of fibers stops a little proximal to the media malleolus. The tendon then extends to the medial side of the tendon of the long flexor o the toes, passes through the groove on the back of the malleolus, across the medial talotibia (tibioastragaloid) ligament, and above the sustentaculum tali to the sole.

Insertion.—The tendon divides into two chief divisions, a deep and a superficial. (1 The deep portion becomes attached chiefly to the tubercle of the navicular bone, and usuall in part also to the first cuneiform. (2) The superficial spreads out to be attached chiefly to th

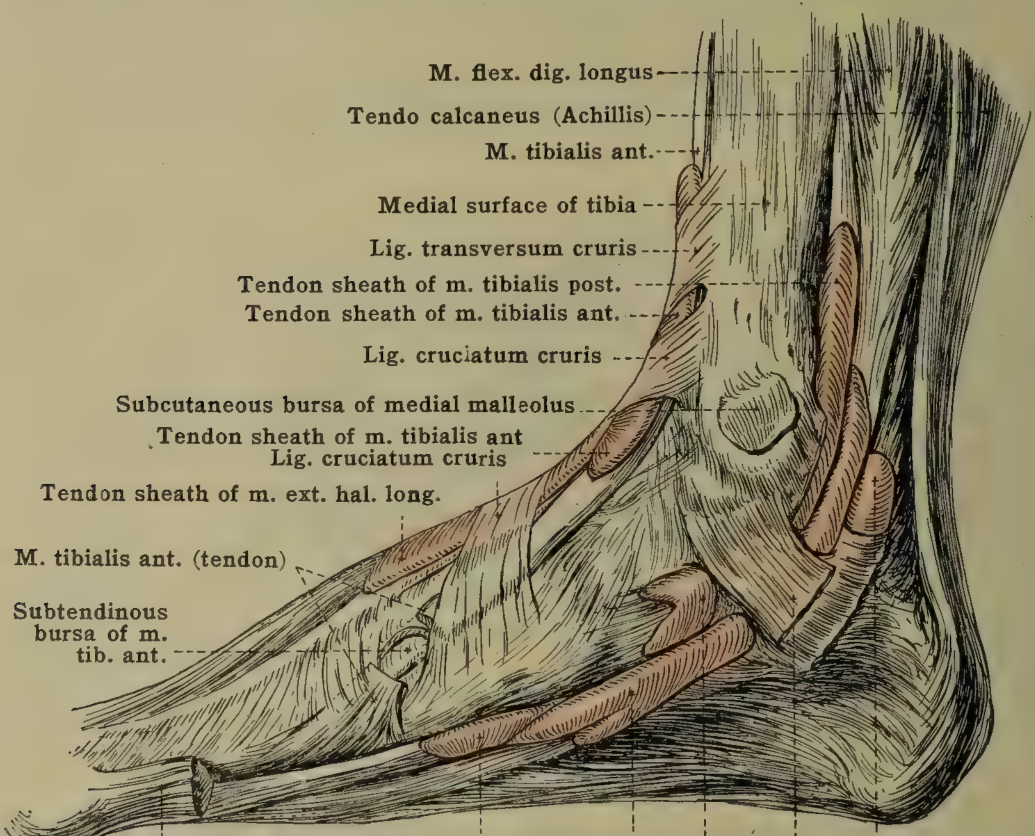


Fig. 482.—Bursæ and Tendon Sheaths of Right Foot, Medial View. (After Spalteholz.)

third cuneiform and the base of the fourth metatarsal, but also in part to the second cuneiform, to the capsule of the naviculocuneiform joint, to the sulcus of the cuboid, and usually also to the origin of the short flexor of the big toe and the base of the second metatarsal. Slips may, however, also be given to other structures. A sesamoid bone is usually found in the tendon either near the calcaneonavicular ligament or the navicular bone.

Nerve-supply.—The nerve arises from the tibial (posterior tibial) in company often with branches to the other muscles of the group. It enters the posterior surface of the muscle in its proximal third, and gives off one or two branches for the tibial fasciculus. The main trunk descends across the middle third of the fasciculi arising from the fibula.

Relations.—The muscle covers the posterior surface of the interosseous membrane, and extends distally over the posterior surface of the tibia beneath the flexor digitorum longus. It is covered proximally by the soleus, distally by the two long digital flexors. The posterior tibial and peroneal arteries and the tibial (posterior tibial) nerve run upon its posterior surface. The tendon in the sole is under cover of the origin of the plantar muscles of the big toe.

Action.—The tibialis posterior adducts the foot and slightly inverts it. The flexor digitorum longus flexes the terminal phalanx on the second and the second on the first, and at the height of its contraction the first on the metatarsals. It also rotates medially to some extent the ends of the fourth and fifth toes, and inverts the foot. The flexor hallucis longus flexes the second phalanx of the big toe on the first, and, less energetically, the first on the metatarsal. It also inverts the foot. All three muscles extend the foot. The flexor hallucis is the strongest of the three in this respect.

Variations.—The muscles of the group may be more or less fused with one another or be united by fasciculi. This is especially common between the two flexors of the toes. The

individual muscles vary in development. The flexor digitorum longus may be more or less divided into separate fasciculi for the individual toes. The slip from the flexor hallucis longus to the flexor digitorum longus varies greatly in extent, but usually passes mainly to the second and third toes, more rarely to the second, third, and fourth, and very rarely to the fifth. In most of the apes the tibial flexor (flexor digitorum) sends tendons to the second and fifth, the fibular flexor (flexor hallucis) to the first, third, and fourth toes. This condition is also sometimes found in man. A slip may pass from the tendon of the flexor digitorum to that of the flexor hallucis longus. There may be a sesamoid bone in the tendon of the flexor hallucis longus as it passes over the talus (astragalus) and calcaneus. The tibialis posterior may be doubled. Aberrant fasciculi may arise from various regions on the back of the leg and join any one of the three muscles of the group.

Abnormal muscles.—**The soleus accessorius.**—Arises by a tendon from the head of the fibula beneath the soleus. It is usually a slender muscle inserted into the medial surface of calcaneus. **The tibialis secundus** (tensor of capsule of ankle-joint).—A small muscle which arises from the tibia beneath the flexor digitorum and is inserted into the capsule of the ankle-joint. **The fibulocalcaneus medialis** (peroneocalcaneus internus of MacAlister, flexor accessorius long. dig. long., etc).—A fasciculus which arises from the lower third of the body of the fibula and gives rise to a tendon which passes beneath the laciniate ligament to the quadratus plantæ or to the tendon of the flexor digitorum longus.

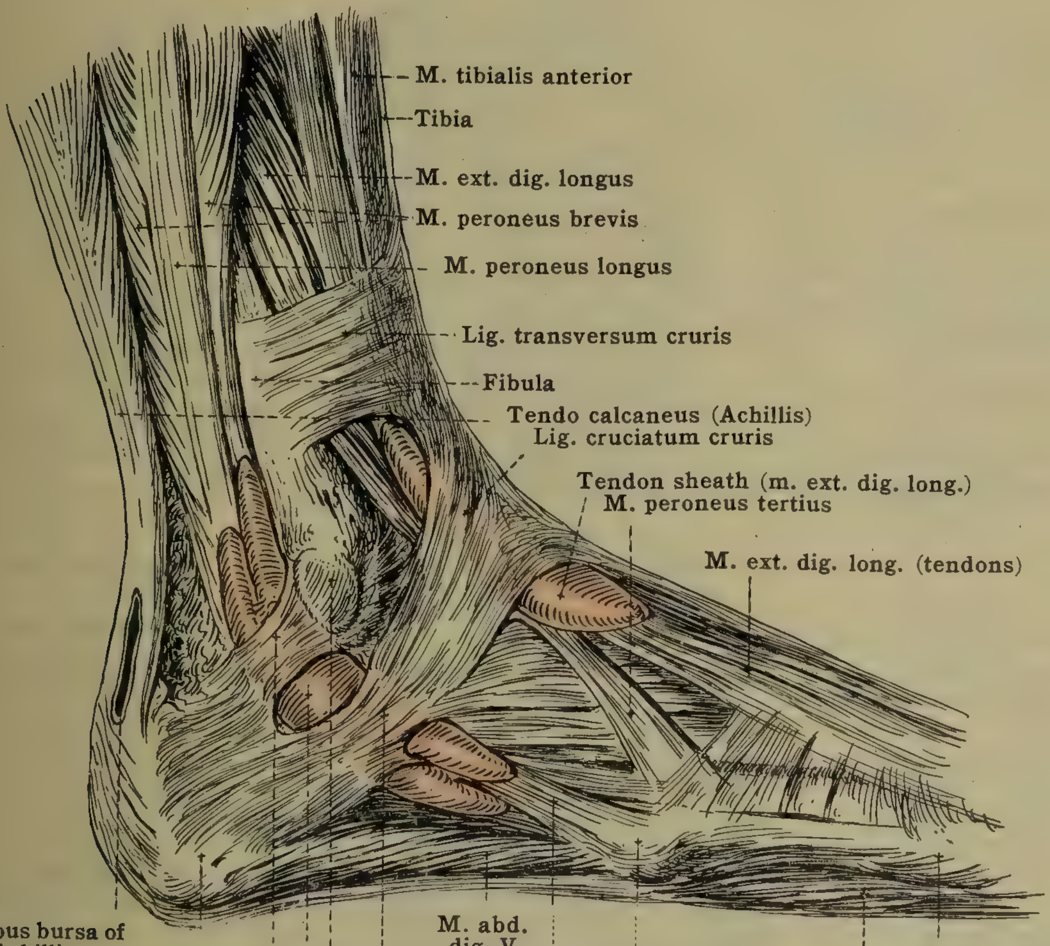


FIG. 483.—BURSÆ AND TENDON SHEATHS OF RIGHT FOOT, LATERAL VIEW. (After Spalteholz.)

BURSÆ

B. subtendinea m. tibialis posterioris.—A small bursa between the navicular fibrocartilage and the tendon.

SYNOVIAL TENDON-SHEATHS (FIGS. 482–484)

Vagina m. flexoris digitorum longi.—The tendon is surrounded by a synovial sheath from the back of the medial malleolus to where it crosses the tendon of the flexor hallucis longus below the navicular bone. It may communicate with the sheath of the tibialis anterior or with that of the flexor hallucis longus. **Vaginæ tendinum digitales.**—The tendons of the long flexor, together with those of the short flexor, are surrounded by synovial sheaths from the heads of the metatarsals to the insertions of the tendons. In structure these resemble those of the fingers. **Vagina m. flexoris hallucis longi.**—The tendon is surrounded by a sheath from the back of the medial malleolus to the crossing of the tendon of the flexor digitorum longus. Another sheath surrounds the tendon from the middle of the first metatarsal to its insertion. **Vagina m. tibialis posterioris.**—The tendon is surrounded by a synovial sheath extending from a region proximal to the medial malleolus to the insertion of the tendon.

Vagina tendinis m. tibialis anterioris.—This sheath surrounds the tendon from above the transverse crural ligament to the talonavicular joint. **Vagina tendinis m. extensoris**

hallucis longi.—The sheath begins above the proximal arm of the cruciate ligament, an ends near the tarsometatarsal joint beneath a band-like thickening of the dorsal fascia of th foot. **Vagina tendinum m. extensoris digitorum longi.**—This sheath surrounds the tendons c the long digital extensor and the peroneus tertius from above the cruciate ligament to th middle of the third cuneiform bone.

Vagina tendinum peroneorum communis.—There is a double sheath for the tendons c the peroneal muscles as they pass back of the lateral malleolus. From this region of union th sheath sends processes along each tendon proximally above the malleolus and distally over th lateral surface of the calcaneus. This process on the tendon of the peroneus longus ofte communicates with the following sheath. **Vagina tendinis m. peronæi longi plantaris.**– This sheath begins in the peroneal groove of the cuboid and ends near the medial border of th long plantar ligament.

FIG. 484.—BURSÆ AND TENDON SHEATHS OF RIGHT SOLE. First and Second Layers o Muscles Removed. (After Spalteholz.)

Clinical aspects. Tenotomy and guides to the tendons.—The **tendo Achillis** should be divided about 3.7 cm. (1½ in.) above its insertion, its narrowest point, which is about on a level with the medial malleolus. The knife should be introduced on the medial side and close to the tendon, so as to avoid the posterior tibial artery.

The **tibialis anterior** may be divided about 25 mm. (1 in.) above its insertion into the first cuneiform, a point which is below the level of its synovial sheath. The tendon has here the dorsalis pedis on its lateral side, but separated by the tendon of the extensor hallucis longus.

The tibialis posterior.—The usual rule for dividing this tendon is to take a point 5 cm. (2 in.) above the medial malleolus, and as accurately as possible midway between the anterior and medial borders of the leg. This point will give the medial margin of the tibia, in close apposition to which the tendon is lying, and is a point at which the tendon is rather farther from the artery than it is below, and is also above the commencement of its synovial sheath.

Owing to the risk of injury to the posterior tibial vessels, the difficulty of ensuring division of the tendons, the following open method is, nowadays, superior, being more certain, and admitting of division of ligaments, e. g., talonavicular and anterior part of deltoid (syndesmotomy of Parker), which are always contracted in advanced talipes equinovarus. A V-shaped flap with its apex over the first metatarsal bone and its two limbs starting, the lower below the margin of the plantar fascia on a line with the medial malleolus, the upper from a point over the head of the talus, is turned backward. The plantar fascia is divided, the tibialis anterior is found, near its insertion, under the upper lip of the wound, the tibialis posterior and the flexor digitorum longus in the lower, the former close to the navicular. If necessary, the calcaneo- and talonavicular and anterior part of the deltoid ligaments can be divided also.

Peronei.—The peronei longus and brevis may be divided 5 cm. (2 in.) above the lateral malleolus, so as to be above the level of their synovial sheath. The knife should be inserted very close to the bone, so as to pass between the fibula and the tendons. Division below the lateral malleolus by a small flap is easier.

D. MUSCULATURE OF THE FOOT

(Figs. 486–490)

The musculature of the foot in its general arrangement is similar to the arrangement of the musculature of the hand. However three major differences should be noted: (1) the extensor digitorum brevis present in the foot is not represented in the hand; (2) the quadratus plantae has no homologue in the hand; and (3) there is no homologue in the foot for the opponens pollicis.

The intrinsic muscles of the foot are taken up in the following groups:

1. Muscle of the dorsum of the foot.
2. Muscles of the sole of the foot.
   a. Flexor digitorum brevis
   b. Muscles attached to the tendons of the flexor digitorum longus
   c. Intrinsic muscles of the great toe
   d. Intrinsic muscles of the little toe
   e. The interosseus muscles

The extensor digitorum brevis is supplied by the deep peroneal nerve, the muscles on the sole of the foot by the medial and lateral plantar nerves.

FASCIÆ

(Fig. 481)

Tela subcutanea.—Over the dorsum of the foot the tela subcutanea contains little fat. On the sole of the foot and the plantar surface of the toes it contains much fat embedded in dense fibrous tissue.

Muscle fasciæ.—Over the **dorsum** of the foot a fascial membrane extends from the cruciate ligament mentioned above to the toes, where it is continued as fibrous sheaths for the extensor tendons. Laterally and medially it is continued into the plantar fascia. Where it overlies skeletal structures it becomes adherent to them. In the main this fascial sheet is thin. Over the base of the first metatarsal it is strengthened by a band which runs from the medial side of this bone over the extensor tendons of the big toe to the base of the second metatarsal. The extensor digitorum brevis is covered by an adherent fascial sheet. The dorsal surface of each dorsal interosseous muscle is likewise covered by an adherent membrane.

The **plantar surface** of the foot is invested by a fascia in which three distinct regions may be observed, a central, a lateral, and a medial. The central region is greatly thickened by bands of fibrous tissue, the **plantar aponeurosis,** which diverge toward the toes from the medial half of the tubercalcanei. These bands become distinct from one another as the toes are approached, and each finally terminates partly in the skin over the head of the corresponding metatarsal and in the digital sheath of the flexor tendons. Some of the fibers are continued into the transverse capitular ligaments, the others extend through near the metatarsophalangeal articulation to the dorsum of the foot. Broader, thicker bands go to the three middle toes than to the big and little toes. At the margins of this central area some fibers radiate into the fascia of the lateral and medial area, some extend laterally into the skin, and some sink into the intermuscular septa described below. Near the toes well-marked transverse bundles of fibers may be seen between the digital bands. The central area of the plantar fascia is not densely adherent to the skin.

The digital sheaths of the flexor tendons of the toes correspond essentially with those previously described (p. 469) for the fingers.

The **medial plantar fascia** is thin and adherent to the skin. It extends between the central plantar and the dorsal fascia over the intrinsic muscles of the big toe. The **lateral plantar fascia** is thick and well-developed near the heel, thin as the little toe is approached. A dense band, the **calcaneometatarsal ligament,** strengthens it between the calcaneus and the tuberosity of the fifth metatarsal.

At the junction of the medial with the central region of the plantar fascia the **medial intermuscular septum** sinks in to be attached to the first cuneiform, the navicular and the tendon of the posterior tibial. A similar **lateral intermuscular septum** sinks in between the lateral and central regions of the plantar fascia and is attached to the long plantar ligament, the tendon sheath of the peroneus longus and the base of the fifth metatarsal. The fascia of each of these

regions in considerable part extends into these septa instead of becoming continuous across them.

The sole is thus divided into three great fascial compartments by these septa, a lateral, a central, and a medial. In the lateral lie the intrinsic pedal muscles of the little toe; in the medial, the abductor and the flexor brevis of the big toe and the distal end of the tendon of the flexor hallucis longus. The central compartment is subdivided by transverse septa into several subcompartments. In the most superficial compartment lies the flexor digitorum brevis; in the second, the tendons of the flexor digitorum longus and its associated muscles, the quadratus plantæ (flexor accessorius) and the lumbrical muscles; in the third, the adductor muscles of the big toe; and in the fourth, the interosseous muscles.

The first two subcompartments are most clearly marked in the region of the tarsus. Distally they become merged by the disappearance of the intervening transverse septum, and longtiudinally subdivided by fibrous septa which serve to make a complete sheath over each digit for the flexor tendons. The sheath over the adductor muscle of the big toe is a thin membrane continued laterally from the medial intermuscular septum. Where the two heads of the adductor muscle advance upon their tendon of insertion, the medial septum has no skeletal attachment, so that the adductor subcompartment of the middle fascial compartment communicates freely with the medial compartment. Over the cuneiform bones the tendon of the flexor hallucis longus passes from the long flexor region of the middle compartment into the medial compartment. Here the medial intermuscular septum divides into two layers which form a sheath for the tendon as it passes to the plantar surface of the flexor hallucis brevis.

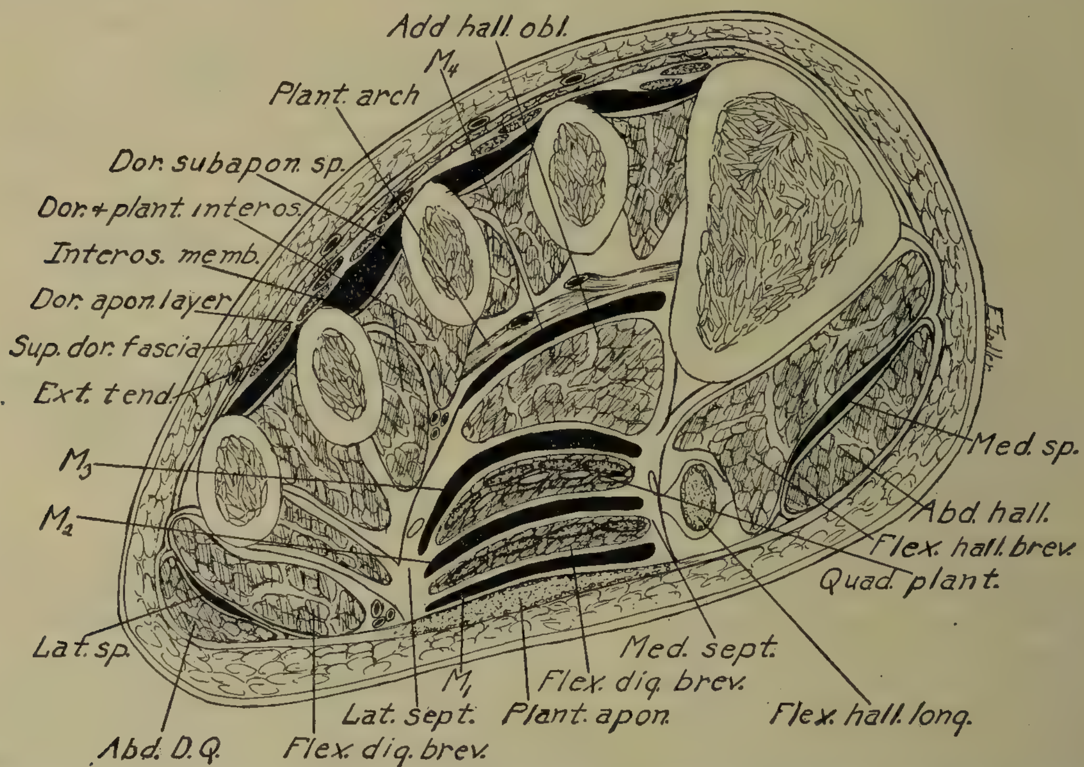


Fig. 485.—Fascial Spaces of Foot Injected. Cross Section of Foot at Level of the Middle of the Fifth Metatarsal Bone (Proximal Surface). (Dr. M. Grodinsky in Surgery, Gynecology & Obstetrics.)

Fascial Spaces of the Foot

Areas between the various fascial layers in the foot represent potential spaces where pus may accumulate when the foot is infected. A study of these spaces and their relationship to the spread of infectious processes was recently completed by Grodinsky (fig. 485). Grodinsky describes four potential median spaces on the plantar side of the foot which he designates as M_1, M_2, M_3 and M_4. M_1 represents the space between the central part of the plantar aponeurosis superficially and the flexor digitorum brevis muscle deeply. M_2 is described as lying between the flexor digitorum brevis and the quadratus plantae. Below the quadratus plantae the third space M_3 is found whose floor consists of the tarsal bones and ligaments posteriorly and more anteriorly the tendon of the peroneus longus the fascial coverings of the adductor hallucis obliquus, and the plantar and dorsal interossei muscles. M_4 is the space deep to the oblique head of the adductor hallucis muscle. In addition a lateral space deep to the abductor digiti quinti, a medial space deep to the abductor hallucis and spaces along the lumbrical muscles are demonstrated by the author. On the dorsum of the foot two spaces are described, a subcutaneous space above the dorsal aponeurosis and a subaponeurotic space between the aponeurosis and the fascia covering the dorsal interosseous muscles. In the leg fascial spaces exist between the superficial and deep muscle layers of the calf, and deep to the fascial sheaths of the peroneal muscles.

MUSCLES

1. Muscle of the Dorsum of the Foot

The **extensor digitorum brevis** (fig. 486) is broad and thin, lies beneath the tendons of the long extensor muscle on the tarsus, lateral to the navicular and

the head of the talus, and sends tendons to the four more medial toes. It arises from the calcaneus. Its nerve-supply is from the deep peroneal.

Origin.—From the lateral and superior surfaces of the body of the calcaneus and from the apex of the cruciate ligament.

Structure and insertion.—The fiber-bundles arise directly from the ligament, and by short tendinous bands from the bone. As they extend distally they become grouped into four bellies. Those of the most medial and largest belly, the **extensor hallucis brevis**, become inserted in a bipenniform manner on the lateral and medial margins of a tendon which begins opposite the cuboid. The insertion of fiber-bundles continues to the base of the first metatarsal. The insertion of the fiber-bundles of the other bellies, which are seldom so distinctly isolated as the first, takes place in a penniform manner into their respective tendons, but the exact mode of attachment is subject to great individual variations. The tendon of the first digit is inserted mainly into the middle of the back of the base of the first phalanx, but it is often also united to the tendon of the long extensor. The other three tendons are fused with the lateral margins

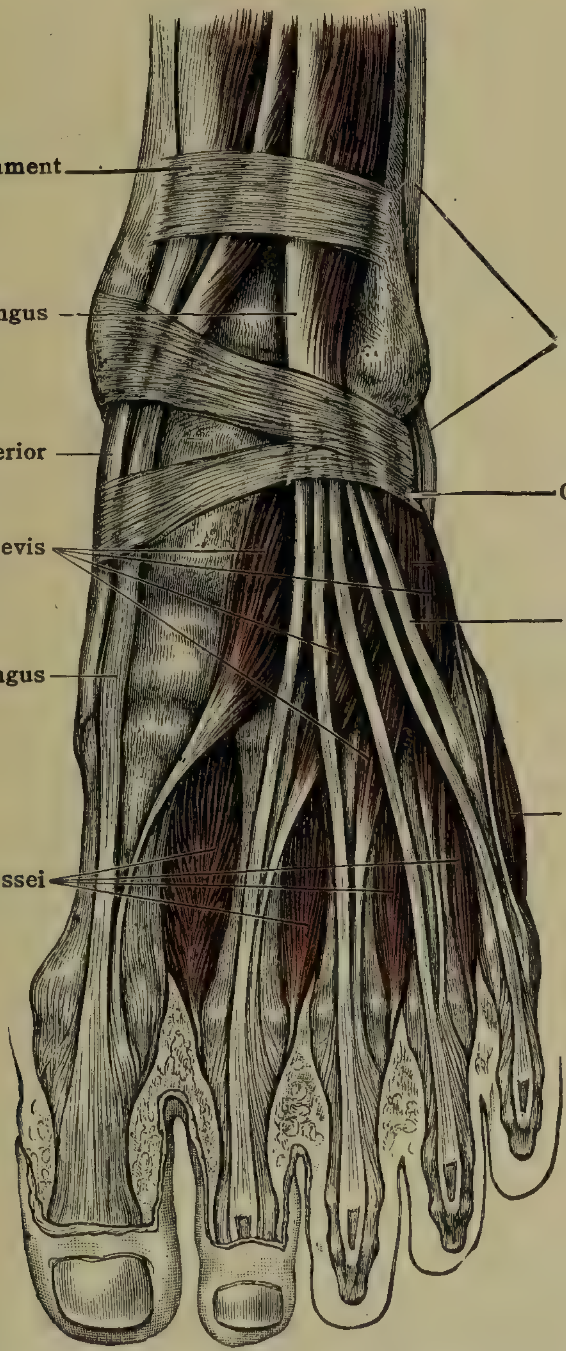


FIG. 486.—THE MUSCLES OF THE DORSUM OF THE FOOT.

of the corresponding tendons of the long extensor near the bases of the three middle digits. They also usually give slips to the bases of the first phalanges of the corresponding toes.

Nerve-supply.—The deep peroneal (anterior tibial) nerve, which, accompanied by the anterior tibial artery, passes beneath the medial belly of the muscle, gives off a branch which passes transversely across the middle of the deep surface of the muscle and sends twigs into it.

Relations.—It lies on the lateral side of the tarsus, beneath the long extensor tendons of the toes. The relations of its tendons have been described above.

Action.—It aids the long extensors in extending the first phalanx of each of the four medial digits. It has but a limited action on the second and third phalanges. It serves also to pull the ends of the toes to which its tendons go toward the little toe.

Variations.—The muscle shows great variation in development. Rarely the whole muscle, more frequently one or more of its digital divisions, may be missing. On the other hand, it may be more highly developed than usual. Accessory fasciculi vary greatly in origin and termina-

tion. Most frequently their tendons go to a metacarpophalangeal articulation or to the second or the fifth toe.

2. Muscles of the Sole of the Foot

a. Flexor Digitorum Brevis (fig. 487)

The **flexor digitorum brevis,** the most superficially placed of the plantar muscles, lies in the midplantar region beneath the plantar fascia and over the tendons of the long flexor of the toes and its associated muscles. It arises from the calcaneus, and has a flat, elongated belly, which toward the middle of the sole is prolonged into four processes, each of which has a special tendon that is inserted into the second phalanx of one of the four lateral toes. The tendons of the muscle correspond to those of the flexor sublimis in the palm. The belly

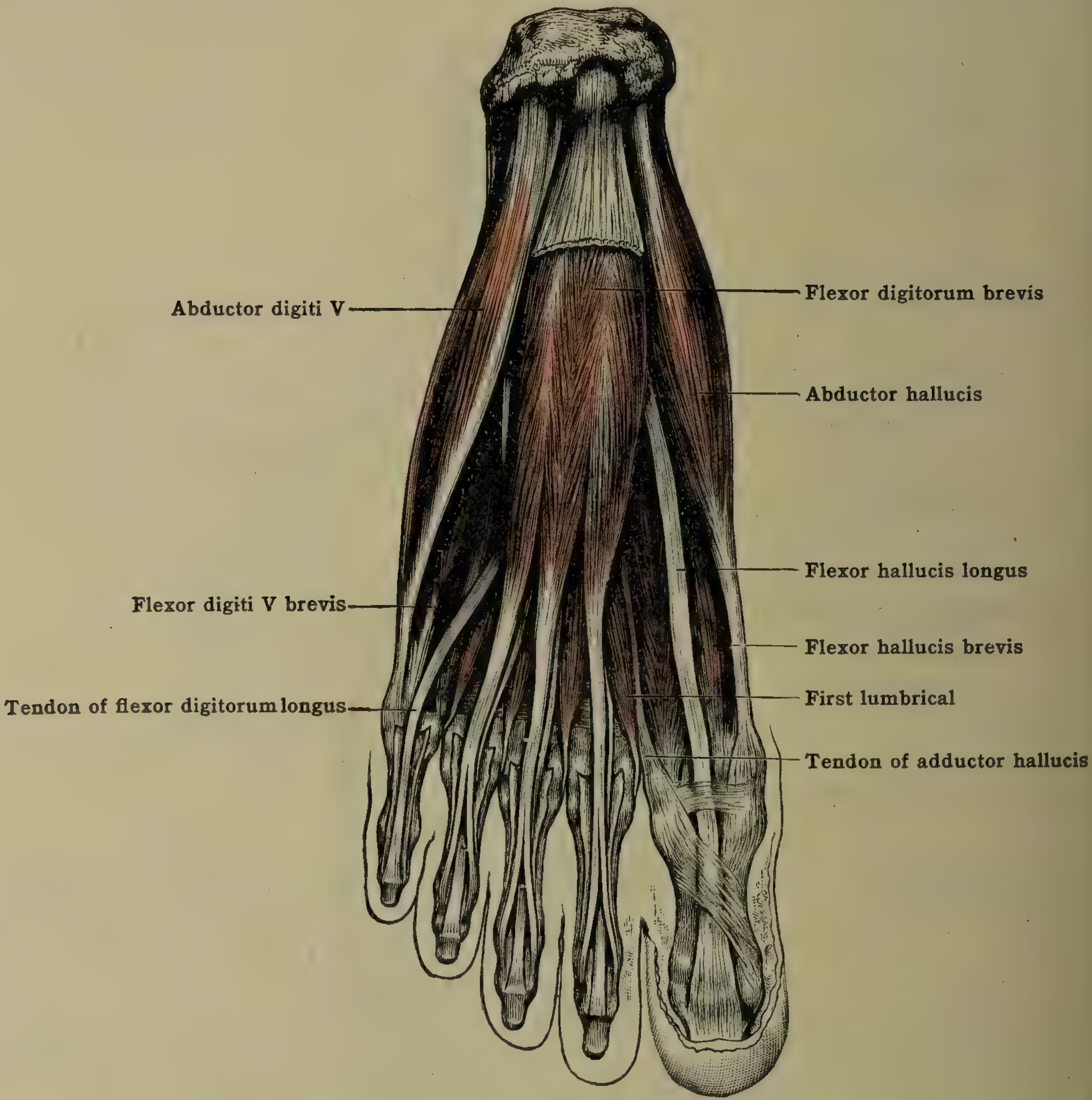


Fig. 487.—First Layer of the Muscles of the Sole.

of the flexor sublimis is supposed to be represented by the soleus. The nerve supply is from the medial (internal) plantar.

Origin.—From (1) the medial process of the tuber calcanei; (2) the posterior third of the plantar aponeurosis; and (3) the medial and lateral intermuscular septa.

Structure.—The constituent fiber-bundles pass distally in a compact mass. The tendons of insertion begin within the muscle substance, and as the fiber-bundles become inserted on them, the separate fasciculi become more and more distinct. The fasciculi for the second and third toes are larger and arise more superficially than those for the fourth and fifth toes. The fasciculus for the fifth toe is often very small, and its tendon takes an oblique course to the insertion.

Insertion.—The tendons of the short flexor pass superficial to those of the long flexor into the osteofibrous canals on the flexor surface of the digits. Upon the first phalanx of each toe the tendon of the short flexor divides and forms an opening (chiasma tendinis) through which the tendon of the long flexor passes, while the tendon of the short flexor becomes attached to the base of the second phalanx. The arrangement is essentially like that described at length for the flexors of the fingers (p. 466).

Nerve-supply.—From the medial plantar nerve by a branch which enters the middle third of the deep surface near the medial margin of the muscle.

Action.—It is a strong flexor of the second row of phalanges.

Relations.—The short flexor is separated from the abductors of the big toe and little toe by strong intermuscular septa (p. 559), and from the long flexor tendons and the quadratus plantæ (flexor accessorius) by a transverse septum in which the lateral plantar vessels and nerve cross the foot. In its distal two-thirds it is separated from the plantar fascia by loose tissue.

Variations.—The muscle shows a tendency toward reduction, one or more of its fasciculi being frequently absent, and occasionally the whole muscle. The fasciculus for the fifth toe is absent in about 20 per cent. of bodies (Le Double). When a fasciculus is absent, its tendon is usually replaced by an accessory tendon from the long flexor. The muscle or its tendons may be more or less fused to the tendons of the flexor digitorum longus.

b. Muscles Attached to the Tendons of the Flexor Digitorum Longus (fig. 488)

The muscles belonging in this group are the **quadratus plantæ** (flexor accessorius), a flat, quadrangular, bicipital muscle which runs from the medial and plantar surface of the body of the calcaneus to the dorsolateral margin and deep surface of the long flexor tendon; and the **lumbricales,** four slender bipinnate muscles which run from the medial sides of the digital slips of the tendon to the medial sides of the four more lateral toes. The quadratus aids the long flexor muscle; the lumbricales extend the last two phalanges and flex the first phalanx of each of the digits to which they pass. The lumbrical muscles correspond to those of the hand. The quadratus is not there represented. The nerve-supply is from the lateral (external) plantar nerve except that for the first lumbrical muscle which gets its supply from the medial (internal) plantar.

The quadratus plantæ (flexor accessorius) (fig. 488).—This muscle *arises* by two heads. The *lateral head* springs by an elongated tendon from the calcaneus in front of the lateral process of the tuber, and from the lateral margin of the long plantar ligament. The *medial head* arises directly from the medial surface of the body of the calcaneus as far back as the medial process of the tuber calcanei, and from neighboring ligaments.

Structure and insertion.—The two heads are separated at their origin by a short triangular space. They soon fuse to form a single belly, but the fiber-bundles of each head in the main are separately inserted. Those from the lateral head diverge to be attached to the lateral margin of the flexor tendon. Those from the medial head are inserted on a tendon that begins on the medial margin and deep surface of this head, becomes broader, and is inserted as a flat aponeurosis on the deep surface of the flexor tendon. There are great individual variations in the structure of this muscle. The fibers of either part may be inserted with those of the other part.

Nerve-supply.—From a branch of the lateral plantar nerve which passes obliquely across the superficial surface of the muscle parallel with the tendon of the flexor digitorum longus.

Relations.—The muscle lies in a fascial compartment with the long flexor tendons. This compartment is bounded on each side by intermuscular septa, deeply by the tarsus, and plantarward by a septum which intervenes between it and the flexor digitorum brevis, and in which the lateral plantar nerve and vessels cross to the lateral side of the foot.

Action.—It assists the long flexor tendon in flexing the toes. It makes the direction of traction on the toes parallel with the long axis of the foot.

Variations.—It is frequently reduced in size. The lateral head is not infrequently missing, the medial head or the whole muscle much more rarely. The mode of attachment to the tendon varies. It may be inserted in part or wholly into the long flexor of the great toe. It may receive, in about one body in twenty (Wood), an accessory slip of origin from the fibula, one of the muscles of the leg, the fascia of the leg or foot, or the medial surface of the calcaneus, etc.

The lumbricales.—The three lateral muscles *arise* from the contiguous sides of the digital tendon-slips of the flexor digitorum longus in the angles of division. The first lumbrical arises on the medial margin of the tendon to the second toe. The fiber-bundles of each muscle converge on both sides of a tendon which becomes free near the metatarsophalangeal joint and is *attached* to the medial side of the first phalanx of the toe to which the muscle belongs. A tendinous expansion is sent into the aponeurosis of the extensor muscle.

Nerve-supply.—The three lateral lumbrical muscles are most frequently supplied by branches of the deep ramus of the lateral plantar nerve, the medial by the first common plantar digital branch of the medial plantar nerve. The latter nerve may supply the two more medial muscles or the more medial muscles may receive a double supply. The branches of the lateral plantar nerve enter the deep surfaces of the muscles in the middle third. The branches of the medial plantar enter the medial borders of the muscles near the junction of the proximal and middle thirds.

Relations.—The lumbrical muscles lie in a plane with the long flexor tendons deeper than the flexor brevis tendons and superficial to the adductor hallucis. The deep branches of the lateral plantar nerve and vessels pass across their deep surface; superficial branches of both plantar nerves across the superficial surface.

Action.—To extend the last two phalanges of the toes and to flex the first.

Variations.—One or more of the muscles may be absent. Sometimes a muscle is doubled. This is more frequently the case with the third and fourth muscles. The first may arise wholly from the tendon of the posterior tibial muscle or from this and the long flexor of the big toe.

The third lumbrical may arise from the flexor digitorum brevis; an anomalous insertion is shown in fig. 488. The second and fourth lumbricals may be inserted into the tendons of the flexor digitorum brevis.

c. Intrinsic Muscles of the Great Toe (figs. 487–489)

These muscles are the abductor, flexor brevis, and adductor. Of the three muscles, the first two lie in the medial fascial compartment, while the last lies in the middle compartment covered by the flexor digitorum longus and its associated muscles.

The **abductor hallucis** (fig. 487), the largest and most superficial of these muscles, lies on the border of the sole medial to the short flexor muscle. It passes from the calcaneus across the tendons of the long flexor muscles, and is inserted

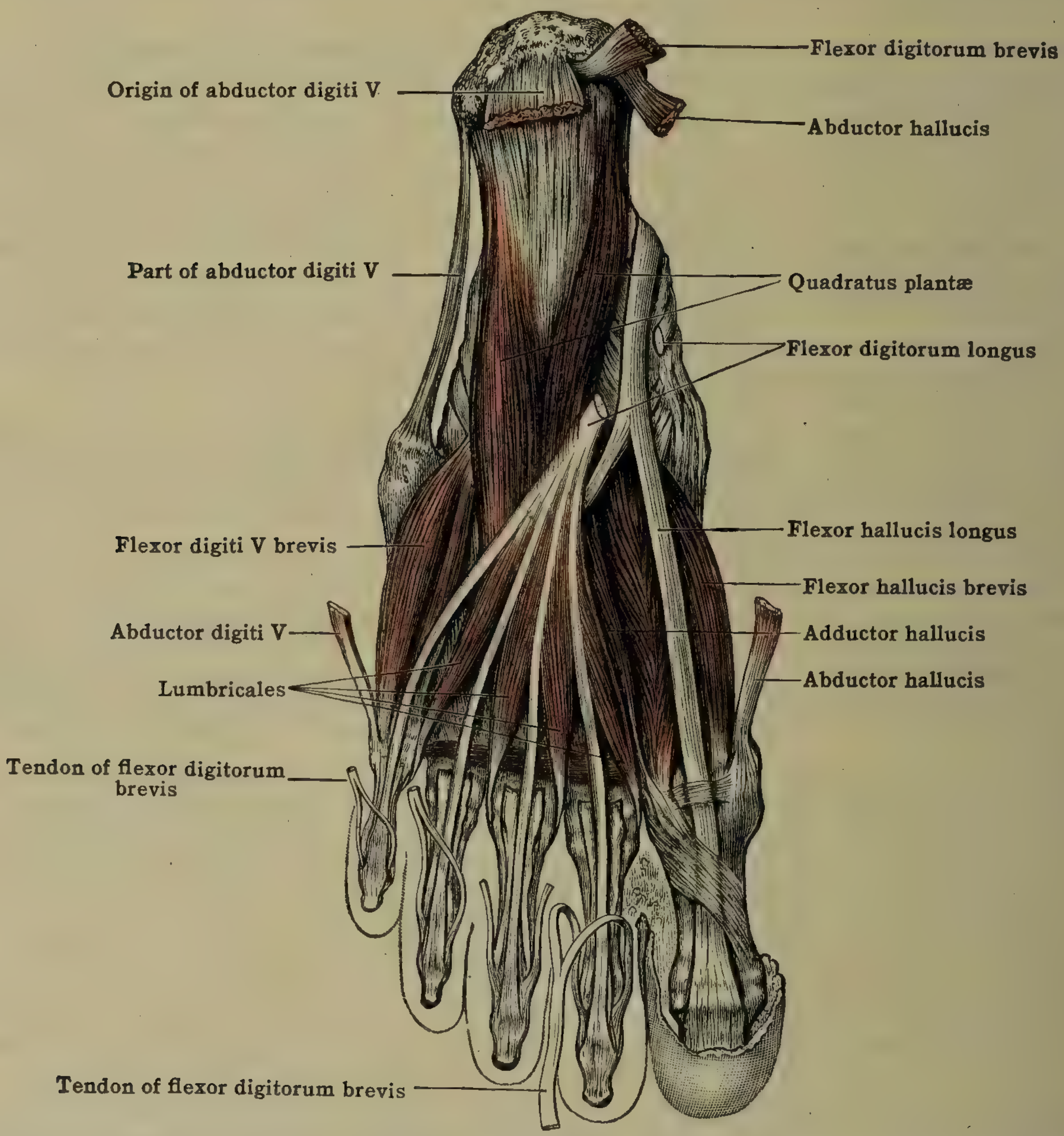


Fig. 488.—Second Layer of the Muscles of the Sole. (Shows an anomalous insertion of the third lumbrical.)

into the medial side of the base of the first phalanx of the great toe and into the medial side of the long extensor tendon. The **flexor hallucis brevis** (fig. 489) is a bicaudal muscle which arises in the region of the cuneiform bones and is inserted on each side of the base of the first phalanx. Its tendons are fused with those of the abductor and the oblique head of the adductor. The **adductor hallucis** (fig. 489) is composed of two distinct heads, an oblique and a transverse. The oblique head extends from the long plantar ligament to the lateral side of the base of the first phalanx of the great toe. Its tendon of insertion is joined by the transverse head, which arises from the capsules of the third to the fifth metatarso-phalangeal joints.

These muscles perform not only the functions indicated by their names, but also extend the second phalanx. They correspond fairly well with those of the thumb. The opponens is not normally present in the foot. The nerve supply for

the adductor is from the lateral (external) plantar nerve; that for the other muscles is from the medial (internal) plantar.

The abductor hallucis (fig. 487).—*Origin.*—From (1) the medial process of the tuber calcanei; (2) the deep surface of the neighboring plantar fascia; (3) the laciniate (internal annular) ligament; (4) the septum between the muscle and the flexor digitorum brevis; and (5) a fibrous arch which extends on the deep surface of the muscle over the plantar vessels and nerves and the long flexor tendons from the calcaneus to the navicular bone.

Structure.—From the medial process of the tuber calcanei a tendinous band passes to the deep, lateral side of the muscle. Numerous tendinous bands arise from the other areas of origin. The fiber-bundles arise from these tendons and directly from the fibrous arch. They are attached in a penniform manner to numerous tendinous slips which extend far up in the muscle. These slips become gradually fused into a tendon which appears on the superficial plantar aspect of the muscle. Opposite the distal half of the first metatarsal bone the tendon leaves the belly of the muscle and becomes closely bound to the medial belly of the flexor hallucis brevis.

Insertion.—In conjunction with the tendon of the medial belly of the flexor brevis into the base of the first phalanx. It usually sends an expansion to the extensor tendon.

Fig. 489.—Third Layer of the Muscles of the Sole.

Nerve-supply.—A branch from the medial plantar nerve usually enters near the middle of the lateral border of the muscle.

Relations.—It is covered by the plantar fascia and is separated from the muscles of the medial compartment by the medial intermuscular septum. It crosses the tendons of the tibialis anterior, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles and the plantar vessels and nerves.

The flexor hallucis brevis (fig. 489).—*Origin.*—From a tendon attached to the first (internal), second and third cuneiform bones. The more lateral of its fibers are continued into the plantar calcaneocuboid ligament and the more medial into the expansion of the tendon of the posterior tibial muscle.

Structure and insertion.—The fiber-bundles give rise to two bellies, a medial and a lateral. Those of the medial belly pass obliquely medially to be inserted into the tendon of the abductor hallucis, and by a short tendon fused with this into the medial side of the plantar surface of the base of the first phalanx. This tendon contains a sesamoid bone. Those of the lateral converge upon the tendon of the oblique head of the adductor, and the two muscles are inserted by a

common tendon, which contains a sesamoid bone, into the lateral side of the plantar surface of the base of the first phalanx.

Nerve-supply.—A branch from the medial plantar (or first plantar digital) nerve divides over the plantar surface of the muscle and gives a twig to each belly near the middle third. Rarely the lateral belly may receive a branch from the lateral plantar nerve.

Relations.—The abductor hallucis covers it medially; the tendon of the flexor hallucis longus passes between its two heads. Branches of the medial plantar vessels and nerve lie on its superficial surface.

The adductor hallucis (fig. 489).—**The oblique head.**—*Origin.*—From (1) the tuberosity of the cuboid and the sheath over the tendon of the peroneus longus muscle; (2) the plantar calcaneocuboid ligament; (3) the third cuneiform; (4) the bases of the second and third metatarsals and (5) a fibrous arch which extends from the plantar calcaneocuboid ligament to the interosseous fascia.

Structure and insertion.—From short tendon-slips the fiber-bundles pass forward to form a thick, fusiform belly which is attached in a bipenniform manner to a flat tendon. The tendon begins about the middle of the plantar surface of the muscle and is inserted in common with that of the flexor brevis into the lateral side of the plantar surface of the base of the first phalanx, and by a slip into the aponeurosis of the long extensor muscle on the back of the big toe.

Nerve-supply.—A branch from the deep ramus of the lateral plantar nerve enters the middle third of the lateral border of the muscle on its deep surface.

The **transverse head** *arises* from the joint-capsules of the third, fourth, and fifth metatarsophalangeal joints and from the transverse capitular ligaments.

Structure and insertion.—Of the three fasciculi, that to the little toe lies nearest the heel, that to the middle toe the most distally. The fiber-bundles take a nearly parallel course to be attached to tendon-slips which are fused into a common tendon that splits and passes on each side of the tendon of the oblique head and is inserted into the sheath of the tendon of the long flexor of the great toe (Leboucq).

Nerve-supply.—A branch from the deep ramus of the lateral plantar nerve enters the middle third of the deep surface of the muscle.

Relations.—The adductor hallucis is crossed superficially by the tendons of the flexor digitorum longus and by the lumbrical muscles. On its deep surface lie the interosseous muscles, and the deep plantar vessels and nerves.

Action.—The actions of the muscles of this group are indicated by the names of the individual muscles. The abductor and the oblique head of the adductor are also flexors of the first phalanx. All the muscles of the group aid in extending the second phalanx. The transverse head of the adductor serves to draw together the heads of the metatarsals after they have been separated by the weight of the body during the tread.

Variations.—The extent of fusion of the abductor and adductor with the two heads of the short flexor varies considerably. The abductor may receive an accessory fasciculus from the medial border of the foot. Either the adductor or the flexor brevis may send a tendon to the base of the first phalanx or to the short flexor tendon of the second toe. The adductor shows frequent variations in relation to its metatarsal attachments, owing to the fact that originally a fasciculus from the body of the second (and third) metatarsal was probably normally present and the transverse head was more developed (Leboucq). The **opponens hallucis** is a fasciculus occasionally found which extends from the short flexor or the medial intermuscular septum to the body of the first metatarsal. This muscle is normal in some monkeys. An **adductor digiti secundi** has been seen to arise from various sources and become attached to the lateral side of the plantar surface of the base of the first phalanx of the second toe. This muscle may be fused with the oblique adductor. A corresponding muscle is found normally in some apes, and in some of the lower animals there is a special adductor for each toe.

d. Intrinsic Muscles of the Little Toe (figs. 487–489)

In this group belong three muscles, an abductor, a flexor and an opponens. The largest of these, the **abductor digiti quinti,** extends superficially over the lateral margin of the foot from the lateral side of the tuber calcanei to the base of the little toe. The **flexor digiti quinti brevis** is a small, flat muscle which lies on the plantar surface of the fifth metatarsal. The **opponens** is a small muscle lying lateral to this. The two, which are often fused, arise from the cuboid. The flexor brevis is inserted into the plantar side of the base of the first phalanx of the little toe. The opponens is inserted into the lateral surface of the metatarsal. The abductor corresponds to the abductor of the little finger. The opponens and flexor brevis probably correspond to the deep part of the opponens of the little finger. The nerve supply is from the lateral plantar nerve.

The abductor digiti quinti (fig. 487).—*Origin.*—From (1) the lateral process of the tuber calcanei and the lateral and plantar surface of the body of the bone in front of this; (2) the lateral intermuscular septum; (3) the deep surface of the lateral plantar fascia, including the fibrous band extending from the calcaneus to the lateral side of the base of the fifth metatarsal bone.

Structure.—The fiber-bundles run obliquely to a flat tendon of insertion. This begins within the muscle near the calcaneocuboid joint, soon emerges on the medial side of the deep surface, and becomes free near the metatarsophalangeal joint. Considerable individual variation in structure is found.

Insertion.—On the lateral surface of the first phalanx of the little toe and the metatarsophalangeal capsule. Often a slip is sent to the extensor tendon. While usually the muscle

glides over the tuberosity of the fifth metatarsal, it frequently sends a second fasciculus to be attached to this bone (**abductor ossis metatarsi quinti**). A special fasciculus from the tuberosity often constitutes the lateral margin of the muscle.

Nerve-supply.—The nerve arises from the lateral plantar. It may be distributed either near the deep or the superficial surface of the muscle. The former appears to be the case when the muscle is slightly developed. The chief intramuscular branches then extend across the middle third of the constituent fiber-bundles near the deep surface. In case the calcaneometatarsal bundles are well developed, the nerve enters the proximal margin of the muscle and its chief branches extend across the middle third of the more superficial muscle-bundles, finally terminating in the distal margin of the muscle.

Relations.—It is ensheathed by the plantar fascia and the lateral intermuscular septum. It lies superficial to the quadratus plantæ (flexor accessorius), the opponens and flexor brevis of the little toe, the long plantar ligament, and the tendon of the peroneus longus muscle.

The flexor digiti quinti brevis (fig. 489).—*Origin.*—From the sheath of the peroneus longus, the tuberosity of the cuboid, and (3) the base of the fifth metatarsal.

Structure and insertion.—The fiber-bundles take a nearly parallel course, although the belly is slightly fusiform. They are attached by short tendinous bands to the base of the first phalanx of the little toe, the capsule of the corresponding joint, and the aponeurosis on the dorsal surface of the toe.

Nerve-supply.—A branch of the superficial ramus of the lateral plantar nerve sends twigs to the middle third of the plantar surface of this and the following muscle.

Relations.—It is covered medially by the plantar fascia, laterally by the abductor of the fifth toe. Medially it lies superficial to the third plantar interosseous muscle.

The oppenens digiti quinti.—This muscle *arises* from the sheath of the peroneus longus and the tuberosity of the cuboid by a slender tendon which passes over the tuberosity of the fifth metatarsal and gives rise to fiber-bundles which are *inserted* on the lateral surface of the fifth metatarsal. This muscle is not recognized by the NK.

Nerve-supply.—From branches of the nerve to the flexor brevis.

Relations.—It is covered by the abductor of the fifth toe.

Actions.—The abductor and flexor brevis abduct the little toe and flex the first phalanx. They act as extensors of the second phalanx. The opponens serves to draw the little toe medially in a plantar direction.

Variations.—The muscles of this group may be more or less completely fused. The abductor, in addition to the variations mentioned above, may send tendons to the third and fourth metatarsals. The opponens is frequently missing. The **abductor accessorius digiti quinti** is a rare muscle which arises from the lateral process of the tuber of the calcaneus and is inserted into the lateral surface of the base of the first phalanx of the little toe.

e. The Interosseous Muscles (fig. 490)

Two groups of **interosseous muscles** are recognized, a dorsal and a plantar. The **dorsal** are the larger and fill the interspaces. The first two are inserted into each side of the base of the first phalanx of the second toe; the third and fourth into the lateral sides of the bases of the first phalanges of the third and fourth toes. The **plantar interossei** lie on the medial side of the ventral surfaces of the third, fourth, and fifth metatarsals, and are inserted each on the medial side of the base of the first phalanx of the corresponding toe. In the hand the axis about which the interosseous muscles are arranged passes through the middle finger, in the foot through the second toe. The dorsal interossei abduct from, the plantar adduct toward, this axis. The nerve-supply is from the lateral plantar nerve.

The interossei dorsales.—Each of the three lateral dorsal interosseous muscles *arises* from —(1) the sides of the shaft and the plantar surface of the bases of the metatarsal bones bounding the space in which it lies; (2) from the fascia covering it dorsally; and (3) from fibrous prolongations from the long plantar ligament. The first has a similar origin except that it is attached medially to the base of the first metatarsal and to a fibrous arch extending from the base to the head.

Structure.—The component fiber-bundles of each muscle are inserted bipinnately on a tendon which begins high in the muscle and becomes free near the metatarsophalangeal joint.

Insertion.—The first and second on each side of the base of the first phalanx of the second toe. The third and fourth on the lateral side of the bases of the proximal phalanges of the third and fourth toes. Each tendon is adherent to the capsule of the neighboring joint. They send no well marked processes to the extensor tendons, as do those of the hand.

The interossei plantares.—Each plantar interosseus *arises.*—(1) from the proximal third of the medial plantar surface of the shaft and from the base of the metatarsal on which it lies; and (2) from expansions of the long plantar ligament.

Structure and insertion.—The obliquely placed fiber-bundles are longer than those of the dorsal interossei, and are inserted in a tendon which lies near the medial border of the muscle, becomes free near the metatarsophalangeal joint, and is inserted into a tubercle on the medial side of the base of the first phalanx of the digit to which it goes.

Nerve-supply.—From the deep branch of the lateral plantar nerve several rami are given off for the interossei. The nerve of each muscle enters the plantar surface in the proximal third. The interosseous muscles of the fourth interspace, however, are usually supplied by a branch from the superficial ramus of the lateral plantar nerve.

Relations.—The interosseous muscles are covered on the plantar surface by a thin fascia on which the deep branches of the lateral plantar nerve and vessels run. The first dorsal inter-

osseous adjoins medially the flexor hallucis brevis and laterally on the plantar surface of the second metatarsal, adjoins the second dorsal interosseous. Dorsal and plantar interossei then alternate across the plantar surface of the foot until the fifth metatarsal is reached. Here the third plantar interosseous adjoins the flexor brevis of the little toe.

Action.—The chief axis of the foot may be taken to extend through the second toe. The dorsal interosseous muscles abduct—pull the digits to which they are attached away from this axis; the plantar interosseous muscles adduct—pull the digits toward the axis. The interossei all flex the first row of phalanges.

Variations.—The second dorsal interosseous may have no attachment to the third metatarsal.

BURSÆ

B. intermetatarsophalangeæ.—Four bursæ between the neighboring sides of the heads of the metatarsal bones and dorsal to the transverse capitular ligaments. **B. mm. lumbricalium.**

FIG. 490.—FOURTH LAYER OF THE MUSCLES OF THE SOLE.

Between the ends of the tendons of the lumbrical muscles and the transverse capitular ligaments. The three medial are more constant than the lateral.

For other bursæ in the foot, see pp. 549, 551 and 557.

MUSCLES GROUPED ACCORDING TO FUNCTION

The exact functions of many of the muscles have not yet been decisively determined. Anatomical studies, the construction of mechanical models, the electrical stimulation of the musculature, and observation of the muscular activities of normal individuals and of individuals in whom given muscles or sets of muscles are absent or paralysed, have all proved valuable methods of investigation, but each method has its drawbacks, and knowledge of the part actually played by individual muscles in the normal activities of the body is as yet merely approximate. Owing to the influence of gravity, the relations of other muscles to the skeleton, and similar factors, a given muscle may perform functions which would

not be deduced from a simple study of the relations of the muscle to the skeleton. Thus through the action of gravity the iliacus flexes not only the hip, but also the knee, and the hamstring muscles flex the hip while flexing the knee. The functions ascribed to various muscles in the following table, although an attempt has been made to base them upon the more recent work on the action of the muscles, must be taken to be merely approximately correct.

The *axes* about which a bone moves at a given joint are frequently complex. For practical purposes, however, it is usually possible to determine an approximate axis about which any given movement takes place. From this standpoint diarthrodial joints may be divided into three groups, uniaxial joints, biaxial joints and multiaxial joints.

In the *uniaxial joints* movements of note may be made merely about one approximated axis. If a muscle acts on such a joint it exerts an effective pull either in one direction about this axis or in the opposite direction. Most joints of this sort are of the hinge-type, like those between the phalanges, and the movements are flexion and extension. In some joints as at the joint between the dens and atlas the joint is of the pivot-type and the movement is one of rotation in one direction or the other.

In *biaxial joints* there are two approximated primary axes of movement. Muscles acting on such joints may cause movement about either axis or about intermediate axes, the resultant of simultaneous movement about both primary axes. Joints of this sort are usually either of the saddle-type, like the carpometacarpal joint of the thumb, or of the condyloid type, like the wrist-joint. About one axis we usually get flexion and extension, about the other axis, abduction and adduction. A given muscle may cause movement about one axis or about both axes.

In *multiaxial joints* movements may be made about axes in three planes, each plane vertical to each of the other planes, and about various intermediate axes. Joints of this type are called ball-and-socket joints, although they are not always, like the shoulder- or hip-joints, similar in form to an ordinary mechanical ball-and-socket joint.

Muscles producing a movement in a common direction are called *synergists,* those which produce movements in opposite directions are called *antagonists.* If all joints were of the uniaxial type it would be relatively easy to arrange the muscles acting on the joints into synergists and antagonists although even in such joints a muscle might be so attached that it would be a flexor after flexon has started, an extensor after extension has started. In case of biaxial, and still more so in case of multiaxial joints, the direction of pull exerted by a given muscle with respect to a given axis varies so much with the positions of the articulating bones that muscles which in one position are antagonists in another position become synergists during the same general movement. Thus when the arm is at the side the clavicular and spinous portions of the deltoid are adductors, and the acromial portion is an abductor of the arm; but after the arm has been raised a certain distance all parts become abductors.

In the following table an attempt has been made to include the names of the main muscles acting upon the chief axes of each joint or joint groups of the head, trunk and limbs. In this table have been included not only the voluntary muscles described in the preceding section, but also several described in other parts of the book.

1. Facial muscles. (Cf. p. 396)

These serve essentially to contract the various visceral orifices of the head or to retract the tissue surrounding them. They do not act on joints.

Ear.

Retractors: auricularis anterior, superior, and posterior.

Orbit.

(*a*) Retractor: epicranius (occipitofrontalis). The levator palpebræ superioris raises the upper eyelid.

(*b*) Contractors: orbicularis oculi, corrugator, and procerus.

Nasal orifice.

(*a*) Dilators: angular head of the quadratus labii superioris, transverse portion of the nasalis, and the dilatores naris.

(*b*) Contractors: pars alaris of the nasalis and the depressor septi nasi.

Oral orifice.

(*a*) Retractors:

Upward: zygomaticus, quadratus labii superioris, caninus.

Lateralward: zygomaticus, risorius, platysma, triangularis, buccinator.
Downward: triangularis, quadratus labii inferioris, platysma.

(b) Contractors: orbicularis oris, compressor labii, incisivus labii inferioris and superioris.

(c) Protractors of the lips: incisivus labii inferioris and superioris, mentalis.

2. Muscles acting on the eyeball (see Section on Eye).
To adduct the pupil: rectus medialis.
To abduct the pupil: rectus lateralis.
To direct the pupil upward: rectus superior, in association with the obliquus inferior.
To direct the pupil downward: rectus inferior, in association with the obliquus superior.

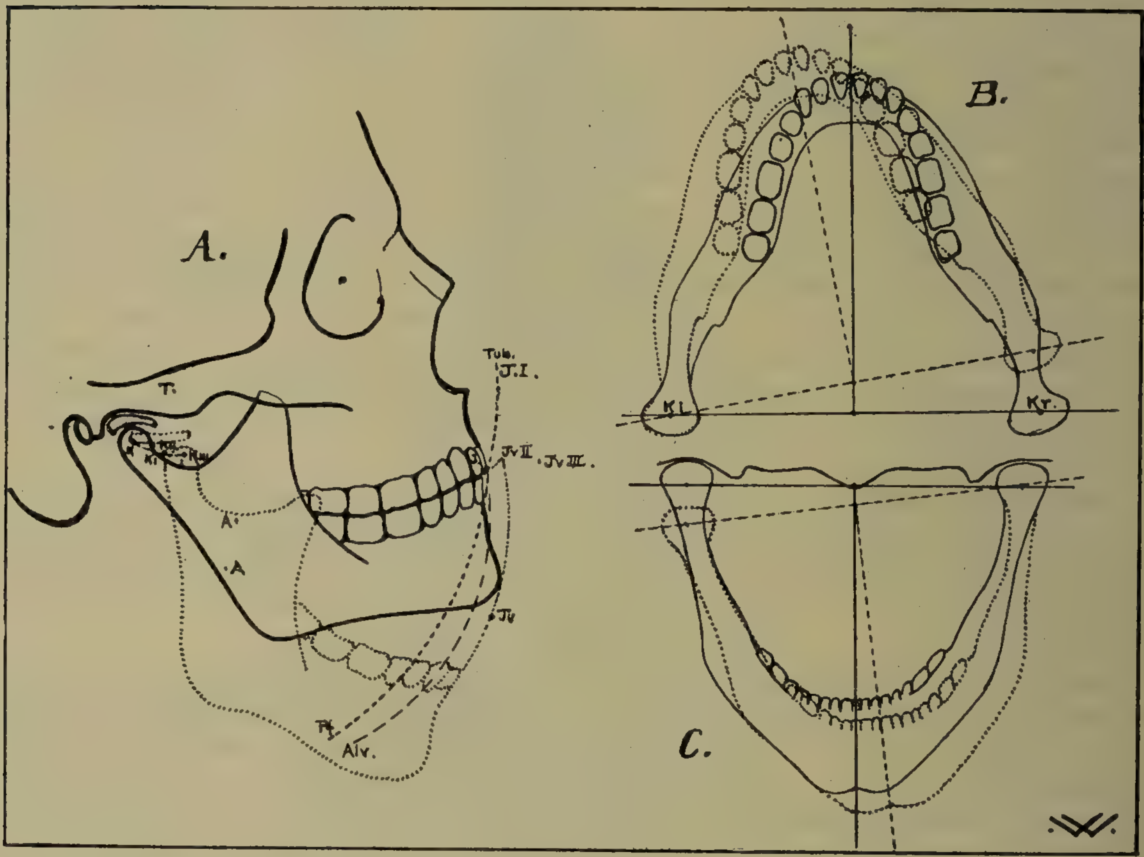


FIG. 491.—CHIEF AXES IN MOVEMENTS OF THE MANDIBLE. (After Fick.)

A. Movement about transverse axes *T* through the articular tubercles of the temporal bones and *K* through the condyles of the mandible. K, K^{1}, K^{11}, K^{111}, successive positions of *K* as the mouth is opened. *J*, *JvII*, movement of the top edge of the incisors in protrusion of the mandible. *JvIII*, position of top edge of the incisors in extreme protrusion of the mandible. Dotted line *JI–Pf*, movement of top edge of central incisors when there is no protrusion of the mandible. Dotted line *JvII–Jv*, movement of the top edge of central incisors when the mandible is protruded.

B. Movement of mandible as seen from above about vertical axis through left condyle at *Kl*. The line *Kl*, *Kr* indicates the position of the tranverse axis about which elevation and depression of the lower teeth takes place.

C. Mandible viewed from behind. Abduction about sagittal axis through right condyle.

3. Muscles acting on the mandible (cf. pp. 285, 405).

(a) Transverse axis above the articular tubercles of the temporal bones (fig. 491 A (T)). As the articular disk glides forward over the articular tubercle it in part moves about an axis above this tubercle, in part takes a more horizontal course than if confined to movement about this axis. The condyles to some extent move forward on the lower surface of the disk. As the mandible moves forward it is depressed slightly so as to permit the incisor teeth of the lower jaw to pass those of the upper jaw.

Retraction of mandible	*Protraction of mandible*
Right and left temporal muscles, posterior two-thirds.	Right and left external pterygoids.

Protraction of the jaw is aided by the internal pterygoid and masseter muscles and the anterior part of the temporal. The digastric is an accessory retractor.

(b) Transverse axis through condyles of mandible (fig. 491 A (K)).

Elevation of mandible	*Depression of mandible*
Temporal muscles	Digastric muscles
Internal pterygoids	Geniohyoids
Masseters	Mylohyoids

In the elevation and depression of the anterior part of the mandible the articular disks and the condyles are pulled forward as the mandible swings about the transverse axis through the condyles. The region of the ramus near where the stylomandibular and sphenomandibular ligaments are attached moves comparatively little as the mouth opens. While some investigators have contended that these ligaments fix the jaw and make a transverse axis of movement, this is denied by others. (See Fick, bibliography.)

(*c*) Rotation about vertical axis through one condyle. (Fig. 491 B (KL)). Slight abduction about anteroposterior axis through same condyle (fig. 491 C).

Rotation about vertical axis left condyle. Upper and lower sets of molars of right side opposed to one another.

Forward movement of lower right molars	*Backward movement* of lower right molars
Right external pterygoid muscle	Right digastric muscle.

The right internal pterygoid, masseter and anterior third of the temporal muscles aid in the forward movement, the posterior two-thirds of the temporal in the backward movement.

4. Muscles acting on the hyoid bone. (Cf. pp. 410, 417.)
   - (*a*) To elevate it: digastric, stylohyoid, styloglossus, mylohyoid, geniohyoid, genioglossus, hyoglossus, and the middle constrictor of the pharynx.
   - (*b*) To depress it: thyrohyoid, sternohyoid, omohyoid, sternothyroid.
   - (*c*) To protract it: genioglossus (inferior portion), geniohyoid, anterior belly of digastric, and the mylohyoid.
   - (*d*) To retract it: posterior belly of digastric, stylohyoid, and the middle constrictor of the pharynx.
5. Muscles acting on the larynx (see Section XI).
   - (*a*) To elevate it: thyrohyoid, stylopharyngeus, pharyngopalatinus, the inferior constrictor of the pharynx, and the elevators of the hyoid.
   - (*b*) To depress it: sternothyroid, sternohyoid, and omohyoid.
   - (*c*) To approximate the vocal folds: cricoarytenoideus lateralis; vocalis; thyroarytenoideus, arytenoideus transversus.
   - (*d*) To make the vocal folds (cords) tense: cricothyroideus.
   - (*e*) To widen the rima glottidis: cricoarytenoideus posterior.
   - (*f*) To shorten and thicken the vocal folds: thyroarytenoideus (externus), vocalis.
   - (*g*) To constrict the aditus and vestibule of the larynx: aryepiglotticus, thyroarytenoideus.
   - (*h*) To widen the aditus and vestibule of the larynx: thyroepiglottideus.
6. Muscles acting on the tongue (see Section X).
   - (*a*) To elevate it: styloglossus (especially along the sides), glossopalatinus, glossopharyngeus, and the elevators of the hyoid bone.
   - (*b*) To depress it: genioglossus (in the center), hyoglossus (at the sides), chondroglossus, and the depressors of the hyoid bone.
   - (*c*) To protrude it: genioglossus (middle and inferior portions).
   - (*d*) To retract it: genioglossus (anterior portion), styloglossus, chondroglossus.
   - (*e*) To shorten it and make it bulge upwards: longitudinalis superior and inferior.
   - (*f*) To narrow it and make it bulge upwards: transversus linguæ.
   - (*g*) To flatten it: verticalis linguæ.

   When the muscles work symmetrically, these movements are symmetrical; when they do not work symmetrically, the tongue is moved from side to side, rotated, etc.
7. Muscles acting on the palate and pharynx (see Section X).
   - (*a*) To narrow the pharyngeal opening of the tuba auditiva (Eustachian tube): levator veli palatini.
   - (*b*) To widen the isthmus of the tuba: levator veli palatini.
   - (*c*) To open the tube: tensor veli palatini, pharyngopalatinus.
   - (*d*) To raise and shorten the uvula: m. uvulæ.
   - (*e*) To depress the soft palate: glossopalatinus, pharyngopalatinus.
   - (*f*) To make tense the soft palate: tensor veli palatini.
   - (*g*) To lift the soft palate: levator veli palatini.
   - (*h*) To approximate the glossopalatine arches; glossopalatinus.
   - (*i*) To approximate the pharyngopalatine arches: pharyngopalatinus, superior constrictor of the pharynx.
   - (*j*) To constrict the pharynx: superior, middle, and inferior constrictors.
   - (*k*) To widen the pharynx: stylopharyngeus and the muscles which protract the hyoid bone.
   - (*l*) To elevate the pharynx: stylopharyngeus, pharyngopalatinus.
8. Muscles acting on the head (cf. pp. 414, 422, 478).

Atlanto-occipital and atlantoepistropheal joints. *Note.*—Flexion and extension (maximum 20° flexion, 30° extension, usually less) and abduction (15° to 20° from the midposition, frequently less) occur chiefly in the atlanto-occipital joints, rotation (about 30° from the midposition) chiefly in the atlantoepistropheal joints. Abduction in the atlanto-occipital joint is accompanied by rotation and extension toward the same side (Fick).

(*a*) Transverse axis above occipital condyles, (fig. 492T).

Extension	*Flexion*
Right and left trapezius	Right and left longus capitis
Right and left semispinalis capitis	Right and left rectus capitis anterior
Right and left obliquus capitis superior	Right and left rectus capitis lateralis

Right and left rectus capitis posterior major
Right and left rectus capitis posterior minor
Right and left splenius capitis muscles

The supra- and infrahyoid muscles working together are accessory flexors. The right and left sternocleidomastoids, and longissimus capitis muscles are accessory extensors.

(*b*) Vertical axis through dens of epistropheus (fig. 492V).

Rotation to right	*Rotation to left*
Left sternocleidomastoid	Right sternocleidomastoid
Left trapezius	Right trapezius
Right splenius capitis	Left splenius capitis
Right longissimus capitis	Left longissimus capitis
Right obliquus capitis inferior	Left obliquus capitis inferior
Right rectus capitis posterior major	Left rectus capitis posterior major
Right longus capitis	Left longus capitis

(*c*) Anteroposterior axis through base of occipital (fig. 492 A).

Lateral movement to right	*Lateral movement to left*
Right sternocleidomastoid and splenius capitis	Left sternocleidomastoid and splenius capitis
Right longissimus capitis	Left longissimus capitis
Right rectus capitis lateralis	Left rectus capitis lateralis
Right obliquus capitis superior	Left obliquus capitis superior
Right semispinalis capitis	Left semispinalis capitis

9. Muscles acting on the vertebral column (fig. 493) (cf. p. 478)
(1) *Cervical region.*

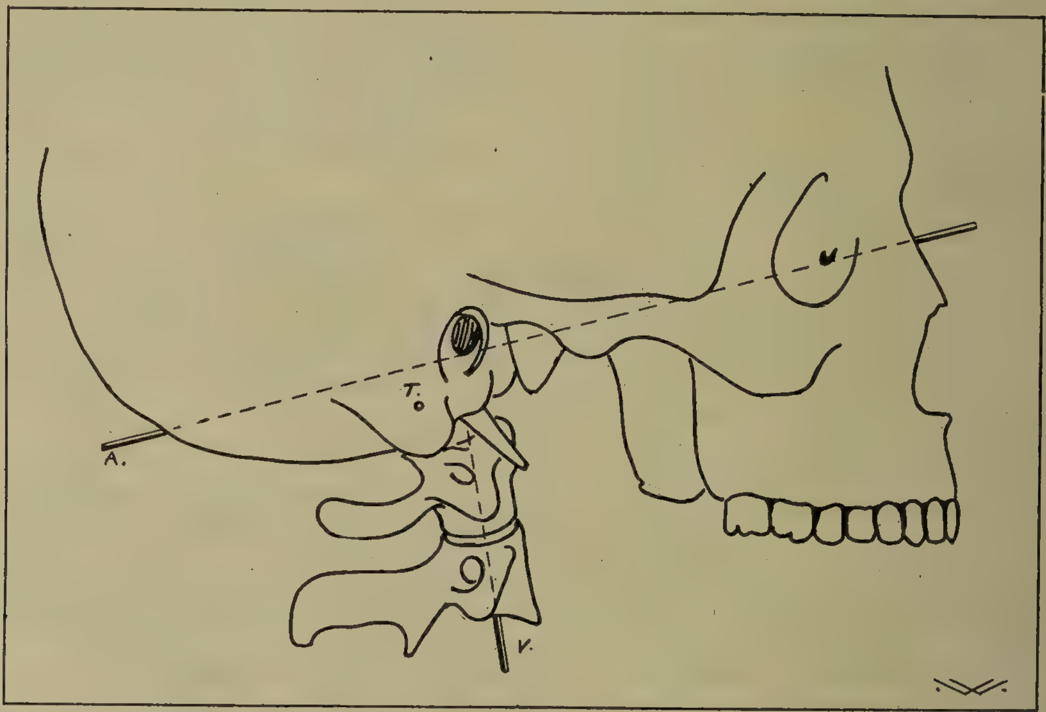


FIG. 492.—CHIEF AXES OF MOVEMENT OF SKULL ON VERTEBRAL COLUMN. *A*, Sagittal axis; *T*, transverse axis; *V*, perpendicular axis.

(*a*) Transverse axes (fig. 493 A (T)).

Extension	*Flexion*
Splenius capitis and cervicis	Sternocleidomastoid
Semispinalis cervicis and capitis	Longus colli and capitis
Longissimus cervicis	Scaleni
Iliocostalis cervicis	
Spinalis	
Interspinales	
Multifidus	
Rotatores	

(*b*) Oblique axes (fig. 493 A (O)).

Oblique rotation to right	*Oblique rotation to left*
Right splenius capitis and cervicis	Left splenius capitis and cervicis
Right longissimus capitis and cervicis	Left longus capitis and cervicis
Left sternocleidomastoid	Right sternocleidomastoid
Right iliocostalis cervicis	Left iliocostalis cervicis
Left semispinalis cervicis	Right semispinalis cervicis
Left rotatores	Right rotatores

Upper part right longus colli
Lower part left longus colli
Left scaleni
Left trapezius

Lower part right longus colli
Upper part left longus colli
Right scaleni
Right trapezius

(*c*) Anteroposterior axes (fig. 493 A (F)).

Abduction to right

Right scaleni
Right sternocleidomastoid
Right splenius capitis and cervicis
Right iliocostalis cervicis
Right longissimus capitis and cervicis
Right semispinalis cervicis
Right intertransverse

Abduction to left

Left scaleni
Left sternocleidomastoid
Left splenius capitis and cervicis
Left iliocostalis cervicis
Left longissimus capitis and cervicis
Left semispinalis cervicis
Left intertransverse

(2) *Thoracic region.*

(*a*) Anteroposterior and transverse axes (fig. 493 B (F, T)).

Abduct to right and extend

Right iliocostalis
Right longissimus dorsi
Right semispinalis
Right multifidus
Right rotatores
Right levatores costarum
Right spinalis

Abduct to left and extend

Left iliocostalis
Left longissimus dorsi
Left semispinalis
Left multifidus
Left rotatores
Left levatores costarum
Left spinalis

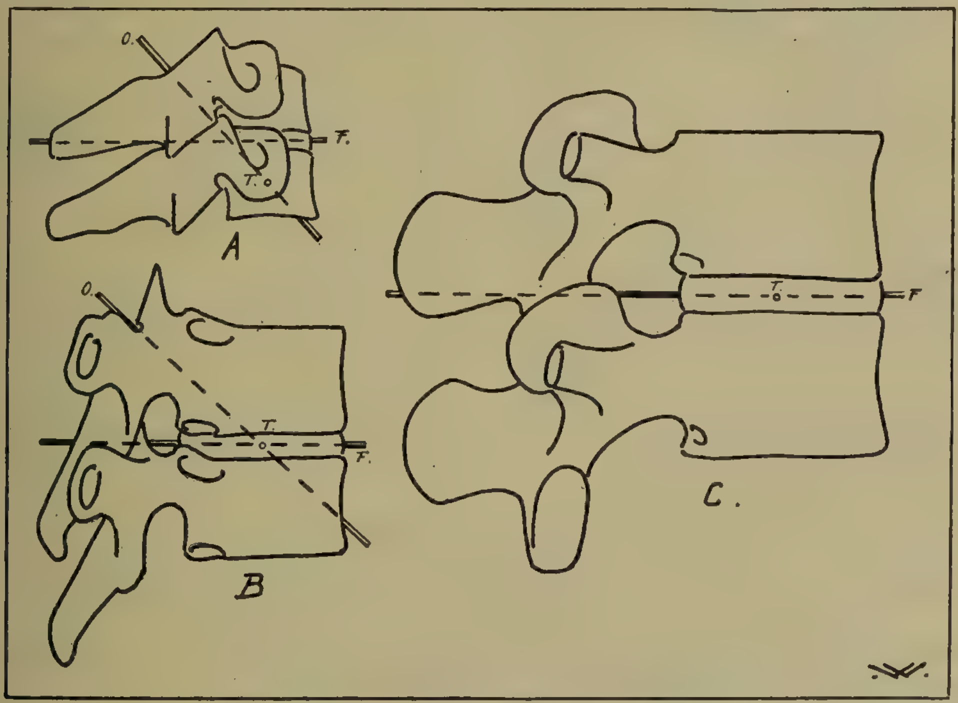


FIG. 493.—CHIEF AXES OF MOVEMENT OF ONE VERTEBRA ON THE NEXT BELOW. *A*, cervical, *B*, thoracic and *C*, lumbar vertebræ. *O*, oblique axis in sagittal plane for rotation combined with abduction; *F*, anteroposterior axis in sagittal plane for abduction; *T*, transverse axis in frontal plane for flexion and extension.

(*b*) Oblique axes (fig. 493 B (O))

Oblique rotation to right

Left semispinalis
Right iliocostalis
Left multifidus
Left rotatores
Right levatores costarum
Left obliquus abdominis ext.
Right obliquus abdominis int.

Oblique rotation to left

Right semispinalis
Left iliocostalis
Right multifidus
Right rotatores
Left levatores costarum
Right obliquus abdominis ext.
Left obliquus abdominis int.

(3) *Lumbar region.*

(*a*) Transverse axes (fig. 493 C (O))

Extension

Right and left quadratus lumborum
Right and left sacrospinalis
Multifidus
Right and left inter-transverse
Right and left interspinal

Flexion

Right and left abdominal muscles

(b) Anteroposterior axes (fig. 493 C (F))

Abduction to right	*Abduction to left*
Right quadratus lumborum	Left quadratus lumborum

The psoas muscles are powerful accessory flexors and abductors of the lumbar region of the spinal column. The right abdominal muscles abduct to the right, the left to the left.

10. Muscles acting on the thorax (fig. 494 A, B and C)

Longitudinal axes through necks of ribs, anteroposterior and vertical axes through rib cartilages near chondrosternal joints. The costochondral and interchondral joints are also involved.

Inspiration.—Shafts of ribs swing outwards and upwards, costochondral angles flattened, sternum elevated and protracted.
External intercostals
Interchondral muscles

Expiration.—Shafts of ribs swing inwards and downwards, costochondral angles increased, sternum depressed and retracted.
Internal intercostals (costal part)
Subcostals
Transversus thoracis

The extensors of the thoracic region of the spine aid in inspiration. In forced inspiration the scalene, the sternocleidomastoid, the rhomboids and serratus anterior, the serratus posterior superior, the trapezius and pectoralis minor, latissimus dorsi, pectoralis major and subclavius may be brought into play. The abdominal muscles and the muscles of the pelvic outlet are essentially antagonists of the diaphragm. The abdominal muscles, the quadratus lumborum-

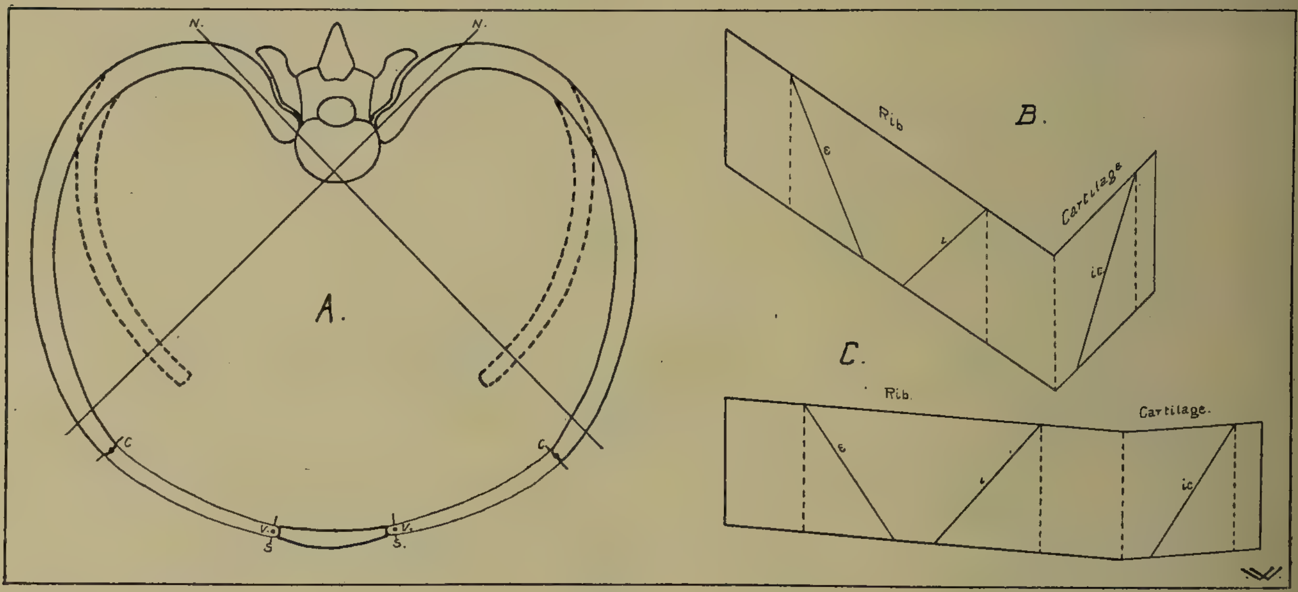


FIG. 494A.—SCHEME TO ILLUSTRATE THE ACTION OF THE RIBS. THE DOTTED LINES REPRESENT THE POSITION OF THE RIBS IN EXPIRATION.

N, axis about which the rib rotates; *C*, axis for costochondral joint; *S*, anteroposterior axis of chondrosternal joint; *v*, vertical axis of chondrosternal joint.

FIG. 494B–C (After Fick).—HAMBERGER'S SCHEME FOR ILLUSTRATING THE ACTION OF THE INTERCOSTAL MUSCLES.

B. Rib depressed. C. Rib elevated.

e, external intercostal; *i*, internal intercostal; *ic*, interchondral part of internal intercostal

the iliocostalis, the longissimus dorsi and the serratus posterior inferior lower the thorax in forced expiration. The relatively simple explanation of the action of the intercostal muscles given by Hamberger in 1748 and illustrated in fig. 494 B and C has been questioned by Hoover, Arch. Int. Med. vol. 30, p. 1, 1922.

The diaphragm plays an essential part in inspiration although according to Fick the part played by the diaphragm is frequently overestimated.

11. Muscles acting on the abdomen. (Cf. p. 488.)
   (a) Constriction of the abdominal cavity: obliquus abdominis externus and internus, the transversus and rectus abdominis and the diaphragm, levator ani, and coccygeus.
   (b) Reduction of pressure in the abdominal cavity: the muscles of inspiration, with the exception of the diaphragm, serve to lessen the compression of the abdominal viscera.
12. Action of the muscles of the perineal region. (Cf. p. 505.)
   (a) To close anal canal: sphincter ani externus.
   (b) To constrict the anal portion of the rectum: levator ani (pubococcygeal portion).
   (c) To constrict the bulbus urethræ and the corpus cavernosum urethræ (corpus spongiosum): bulbocavernosus.
   (d) To elevate the prostate gland: levator ani.
   (e) To constrict the vagina: bulbocavernosus, levator ani (pubococcygeal portion), constrictor vaginæ.

(*f*) To assist in erection of penis and clitoris: ischiocavernosus, bulbocavernosus, and sphincter urethræ membranaceæ.

(*g*) To compress the urethra and the bulbourethral (Cowper's) or the great vestibular (Bartholin's) gland: sphincter urethræ membranaceæ and the transversus perinei profundus.

(*h*) To support and lift the pelvic floor: levator ani, coccygeus, transversus perinei profundus and superficialis.

13. Muscles acting on the shoulder-girdle at the sternoclavicular joint (fig. 495) (cf. pp. 310, 414, 424, 436).

It is assumed that movement at the acromioclavicular joint, while enabling the scapula to accommodate itself to the chest wall, at the same time increases the extent of the rotation of the scapula about the clavicular (acromiosternal) axis.

(*a*) Dorsoventral axis (fig. 495)

Abduction (scapula raised)	*Adduction (scapula depressed)*
Levator scapulæ	Pectoralis minor
Trapezius (upper part)	Subclavius
	Trapezius (lower part)

The lower part of the serratus anterior is an accessory adductor. The pectoralis major (lower part) and latissimus dorsi, adductors of the arm, also indirectly adduct the scapula. The clavicular part of the sternocleidomastoid and the middle part of the serratus anterior are accessory abductors.

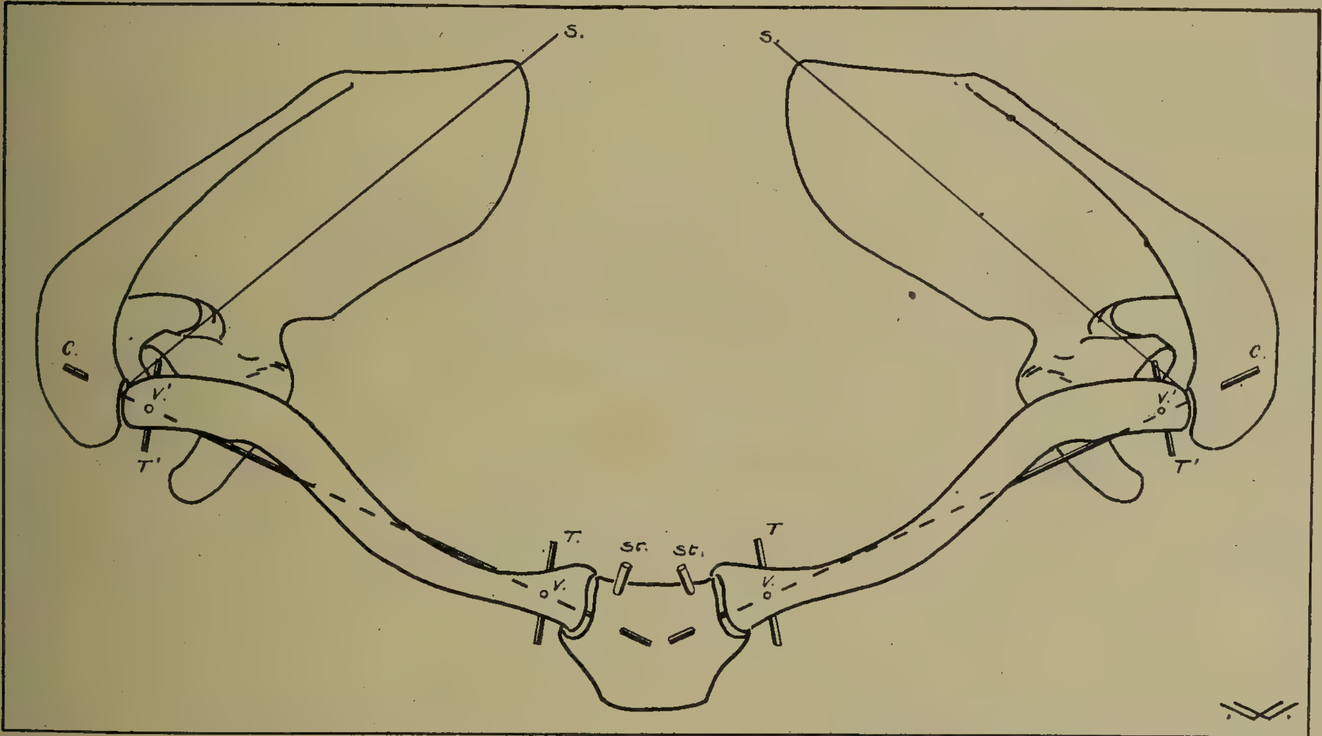


Fig. 495.—Chief Axes of Movement of the Shoulder Girdle.

Viewed from above. *S*, scapular axis; *C*, clavicular axis; *V*, vertical axis through sternal end of clavicle; *V′*, vertical axis through acromial end of clavicle; *St*, sternal axis for dorsoventral movements at sternoclavicular joint; *T*, ventrodorsal axis for elevation and depression about the sternoclavicular joint; *T′*, dorsoventral axis for acromioclavicular joint.

(*b*) Vertical axis (fig. 495)

The clavicle moves on the interarticular disk about a vertical axis through the head of the clavicle; the clavicle and disk move about an oblique axis through the sternum.

Retraction (scapula carried backward)	*Protraction (scapula carried forward)*
Rhomboids	Serratus anterior
Trapezius (middle part)	Pectoralis minor
(The latissimus dorsi aids this movement)	(The pectoralis major, upper sternal part, aids this movement)

(*c*) Clavicular axis (fig. 495)

Rotation in the direction of supination (glenoid cavity turned upward)	*Rotation in direction of pronation (glenoid cavity turned downward)*
Trapezius	Pectoralis minor
Serratus anterior (lower part)	Rhomboidius major

In the upward rotation the acromion and outer end of the clavicle are elevated and pulled backwards, as well as rotated. The reverse is true of the downward rotation. The pectoralis major (pectoral portion), and latissimus dorsi are accessory rotators in the direction of pronation.

14. Muscles acting on the shoulder-joint (fig. 496) (cf. pp. 317, 430).

(*a*) Dorsoventral axis (fig. 496 A)

Abduction	*Adduction*
Deltoid	Pectoralis major (lower part)
Supraspinatus	Latissimus dorsi
	Teres major

With the arm at the side the clavicular and spinal parts of the deltoid are adductors but as the arm is abducted these parts become abductors. The subscapularis meanwhile changes from an abductor to an adductor. The long head of the biceps and the upper part of the infraspinatus are strong accessory abductors. The long head of the triceps, the coracobrachialis, the short head of the biceps and the teres minor are strong accessory adductors when the arm is at the side

(*b*) Transverse axis, arm at side; perpendicular axis, arm at 90° (fig. 496 P)

Extension	*Flexion*
Deltoid (spinal part)	Deltoid (clavicular part)
	Pectoralis major (clavicular part)
	Coracobrachialis

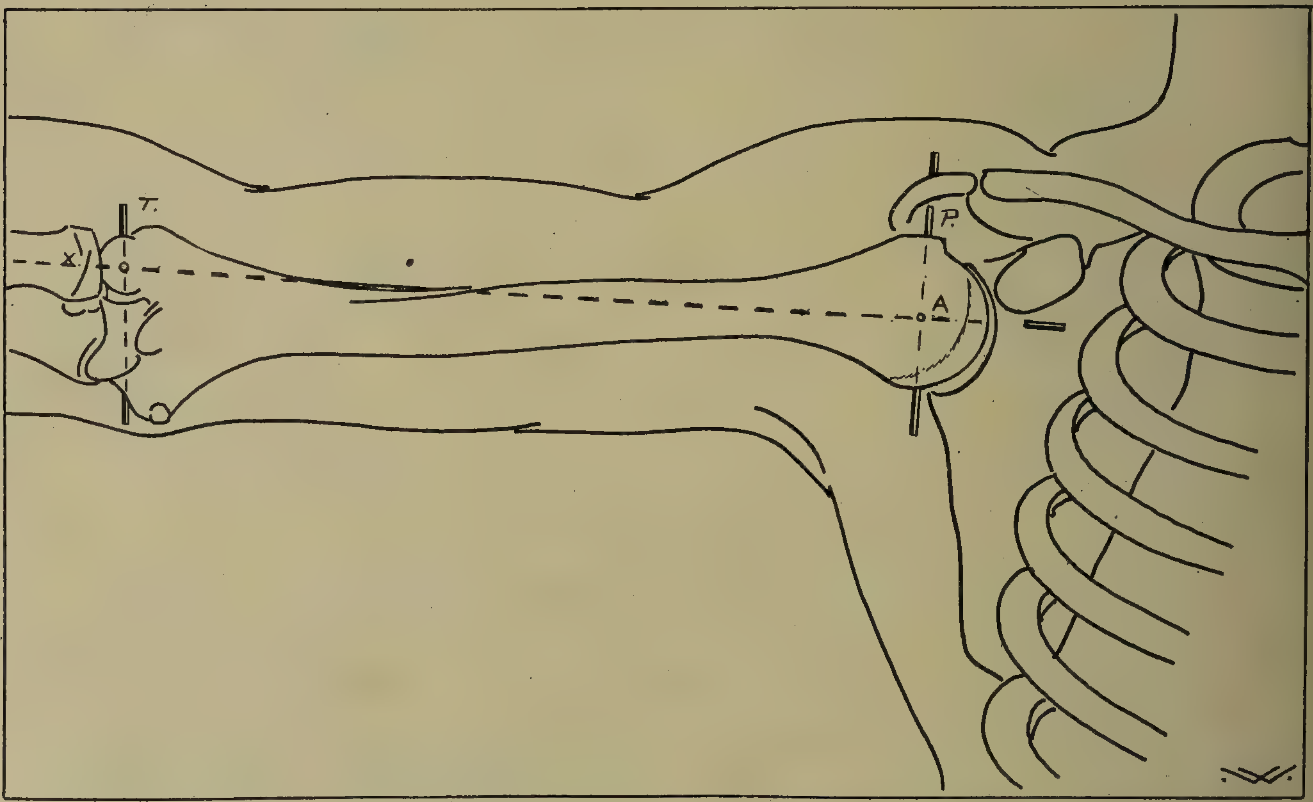


FIG. 496.—CHIEF AXES OF MOVEMENT AT SHOULDER AND ELBOW JOINTS.

A, dorsoventral axis of shoulder-joint for abduction and adduction; *P*, perpendicular axis of shoulder-joint, arm adducted for flexion and extension. When the arm is at the side this axi; passes transversely through the body; *A–X*, longitudinal axis through humerus, for rotations *T*, transverse axis through humerus for flexion and extension at elbow joint.

The latissimus dorsi, teres major, and subscapularis (lower part), when the arm is at the side are strong accessory extensors; the short head of the biceps is a strong accessory flexor. The subscapularis is a powerful accessory flexor when the arm is abducted. The infraspinatus is a flexor.

(*c*) Humeral axis (fig. 496 A–X)

Lateral rotation (*supination*)	*Medial rotation* (*pronation*)
Infraspinatus	Subscapularis
Teres minor	

The spinal part of the deltoid is also a lateral rotator. The adductor muscles, the clavicular part of the deltoid, and the long head of the biceps are strong accessory medial rotators. An important function of the coracobrachialis muscle and of the scapular attachments of the biceps and triceps muscles appears to be to hold the head of the humerus in the glenoid cavity.

15. Muscles acting on the forearm at the elbow-joint (figs. 496, 497) (cf. p. 444, 446, 449).

Transverse axis (figs. 496, 497 T)

Extension	*Flexion*
Triceps	Brachialis
Anconeus	Brachioradialis

The biceps muscle, a powerful flexor when the forearm is supinated, is a much weaker one when the forearm is pronated. The pronator teres and extensor carpi rad. long. are strong accessory flexors of the elbow-joint, the flexor carpi radialis, extensor carpi radialis brevis and palmaris longus are weaker accessory flexors.

16. Muscles acting on the radioulnar joints (figs. 497, 498) (cf. p. 449).

In the ordinary use of the upper extremity, supination of the foreman is usually accompanied by extension at the elbow-joint and lateral rotation at the shoulder-joint; pronation with flexion at the elbow-joint and medial rotation at the shoulder-joint.

Longitudinal axis

Supination	*Pronation*
Biceps	Pronator teres
Supinator	Pronator quadratus

The brachioradialis and extensor carpi rad. long. bring the forearm into an intermediate position. When the arm is extended they supinate, but as the arm is flexed they tend more and more to bring the arm into a pronate position. The flexor carpi radialis is a powerful accessory pronator.

17. Muscle acting on the hand at the wrist-joint (fig. 498) (cf. p. 449).

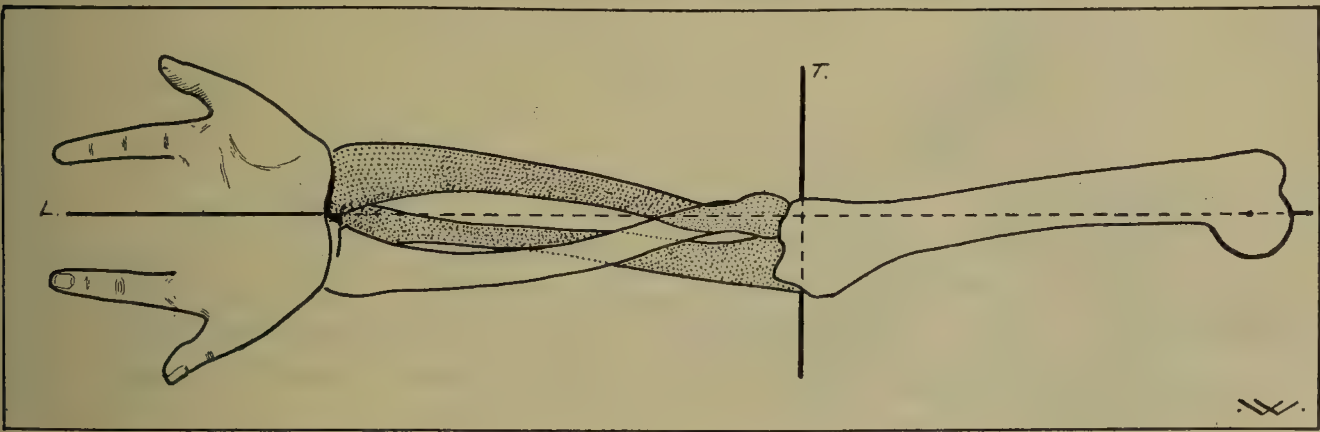


Fig. 497.—Forearm in Pronation and Supination. (After Fick.)
T, transverse axis at elbow-joint for flexion and extension; *L*, longitudinal axis of forearm for pronation and supination.

(*a*) Transverse axis (fig. 498 T)

Extension (*dorsal flexion*)	*Flexion* (*volar flexion*)
Extensor carpi radialis brevis	Flexor carpi ulnaris
Extensor carpi radialis longus	Flexor carpi radialis
Extensor carpi ulnaris	Palmaris longus

The long flexors and extensors of the thumb and fingers are accesory flexors and extensors of the wrist-joint. The long abductor of the thumb is also an accessory flexor of the wrist.

(*b*) Dorsoventral axis (fig. 498 V)

Radial abduction	*Ulnar abduction*
Extensor carpi radialis longus	Flexor carpi ulnaris
Extensor carpi radialis brevis	Extensor carpi ulnaris

The abductor pollicis longus and extensor pollicis longus muscles are powerful accessory radial abductors.

18. Muscles acting on the carpometacarpal joints (fig. 498) (cf. p. 472). Combined transverse and perpendicular axes (A and T)

Thumb

According to Fick and others there is some voluntary rotation possible at the first carpometacarpal joint.

Abduct and repose	*Adduct and oppose*
Abductor pollicis longus	Opponens
Abductor pollicis brevis	Adductor

The extensors of the thumb are accessory reposers. The long and short flexors aid in opposing.

Little finger

Abduct and repose	*Adduct and oppose*
Extensor carpi ulnaris	Opponens

The abductor digiti quinti and extensor digiti quinti proprius aid in reposing; the third volar interosseous, the fourth lumbrical and the flexors of the little finger in opposing.

19. Muscles acting on the metacarpophalangeal joints (fig. 498).

(*a*) Transverse axes

Thumb

Extension	*Flexion*
Extensor pollicis brevis	Flexor pollicis brevis

The extensor pollicis longus is an accessory extensor. The adductor and abductor brevis and the flexor pollicis longus are accessory flexors.

Little finger

Extensor digiti quinti proprius	Flexor digiti quinti brevis Fourth lumbrical Third volar interosseous

The abductor and long flexors of the little finger are accesory flexors of this joint.

Other fingers

Extension	*Flexion*
Extensor digitorum communis Extensor indicis proprius	Lumbricals Interossei

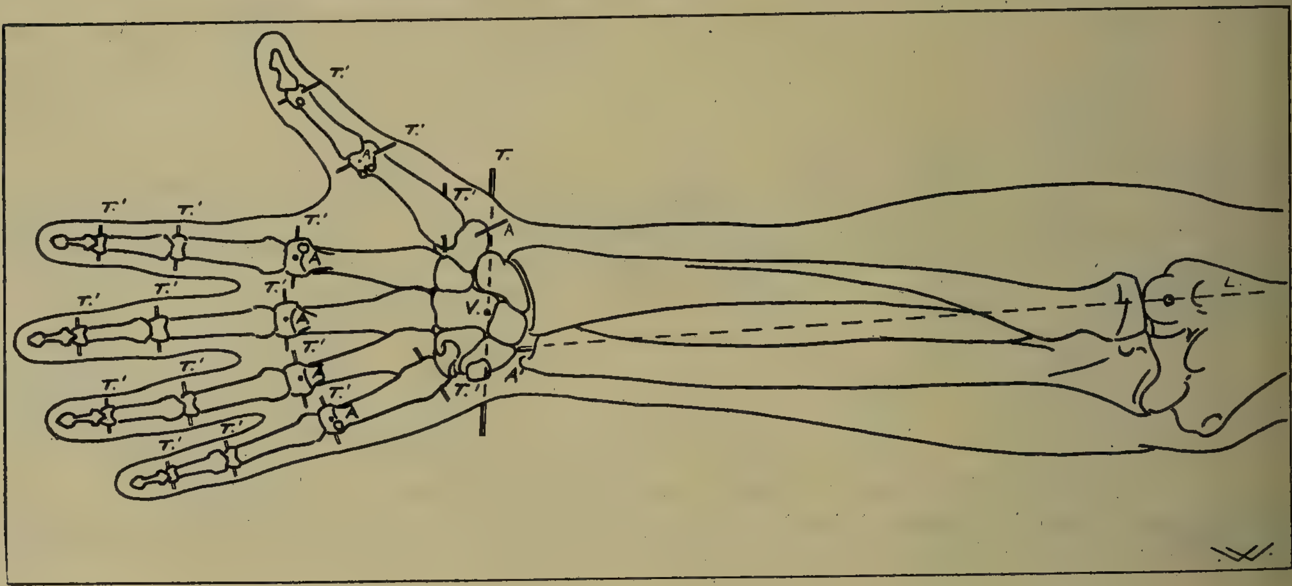


Fig. 498.—Chief Axes of Movement of Forearm, Wrist and Hand.

L, longitudinal axis of forearm for pronation and supination; *T*, compromise transverse axis for flexion and extension at wrist; *V*, volardorsal axis through carpus for ulnar and radial abduction of the hand; *T′*, transverse axes for flexion and extension of the thumb and fingers; *A*, volardorsal axes for radial and ulnar abduction of the thumb and fingers.

The flexor sublimus and flexor profundus are accessory flexors of these joints.

(*b*) Perpendicular axes

Abduct from the long axis of the middle finger	*Adduct toward the long axis of the middle finger*
1st and 2nd lumbricals Dorsal interossei Abductor digiti quinti	Volar interossei 3d and 4th lumbricals

20. Muscles acting on the interphalangeal joints (fig. 498).

Transverse axes

Thumb

Extension	*Flexion*
Extensor pollicis longus	Flexor pollicis longus

The flexor pollicis brevis and abductor pollicis brevis are accessory extensors of this joint.

Fingers; proximal joints

Interossei Lumbricals Abductor digiti quinti	Flexor digitorum sublimis

Fingers; distal joints

Extension
Interossei
Lumbricals
Abductor digiti quinti

Flexion
Flexor digitorum profundus

The extensor digitorum communis, extensor indicis proprius and extensor digiti quinti proprius are accessory extensors of the joints.

21. Muscles acting on the pelvis.
Thoracic and thoracolumbar joints (fig. 499).

Vertical spinal axes

Rotation of pelvis to right
Left internal oblique
Right external oblique

Rotation of pelvis to left
Right internal oblique
Left external oblique

The intrinsic dorsal muscles also play a part. See action of muscles on the vertebral column.

Lumbar and lumbosacral joints (figs. 493, 499).

(*a*) Ventrodorsal axes

Abduction of pelvis to right
Right quadratus lumborum
Right sacrospinalis

Abduction of pelvis to left
Left quadratus lumborum
Left sacrospinalis

The abdominal, the latissimus dorsi and the psoas muscles are accessory abductors.

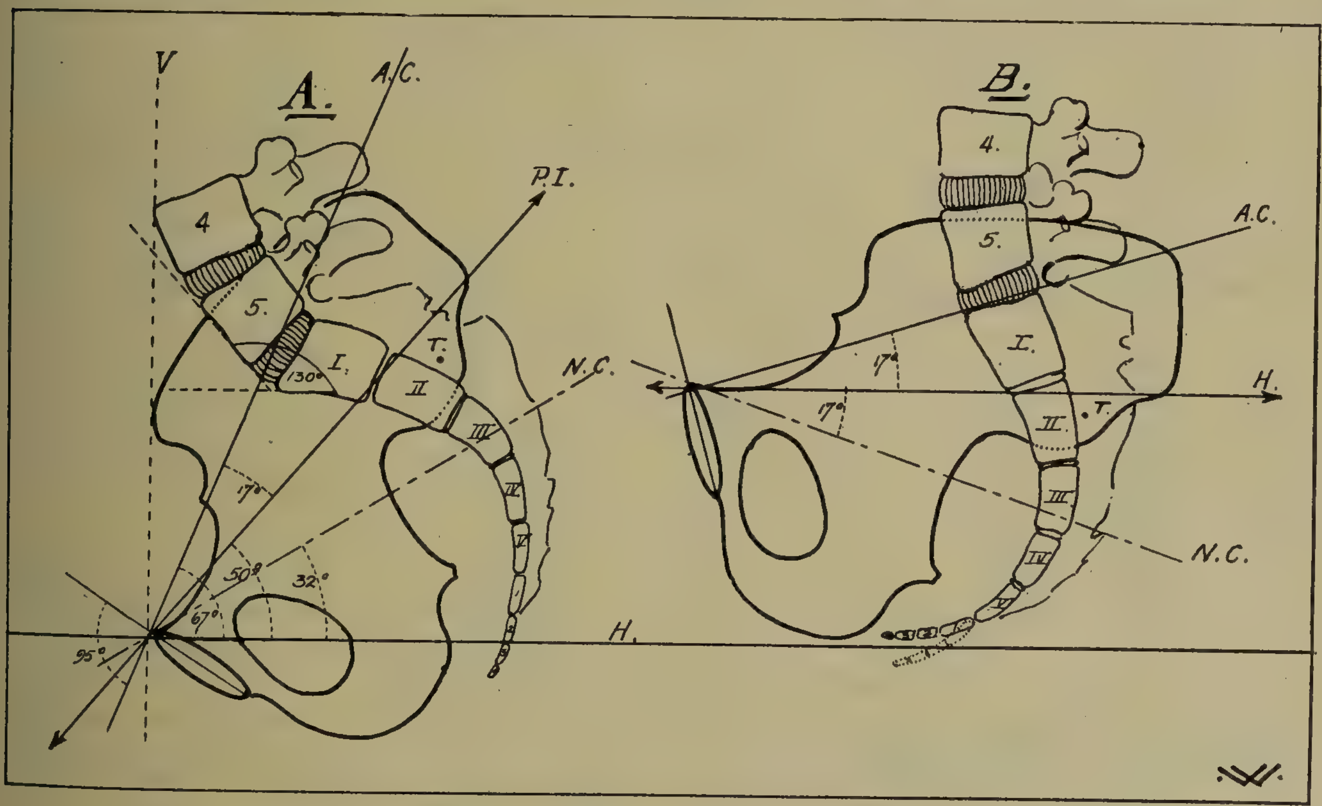


FIG. 499.—EXTENSION AND FLEXION OF THE PELVIS. (After Fick.)
A, pelvis, standing position; *B*, pelvis, sitting position; *A.C.*, anatomical conjugate; *N.C.* normal conjugate; *H*, horizontal plane; *V*, vertical plane; *P.I.*, pelvic inclination; *T*, approximate position for transverse axis in movements at the sacroiliac joint.

(*b*) Transverse axes

Extension of pelvis
Quadratus lumborum
Sacrospinalis

Flexion of pelvis
Rectus abdominis
Oblique abdominal muscles
Psoas minor

The psoas major muscle is a powerful accessory flexor of the pelvis, the latissimus dorsi is an accessory extensor.

22. Muscles acting on the thigh at the hip-joint (fig. 500 B) (cf. pp. 521, 530).

(*a*) Transverse axes

Extension
Gluteus maximus

Flexion
Iliopsoas
Pectineus

The adductor magnus (posterior lower part) and also the hamstring muscles are accessory extensors; the gluteus medius, piriformis and obturator internus are weaker accessory extensors. The rectus femoris and the adductor longus and brevis, the obturator externus,

tensor fasciæ latæ, and sartorius, are powerful accessory flexors of the hip-joint; the gluteus minimus, adductor minimus, gracilis and quadratus femoris are weaker accessory flexors.

(b) Ventrodorsal axis

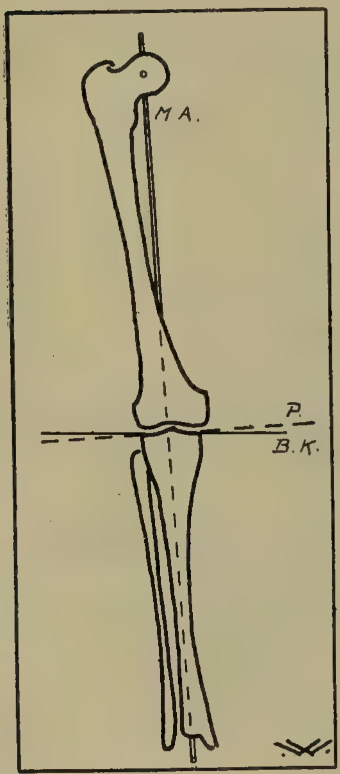
Abduction	*Adduction*
Gluteus medius	The adductors
Gluteus minimus	Pectineus
Piriformis	Obturator externus
Tensor fasciæ latæ	

The rectus femoris, and sartorius are accessory abductors. The gluteus maximus and quadratus femoris are powerful accessory adductors in the standing position. The gracilis, adductor minimus, biceps, semitendinosus, semimembranosus and obturator internus are weaker accessory adductors.

(c) Vertical axis (thigh flexed 90°)

Abduction	*Adduction*
Gluteus maximus	Iliopsoas

(In addition to the abductors and adductors given above.)



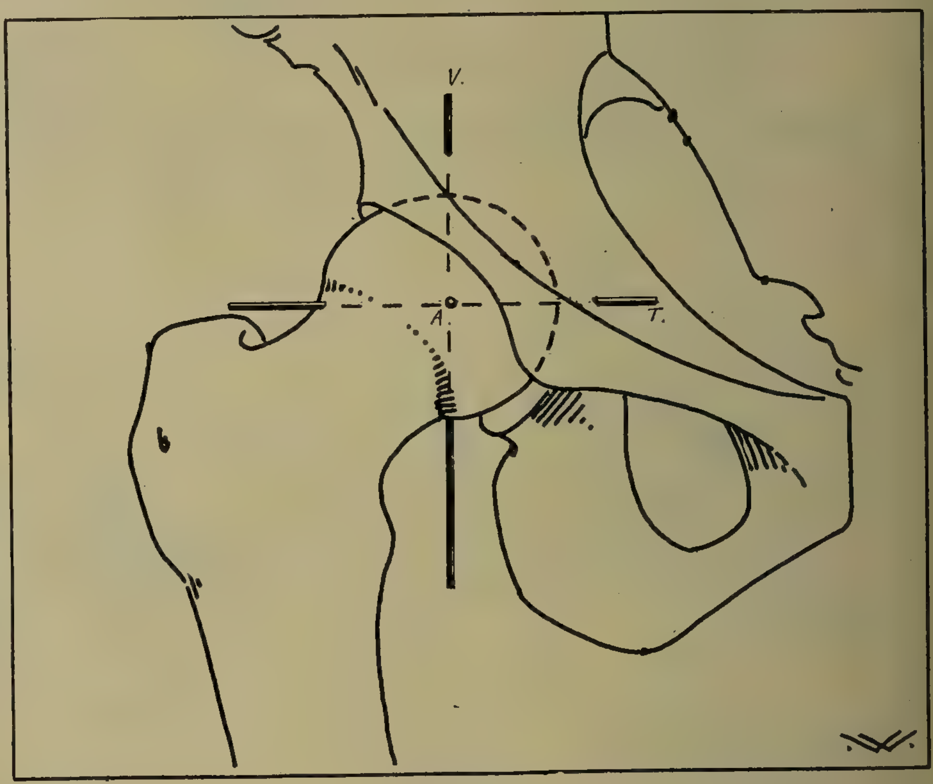


Fig. 500.—Axes of Lower Limb.

A. Mechanical axes of thigh and leg (after Fick). *M.A.*, mechanical axis; *P*, perpendicular to mechanical axis; *B.K.*, base of knee.
B. Axes for movements at the hip-joint. *A*, dorsoventral axis for abduction and adduction: *T*, transverse axis for flexion and extension; *V*, vertical axis for rotation.

(d) Femoral axis

Lateral rotation	*Medial rotation*
Quadratus femoris	Gluteus minimus (ventral part)
Obturator internus and gemelli	Gluteus medius (ventral part)
Obturator externus	Tensor fasciæ latæ
Piriformis	

The gluteus maximus is a powerful lateral rotator as well as an extensor; the rectus femoris, the lower part of the adductor magnus, the biceps, sartorius, gracilis and the dorsal part of the gluteus medius are accessory lateral rotators. The iliopsoas and the adductors longus, brevis and minimus are strong medial rotators; the pectineus, semitendinosus, semimembranosus and tensor fasciæ latæ are weaker accessory medial rotators.

23. Muscles acting on the leg at the knee-joint (fig. 501) (cf. pp. 530, 550).

(a) Transverse axis

Extensors	*Flexors*
Quadriceps femoris	Semimembranos
	Semitendinosusu
	Biceps
	Gracilis
	Sartorius
	Popliteus

The gastrocnemius is a powerful accessory flexor of the knee-joint. The gluteus maximus and tensor fasciæ latæ through the iliotibial band help to hold the extended knee firm.

(*b*) Tibial axis (knee flexed)

Lateral rotation	*Medial rotation*
Biceps	Semimembranosus
Tensor fasciæ latæ	Semitendinosus
	Sartorius
	Popliteus
	Gracilis

24. Muscles acting on the foot at the ankle-joint (fig. 502) (cf. p. 543).

Transverse axis

Extension (plantar flexion)	*Flexion* (hyperextension)
Gastrocnemius	Tibialis anterior
Soleus	Peroneus tertius
Peroneus longus	
Tibialis posterior	
Peroneus brevis	

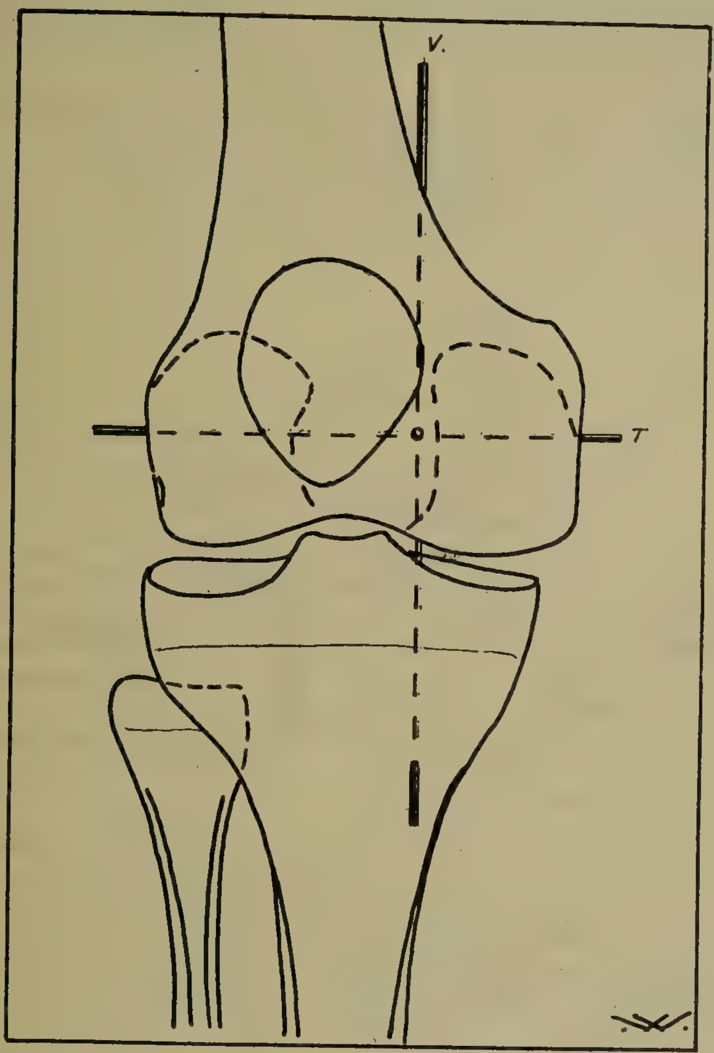


Fig. 501.—Axes of Movement at Knee-joint.

T, transverse axis, for flexion and extension. *V*, vertical (tibial) axis, for lateral and medial rotation.

The long extensors of the toes and the peroneus tertius flex; the long flexors of the toes extend the foot at this joint.

25. Muscles acting on the foot at the inferior articulation of the talus (artic. talocalcanea and talocalcaneonavicularis) (fig. 502).

Talocalcaneal axis

Inversion (adduction)	*Eversion* (abduction)
Tibialis posterior	Peroneus longus
	Peroneus brevis
	Peroneus tertius

The gastrocnemius, soleus, flexor hallucis longus, flexor digitorum longus and tibialis anterior are accessory inverters at this joint; the extensor digitorum longus and extensor hallucis longus are accessory everters.

26. Muscles acting on the foot at Chopart's joint (talonavicular-calcaneocuboid joints).

Calcaneo-midmetatarsal axis

Inversion (medial rotation)	*Eversion* (lateral rotation)
Tibialis posterior	Peroneus longus
	Peroneus brevis
	Peroneus tertius

The tibialis anterior, flexor digitorum longus, flexor hallucis longus, and extensor hallucis longus are accessory inverters at this joint; the extensor digitorum longus is an accessory everter.

27. Muscles acting on the metatarsophalangeal joints.

(*a*) Transverse axes

Extension	*Flexion*
Big toe	
Extensor hallucis longus	Flexor hallucis brevis.

The abductor and adductor hallucis muscles and the flexor hallucis longus are accessory flexors.

Little toe

Extensor longus digitorum	Flexor brevis digiti quinti
Extensor brevis digitorum	4th lumbrical
	3rd. plantar interosseus

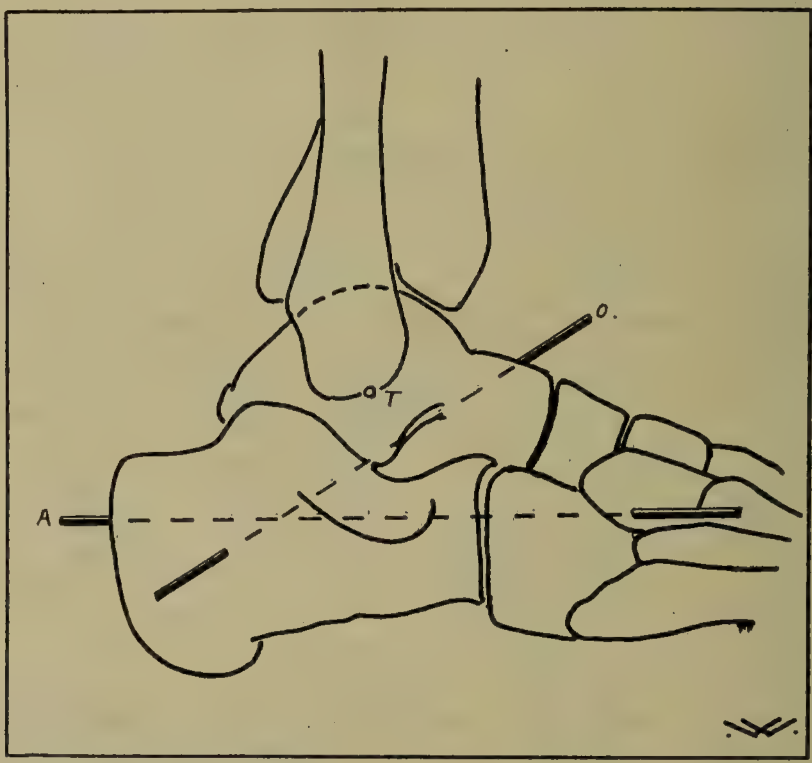


Fig. 502.—Chief Axes for Ankle-joint and Foot.

T, transverse axis for flexion and extension at talotibial joint; *O*, compromise axis for inversion and eversion at talocalcanial and talonavicular joints; *A*, compromise axis for inversion and eversion at Chopart's joint.

The abductor digiti quinti and the long and short flexors of the toes are accessory flexors of this joint.

Other toes

Extensor longus digitorum	1st., 2nd., and 3d. lumbricals
Extensor brevis digitorum	Dorsal interossei
	1st. and 2nd. plantar interossei

The long and short flexors of the toes are accessory flexors at these joints.

(*b*) Perpendicular axes

Abduction from long axis through second toe	*Adduction toward long axis through second toe*
Abductor hallucis	Adductor hallucis
Dorsal interossei	Plantar interossei
1st. lumbrical	2nd., 3d., and 4th. lumbricals
Abductor digiti quinti	

The transverse head of the adductor of the big toe draws the distal ends of the metatarsals closer together. The axes for this slight movement pass through the cuneiform and cuboid bones.

28. Muscles acting on the interphalangeal joints.

Transverse axes

Extension		*Flexion*
	Big toe	
Extensor hallucis longus Extensor hallucis brevis		Flexor hallucis longus
	Other toes	
Extensor digitorum longus Extensor digitorum brevis		Flexor digitorum longus Quadratus plantæ Flexor digitorum brevis (2nd. phalanx only)

The adductors and abductors of the big and little toes may be accessory extensors of the interphalangeal joints.

References.—For *development* of the muscular system, consult the list given by W. H. Lewis, Development of the Muscular System, in Keibel and Mall's Human Embryology; for *variations:* LeDouble, Traité des variations du systeme musculaire de l'homme; for *action of muscles:* Duchenne, Physiologie des movements démontrée à l'aide de l'expérimentation électrique et l'observation clinique, etc. (1867); Fick, Handbuch der Anatomie und Mechanik der Gelenke unter Berücksichtigung der bewegenden Muskeln, in von Bardeleben's Handbuch; Strasser, Lehrbuch der Muskel und Gelenkmechanik; Sherrington, the integrative action of the nervous system (1906), and Mackenzie, the Action of the Muscles, including Muscle Rest and Muscle Re-education; for the *extremities:* Frohse und Fränkel, Die Muskeln des menschlichen Armes und Beines, in von Bardeleben's Handbuch; for the *head* and *trunk:* Eisler, Die Muskeln des Stammes, in von Bardeleben's Handbuch; for the *pelvis:* Holl, Die Muskeln und Fascien des Beckenausganges. *Fascial spaces of the hand* by Kanavel, Infections of the Hand, 1921; *fascial spaces of the foot* by Grodinsky, Surg., Gyn. and Obs., vol. 49, p. 737. Further references to the literature upon the muscular system may be found in Poirier and Charpy's Traité d'anatomie humaine.

SECTION VI

THE BLOOD-VASCULAR SYSTEM

By H. D. SENIOR, M.D., F.R.C.S.

PROFESSOR OF ANATOMY, NEW YORK UNIVERSITY

THE organs of circulation consist of a system of tubes or vessels which during life are filled with fluid constantly moving in one direction. The major portion of the system is concerned with the continuous distribution of blood throughout the body and is called the **hemal or blood-vascular** system. A circumscribed part of the hemal circulation is differentiated into a rhythmically contracting propulsory organ called the heart. The minor portion of the system is called the **lymphatic system.** The lymphatic vessels convey fluid, the lymph, from the tissues to the hemal system.

The essential functions of the blood-vascular system are performed by the smallest of all the blood-vessels, the **capillaries** [vasa capillaria], which form a network pervading practically all the tissues of the body. Blood is carried to and from the capillaries by larger vessels called the **arteries** and **veins** respectively. The heart receives blood from the veins and propels it, in turn, into the arteries.

In order to distribute oxygen to the tissues, the blood must of necessity pass through the respiratory organ before being delivered to the body at large. In gill-breathing vertebrates, the blood, having received oxygen in its passage through the gills, passes on to the tissues. The entire circuit is here accomplished by a single continuous chain of vessels in which capillaries occur twice, once in the gills and again in the organs and tissues in general. In man, as in other higher vertebrates, lungs assume the function of the gills. Having received oxygen in the lungs the blood is returned again to the heart before being redistributed throughout the body. There are thus in man two separate circuits or systems of blood-vessels, one traversing the lungs and a second ramifying throughout the body. The former is known as the **pulmonary** circulation; the latter as the **systemic.** Each has its own arteries, capillaries and veins; the heart is common to both. From the time of birth the heart is longitudinally divided into right and left halves, so that the two streams which enter it are entirely separated. The blood entering the left side of the heart has issued from the pulmonary circulation to be driven into the systemic; the blood entering the right side, having traversed the systemic circuit, is returned again to the lungs.

The heart and blood-vessels have a continuous lining of flattened cells called endothelium; the hemal system is, therefore, a closed circuit.* The main thickness of the heart, arteries and veins consists of additional tissue developed around the endothelial lining. It is due to this tissue that the blood is continuously delivered to, and withdrawn from, the capillaries under suitable conditions of pressure and velocity. The heart is mainly composed of rhythmically contracting muscle and its valves are so arranged that the blood contained within it is driven intermittently in one direction. The walls of the largest arteries are formed to a great extent of elastic tissue, and, being constantly under tension from within, are instrumental in converting the stream, intermittently received from the heart, into a continuous flow. The walls of the medium sized to smallest arteries are mainly muscular. The smallest arteries are microscopic in size and known as **arterioles** [arteriolæ]. The muscular arteries are capable of general or local alterations of caliber; they are thus largely concerned in the maintenance of the arterial pressure and in the regulation of the volume of blood which enters given localities under varying conditions. The veins have much thinner walls than the arteries, and the venous pressure is extremely low.

When an artery divides, the combined caliber of its branches is greater than that of the vessel itself. Since the arteries divide repeatedly the bed of the blood-stream increases in proportion as the vessels diminish in size. The rate of increase, slow at first, becomes enormous in the arterioles. Conversely, the bed of flow diminishes as the heart is approached from the venous side. The velocity of flow in the capillaries must necessarily be much lower than in the great arteries and veins. From the relative slowness of the blood flow in the systemic capillaries, it has been estimated that their total bed is eight hundred times greater than that of the main arterial stem.

Variations.—The distribution of the chief arteries and veins of different individuals varies so slightly in the aggregate that the descriptions given by anatomists nearly two hundred years ago differ but slightly from those in current use. Deviations from the usual type of vascular

* There remains some doubt as to whether this statement is applicable to the spleen. That it is applicable to the bone marrow was shown by Doan and by Drinker, Drinker and Lund in 1922.

distribution are occasionally encountered in the adult, however, and their presence seems always to depend upon some disturbance of the usual course of development. When once the primitive vessels have made their appearance, the progress of vascular development is characterized by the successive appearance of alternative arterial or venous channels for the transit of blood to, or from, the capillaries of the various regions of the body. Some of the earlier channels persist throughout development; while others, remaining for a shorter or longer period, eventually disappear. Others, again, by forming connections with their fellows, or with channels of later development, may take a larger or smaller share in the composition of one or more of the adult arteries or veins. The normal vascular pattern of the human body, having been repeatedly modified during the progress of development, may be said, at length, to attain its permanent form. The production of an adult vascular system of so-called normal type in any particular individual, depends, therefore, upon the exact repetition of a complicated series of developmental changes. Should one of the numerous embryonic vessels concerned in the process fail to perform its customary role, some noticeable departure from the normal type will be encountered in the adult vascular system. Variations thus produced are more prone to occur in some regions than in others. Apart from such extensive anomalies as those in which imperfections of the aorta or pulmonary artery occur in association with arrested development of the cardiac septa, variations of blood-vessels are not, as a rule, attended with impairment of function. A list of the chief variations in the arteries and veins is given later, in connection with their morphogenesis.

In the following section the heart and pericardium will first be considered followed by the arteries and veins.

A. THE HEART AND PERICARDIUM

1. THE HEART

The **heart** [cor] is a hollow organ principally composed of muscle, the **myocardium.** It is lined internally by **endocardium** which is continuous with the intima of the blood-vessels. Externally, it is covered by the **epicardium,** a serous membrane continuous with the serous lining of the pericardium. The form of the heart, when removed from the body without previous hardening, is that of a fairly regular truncated cone. The **base** [basis cordis] is poorly circumscribed but corresponds, in the general way, to the area occupied by the roots of the great vessels and the portion of the heart-wall between them. The base of the heart is held in position chiefly by the great vessels, which are attached to the pericardium. It is not fixed, however, for during systole the base performs a greater excursion than does the apex. The remainder of the organ is capable of free movement within the pericardial cavity.

The interior of the heart is longitudinally divided into right and left cavities by a septum passing from base to apex. Each cavity is subdivided into an **atrium** [atrium cordis] and a **ventricle** [ventriculus cordis], the former receiving the ultimate venous trunks and the latter giving rise to the main arteries. Thus the left atrium receives the four pulmonary veins, and the right atrium the superior and inferior vena cava and the coronary sinus; the aorta issues from the left ventricle and the pulmonary artery from the right. The ventricles, which constitute the major portion of the heart, may be recognized by their very thick walls. The atria have thinner walls and are less capacious than the ventricles; projecting from each is a diverticulum or **auricle** [auricula cordis]. The auricles (which receive their name from their resemblance to dog's ears) partially embrace the roots of the pulmonary artery and aorta.

Orientation of the heart.—The apex of the heart [apex cordis] points forward, to the left and downward. The base is directed backward, to the right and upward. The longitudinal axis of the heart forms an angle of about 40° with the horizontal plane and also with the median sagittal plane of the body.

The long axis of the heart is therefore slightly more horizontal than vertical, and slightly more anteroposterior than transverse, and the atria are posterior to, rather than above the ventricles. To arrive approximately at the direction of the longitudinal axis of the heart, it is necessary to select the central point of the base. By cutting the vessels short in several hearts, hardened by formalin before removal, a point immediately to the left of the right lower pulmonary vein was selected in determining the data above given. A steel pin was passed through this point to the apex cordis, and the angles controlled by frontal and transverse sections of the thorax. Mention of angular measurements of the axis of the heart could be found only in the text-books of Testut and Luschka; the former gives 40° to the horizontal plane, the latter 60° to the midsagittal. Luschka's angle appears to be too large; but further investigation in this direction is desirable

Size and weight.—The heart measures about 12.5 cm. (5 in.) from base to apex in the adult, and 8.7 cm. (3½ in.) at its broadest, and 6.2 cm. (2½ in.) at its thickest portion. In the male its weight averages about 312 gm. (eleven ounces), and in the female about 255 gm. (nine ounces). The weight of the heart forms approximately 0.4 to 0.45 per cent. of the total

body-weight in the male of normal build and about 0.53 per cent. in the female; in emaciated individuals it usually weighs relatively more, and relatively less in the fat. The *volume* of the heart in diastole may be estimated during life in cubic centimeters by the use of the following formula, $0.53\ A\ {}^{3}\!/_{2}$, A being the X-ray silhouette of the diastolic area in square centimeters, after making due allowance for divergence of rays (Bardeen). The heart weight may be computed by multiplying $1/20\ A\ {}^{3}\!/_{2}$ by 0.0055.

EXTERIOR OF THE HEART

In hearts which have been hardened by injection before removal from the body, the regularity of the heart-cone is disturbed by a well-marked triangular

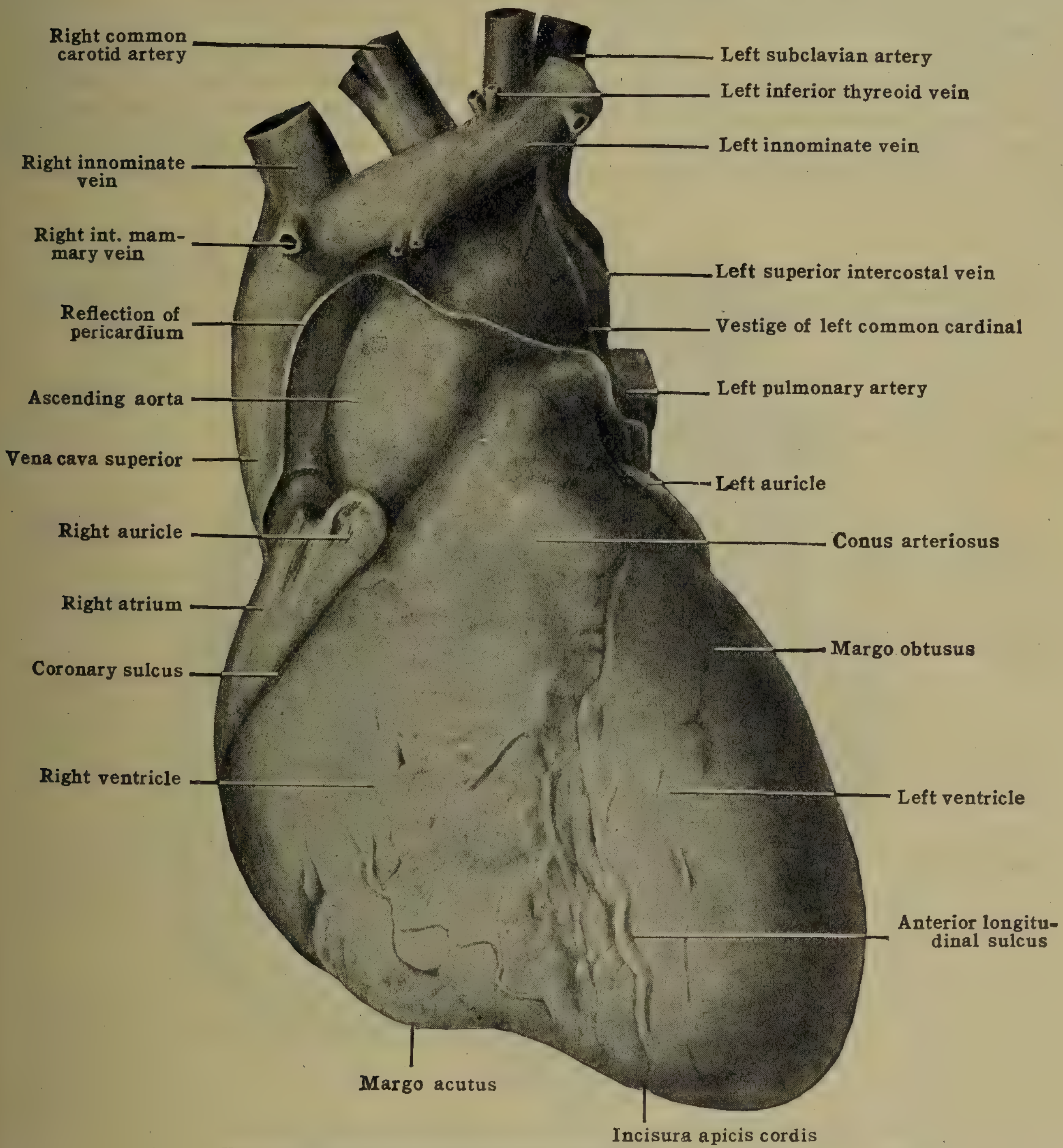


FIG. 503.—STERNOCOSTAL SURFACE OF THE HEART.

facet, imparted by contact with the diaphragm. This facet is the **diaphragmatic surface** [facies diaphragmatica], which is directed downward and slightly backward (fig. 505). It ends abruptly along a sharp margin extending from the apex toward the right. This margin is the **margo acutus** (fig. 503); it separates the diaphragmatic surface from the sternocostal surface. The other margin of the diaphragmatic surface is more rounded and shades gradually into the rounded margo obtusus (fig. 506), which passes almost insensibly into the sternocostal surface. The convex **sternocostal** surface [facies sternocostalis] (fig. 503), directed forward and somewhat upward and to the right, is triangular and bounded below by the margo acutus. To the left it goes over into the margo obtusus along a line extending from the apex of the heart to the root of the pulmonary artery. The **margo obtusus** corresponds to the rounded left side of the left ventricle.

The interventricular sulcus is a slightly marked groove indicating the separation of the ventricles upon the exterior of the heart. It lodges coronary blood-vessels and a moderate quantity of fat which can be seen through the epicardium. The part of this groove seen on the sternocostal surface is the **sulcus longitudinalis anterior.** It runs obliquely over the upper part of the margo obtusus on to the sternocostal surface. Crossing the margo acutus to the right of the apex it is continuous with the **sulcus longitudinalis posterior** upon the diaphragmatic surface. The diaphragmatic surface is formed about equally by the right and left ventricles, and the sternocostal surface mainly by the right. Where the longitudinal sulcus crosses the margo acutus it produces a slight notch, the **incisura (apicis) cordis.**

The atria are separated externally from the ventricles by the **sulcus coronarius.** This groove is occupied by the coronary sinus on the diaphragmatic surface of the heart but becomes more distinct as it passes below the lateral and anterior aspects of the auricles. Between the auricles it is shallow and passes behind the aorta and pulmonary artery through the transverse sinus of the pericardium.

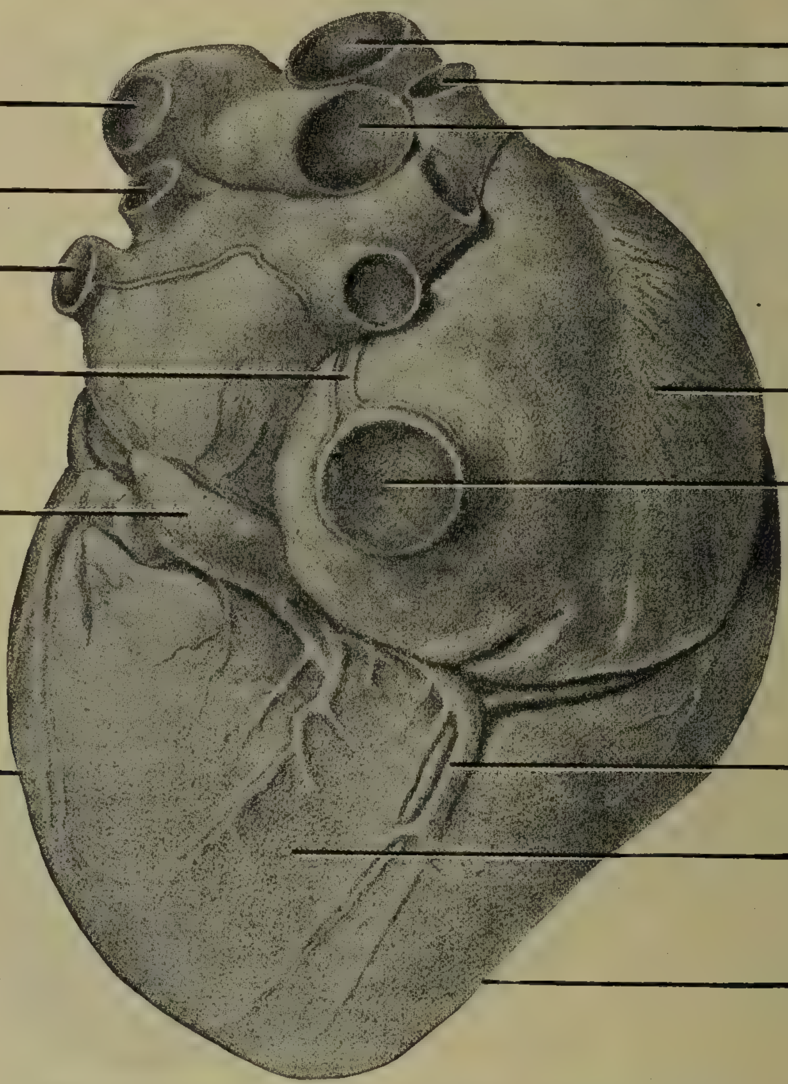


Fig. 504.—Base and Diaphragmatic Surface of the Heart. (After His.)

ATRIAL PORTION

The **atrial portion of the heart** is situated behind, and slightly to the right of and above, the ventricular portion. On the external surface, its separation into right and left atria is not indicated posteriorly, except in distended hearts (such as that shown in fig. 504); in these it is marked by a slight groove connecting the left sides of the superior and inferior vena cava. The auricles are separated anteriorly by the deep notch which lodges the aorta and pulmonary artery. A slight groove on the back of the right atrium which connects the right sides of the superior and inferior vena cava, is the **sulcus terminalis** (figs. 504, 505). This represents the right limit of what was, in the embryo, the sinus venosus, the embryonic sinus venosus having become an integral part of the adult right atrium. The superior and the inferior cava join the posterior part of the right atrium above and below, respectively. The coronary sinus courses downward, backward and to the right to enter the right atrium anteriorly to and somewhat

above the place of entrance of the inferior vena cava. The four pulmonary veins run nearly transversely and somewhat forward into the right and left sides of the left atrium.

The interior of the atrial portion of the heart is divided into right and left cavities by the **septum atriorum.** This septum is a composite structure, having been developed (see p. 603) in two independent parts, neither of which is a complete septum in itself. The two incomplete septa, however, partly overlap one another so that, by lateral fusion at the time of birth, they together produce the impervious structure of the adult heart (fig. 505). Of these septa, the first to be formed is the **membranous septum** [pars membranacea septi atriorum]. To the right of this is developed a muscular septum, the margin of which forms the greater part of the **limbus fossæ ovalis** of the adult right atrium. The margin of the membranous septum is recognizable as a fold of endocardium on the septal wall of the left atrium; it is called the **valvula foraminis ovalis** (falx septi NK).

Upon the septal wall of the adult **right atrium** [atrium dextrum] (fig. 508), immediately above the inferior cava is the **fossa ovalis**, of which the floor is formed

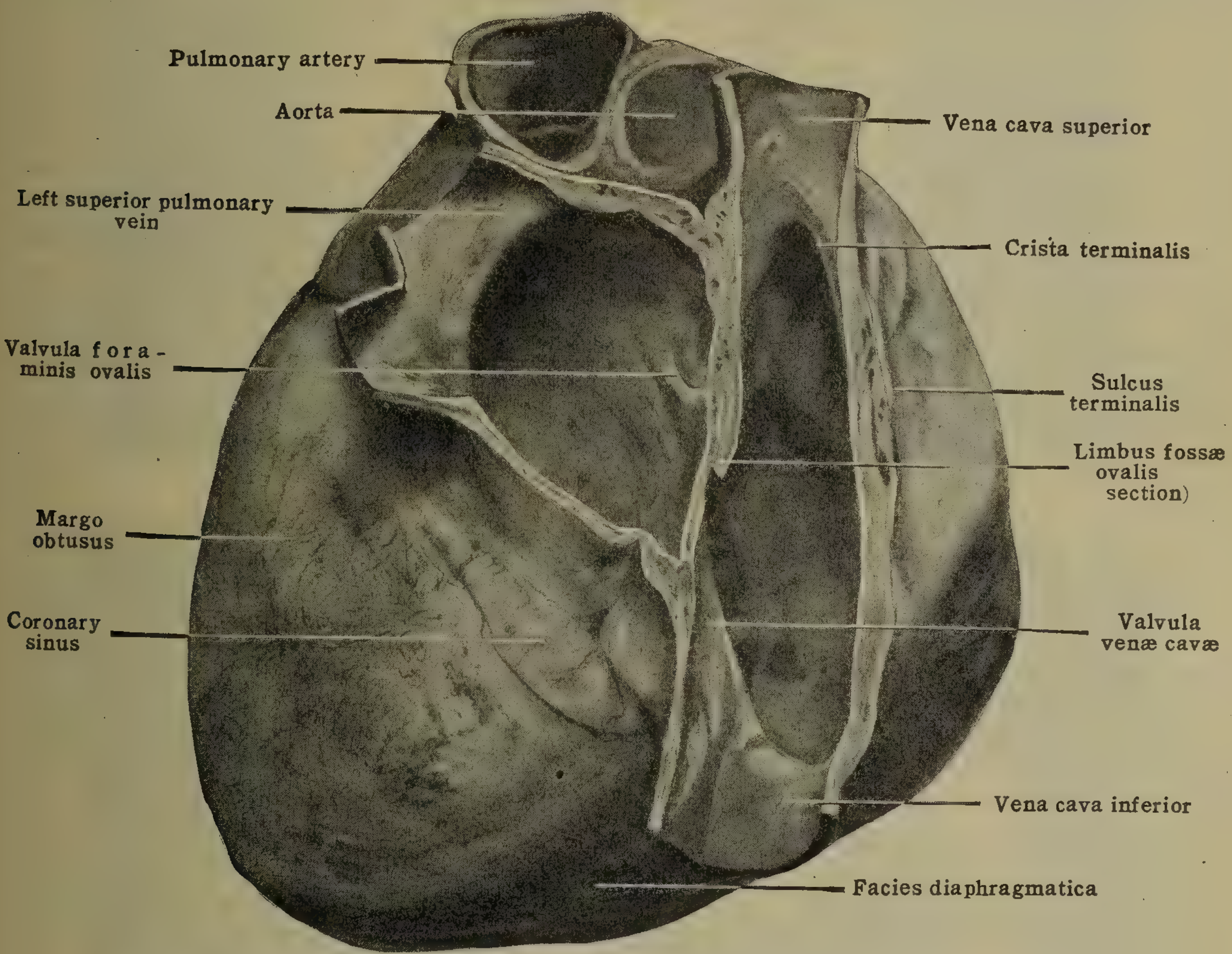


Fig. 505.—Atria Opened Posteriorly to Show the Septum Atriorum.

by the membranous septum. Surrounding the fossa ovalis except below (indeed producing the fossa) is the limbus fossæ ovalis which is continuous anteriorly and below with the **valvula venæ cavæ** (inferioris Eustachii). Anterior to the fossa ovalis is the orifice of the coronary sinus, which is guarded by the **valvula sinus coronarii** (Thebesii) (fig. 508). Leading from the front of the atrium forward and slightly downward and to the left is the **ostium venosum** of the right ventricle (right atrioventricular orifice) guarded by the tricuspid valve. Above and behind the venous ostium is the auricle, the exterior of which is in contact medially with the root of the aorta. To the right of the superior and inferior caval orifices there is a vertical ridge, the **crista terminalis,** which corresponds to the sulcus terminalis on the exterior (figs. 505, 508).

The portion of the atrium bounded laterally by the crista terminals and medially by the septum atriorum is smooth, the **sinus venarum**; in the embryo it is separated from the atrial cavity proper by the right and left sinus valves. The crista terminalis marks the original line of attachment of the right sinus valve. The valve itself has disappeared, excepting the lower part which persists as the caval and the coronary valves. These valves vary in size considerably in different specimens, and are frequently netlike from numerous perforations.

The conversion of a portion of a single valve into two separate parts, which meet at an acute angle, is brought about by local blending between the sinus valve and an embryonic structure called the sinus-septum. This septum is a ridge dividing the right horn of the sinus venosus from the transverse portion of the sinus (the coronary of the adult); it probably contributes somewhat to the formation of both the coronary and caval valves. The left sinus valve usually disappears by blending with the septum atriorum, becoming a part of the limbus fossæ ovalis; it occasionally remains partially separate in the adult.

The interior of the right auricle and of the portion of the atrium upon the lateral side of the crista terminalis is thrown into ridges, **musculi pectinati** (trabeculæ carneæ NK), by prominent bands of the atrial myocardium. The musculi pectinati end abruptly by joining the crista. The orifice of the superior cava has no valve and is directed downward and somewhat forward; below it, on the posterior wall of the atrium, there has been described the **tuberculum intervenosum** (Loweri).

Apart from the posterior circumference of the superior cava itself and the limbus fossæ ovalis, the human heart appears to contain nothing in this region that could be described as a tubercle. The fossa ovalis is just above (almost within) the inferior caval orifice. Opening into the right atrium, particularly upon the septal and right lateral walls, are numerous *foramian venarum minimarum* (Thebesii).

The **left atrium** [a. sinistrum] (fig. 504) is situated upon the left side of, and somewhat posteriorly to the right. It is behind the root of the aorta, and the left auricle lies to the left of the root of the pulmonary artery. Opening into the left atrium posteriorly, on the right and left sides, respectively, are the right and left upper and lower pulmonary veins. The valvula foraminis ovalis forms a more or less distinct crescentric ridge on the septal wall (fig. 505). The valvula may not be attached to the limbus fossæ ovalis, in which case there is a communication between the two atria. This, however, does not necessarily lead to admixture of arterial and venous blood during life. The **ostium venosum** (atrioventricular orifice) of the left ventricle, guarded by the mitral valve, leads from the anterior part of the atrium forward and slightly downward and to the left. The interior of the left atrium proper is smooth; in the auricle musculi pectinati are well marked.

ATRIOVENTRICULAR VALVES

The **atrioventricular valves** (figs. 507, 508, 509) are attached around the venous ostia of the ventricles in such a way as to give freely into the ventricles, but to prevent regurgitation of blood into the atria during ventricular systole. Each valve is continuous along its line of attachment, but its free edge is notched so as to produce an irregular margin; some of the notches are so deep as to partially divide the valve into cusps. The right atrioventricular valve is commonly divided by three deep notches into three cusps; this valve is therefore called the **tricuspid** [valvula tricuspidalis]. The left is similarly divided into two cusps and is called the **bicuspid** [v. bicuspidalis] or **mitral.** The depth of the notches, however, is very variable and there may be an increase or (more rarely) a diminution in the number of cusps; the addition of subsidiary cusps is quite common. Each valve cusp is tied down to the **papillary muscles** [mm. papillares] of the ventricle by **chordæ tendineæ.** The latter are fibrous cords, generally branched, of varying thickness. The thinnest cords are attached to the free margin of the cusp; those of intermediate thickness to the ventricular surface a few millimeters from the free margin, and the thickest to the ventricular surface near the attached margin. The valves are smooth and glistening on the atrial aspect, but rough and fasciculated, from the attachment of the chordæ, on the ventricular aspect. The cusps of the *mitral valve* are called *anterior* and *posterior* (velum septale or aorticum and dorsale NK); those of the *tricuspid, anterior, posterior* and *medial* (velum ventrale, dorsale and septale NK). Each cusp receives chordæ from more than one papillary muscle and each papillary muscle sends chordæ to more than one cusp. The chordæ tendineæ of the mitral valve are thicker than those of the tricuspid.

VENTRICULAR PORTION

The **ventricles** form the greater part of the heart. In the adult the relation of the ventricles to one another is as follows. The left [ventriculus sinister] has the form of a narrow cone, the apex of which forms the apex of the heart.

The right ventricle [ventriculus dexter] is crescentic in section and appears to be partially wrapped around the right or lower wall of the left ventricle which forms the septum ventriculorum (fig. 506). The **left ventricle** forms the margo obtusus of the heart, about half the diaphragmatic surface, and a small part of the sternocostal surface. The **right ventricle** forms about half the diaphragmatic surface and the major part of the sternocostal surface; it takes no share in the formation of the apex of the heart.

Fig. 506.—Section of the Ventricles in Systole and Diastole. (After Krehl.)

The **interventricular septum** [septum ventriculorum] is thick and muscular except for a small area near the root of the aorta which is membranous [septum membranaceum ventriculorum]. The latter can be seen from the left ventricle in the angle between the attached edges of the right and posterior aortic valves (fig. 509). The membranous septum is partly concealed on the right side by the medial cusp of the tricuspid valve which is attached to it near its upper end.

The portion of the membranous septum above the attachment of the medial tricuspid cusp is therefore atrioventricular, since it intervenes between the right atrium and the left ventricle.

The membranous septum is the extreme lower part of the independent septum (s. aorticum) which divides the aortic root from the pulmonary artery and conus arteriosus. The aortic septum partially subdivides, also, the right ventricle by separating the conus arteriosus from the remaining part of the interior. The relation borne by the part of the aortic septum which intervenes between the conus arteriosus and aortic root to the septum ventriculorum is well shown by His, in fig. 507.

The greater part of the interior of both ventricles is thrown into ridges by myocardial bundles of large size. These fasciculi [**trabeculæ cordis**] either stand out in relief only, or, by being undermined, form bands enveloped by endothelium. A careful examination of the endocardium of fresh hearts will reveal a plexiform network of **Purkinje fibers.** These fibers, belonging to the atrioventricular conducting system, become visible to the naked eye when the endocardium has been exposed to the air long enough to become partially dry.

The wall of the **right ventricle** [ventriculus dexter] (figs. 507, 508) is much thicker than that of the atria, but not so thick as that of the left ventricle. The

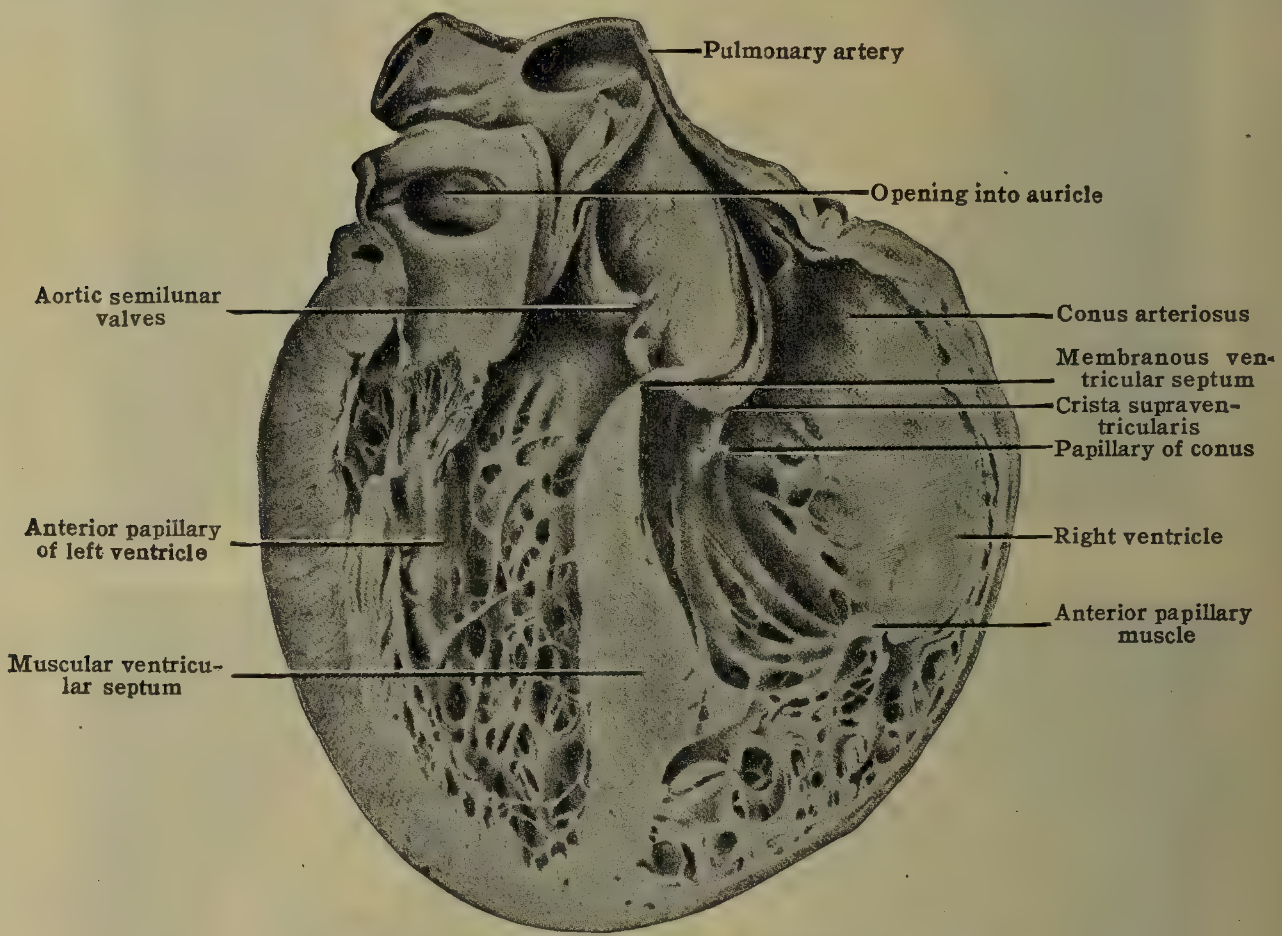


Fig. 507.—The Interior of the Ventricles, Anterior Half. (After His.)

upper and anterior part of the right ventricle lies in front of the root of the aorta. This portion of the ventricle is called the **conus arteriosus** and is separated from the remainder of the right ventricle by a muscular spur which extends from the back of the conus to the right venous ostium. The spur is the **crista supraventricularis**; its relation to the partition between the conus and aorta, and to the septum membranaceum, shows that it forms part of the embryonic aortic septum (see morphogenesis of the heart).

Two papillary muscles in the right ventricle are constant in position, the large **anterior papillary muscle,** and the small **papillary muscle of the conus** (Luschka). The anterior papillary is situated on the sternocostal wall, near the junction of this with the septal wall. The papillary of the conus is placed just below the septal end of the crista supraventricularis. The **posterior papillary muscles** form an irregular group springing from the diaphragmatic wall of the ventricle. Some of the chordæ tendineæ stretch directly from the septal wall (with or without small muscular elevations at their bases) to the medial cusp of the tricuspid valve. The chordæ tendineæ from the anterior papillary go to the anterior and posterior cusps; those from the conus papillary to the medial and anterior, and those from the posterior papillary muscles to the medial and posterior cusps of the tricuspid valve, respectively.

A band of myocardium is often found to extend from the septal wall of the right ventricle to the anterior papillary muscle; this is the **moderator band,** which contains a part of the right limb of the atrioventricular bundle. If the moderator band joins the anterior papillary near its base, as it frequently does, it is difficult to distinguish it from the trabeculæ cordis which ordinarily occupy this situation.

The term moderator band was originally applied to this bridge or band of muscle under the impression that it prevented overdistention of the ventricle. Since the discovery of the conducting system of the heart it has been known that there is always a band which conducts the right limb of the atrioventricular bundle from the septum to the anterior papillary muscle. Whether the band is isolated from the other trabeculæ, and therefore readily recognizable, appears to depend somewhat upon the relation of the base of the papillary muscle to the septum ventriculorum.

The wall of the **left ventricle** [ventriculus sinister] (figs. 507, 509) is very thick except at the extreme apex, and at the membranous septum. In the left

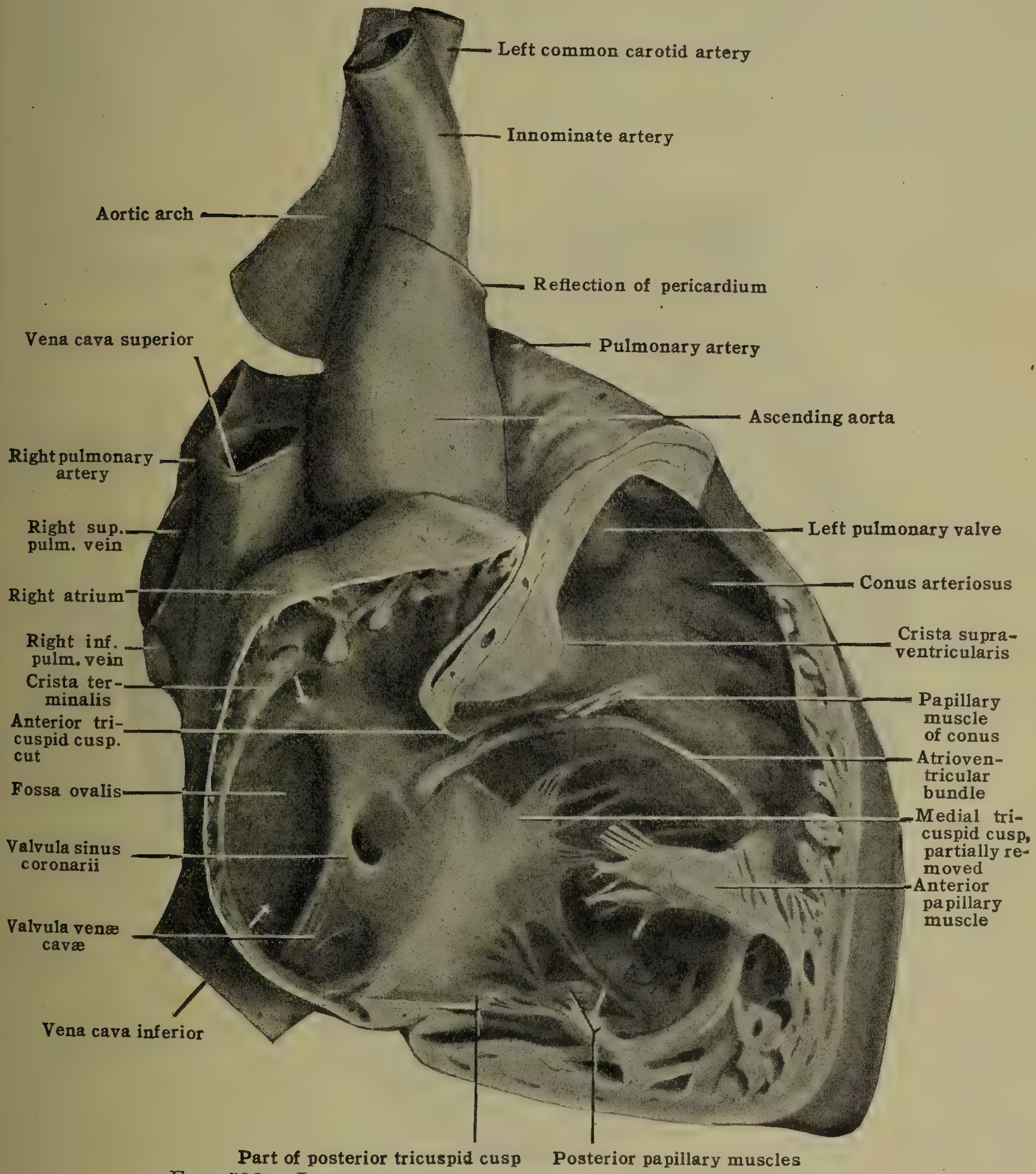


Fig. 508.—Interior of the Right Atrium and Ventricle.
The atrioventricular bundle is dissected out.

ventricle are two large papillary muscles, generally known as **anterior** and **posterior**; both send chordæ tendineæ to each cusp of the mitral valve. On the septal wall of the ventricle the left limb of the atrioventricular bundle can usually be seen as a broad, flattened band beneath the endocardium. The band appears just below the septum membranaceum and divides into strands which go to the two papillarly muscles. The strands in many places bridge across part of the ventricle to reach the papillary muscles, covered only by tubes of endocardium.

These bridging strands connecting the papillary muscles with the septum ventriculorum, which were formerly called 'false chordæ tendineæ,' are exactly comparable to the moderator band of the right ventricle which occasionally consists of atrioventricular bundle and endocardium only.

SEMILUNAR VALVES

The **semilunar valves** [valvulæ semilunares] guard the arterial ostia of the ventricles. The aortic ostium is directed upward and slightly forward and to the right; the pulmonary backward and slightly upward and to the left. Each valve, of which there are three to each ostium, is a pocket-like fold of endocardium strengthened by fibrous tissue (fig. 510). The free edge of each valve is directed away from the ventricle, so that excess of pressure within the great vessels brings the three valves of either ostium into mutual apposition. In the middle of the free edge of each valve there is a small fibrocartilaginous **nodule** (noduli velorum semilunarium NK); radiating from this toward the entire fundus, and along the extreme free edge of the valve, are fibrous thickenings. On either side of the nodule, between the thicker margin and fundus, the

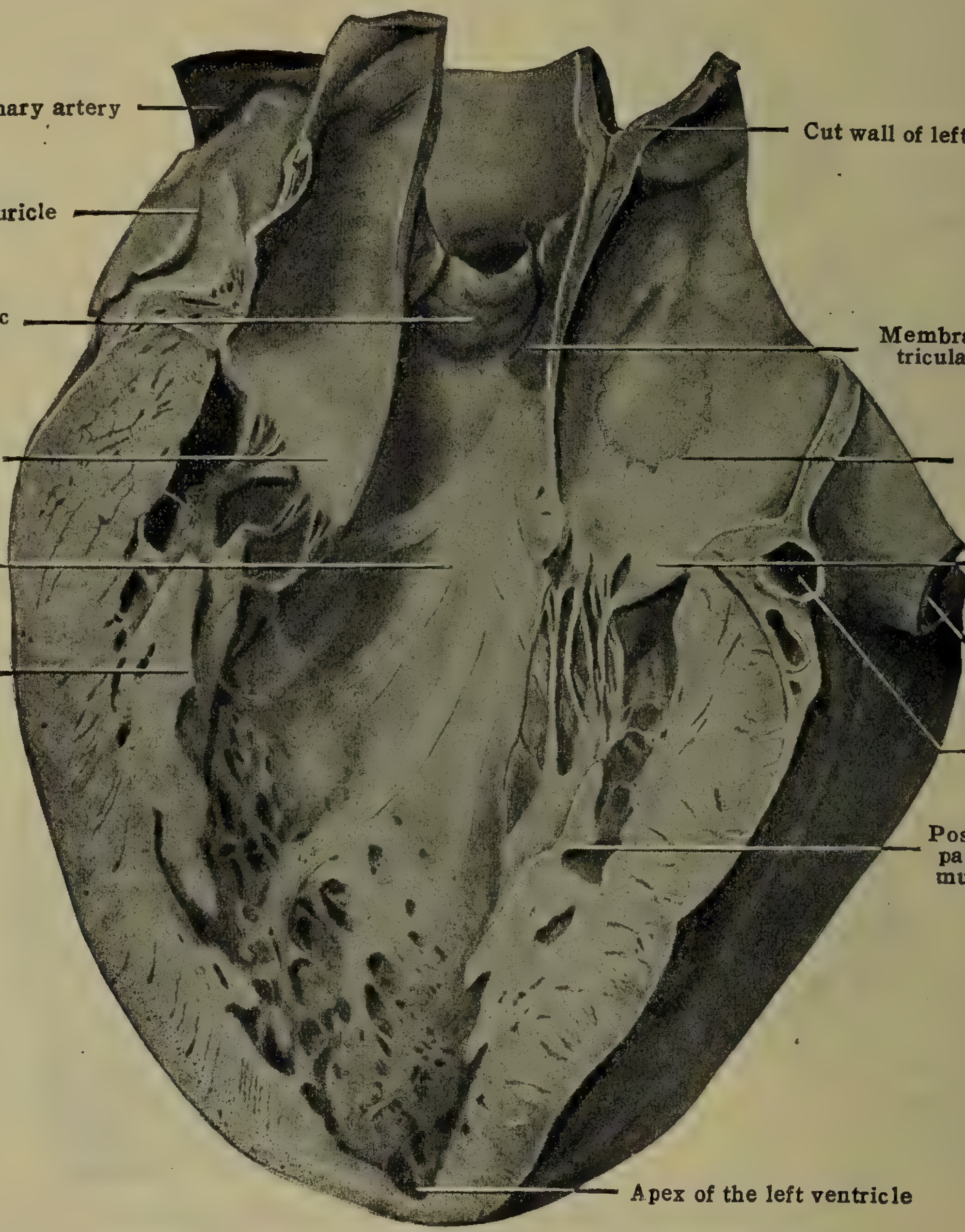


FIG. 509.—LEFT VENTRICLE AND PART OF THE ATRIUM.
The aorta is opened through the anterior cusp of the mitral valve. The plainly visible left limb of the atrioventricular bundle has been accentuated.

valve is thin over a crescentic area called the **lunula** (lunulæ velorum semilunarium NK).

The aortic valves are called the right, left, and posterior; the pulmonary valves, the right, left, and anterior.* The aortic semilunar valves are stronger

* These BNA names of the aortic and pulmonary valves are not based upon their relative positions in the body. From transverse sections through the thorax (see any good atlas) it may be seen that one aortic valve is anterior, one pulmonary valve posterior, and the other aortic and pulmonary valves are right and left. If the removed heart is held so that the ventricles are on the right and left of the septum, respectively, the valves take the positions indicated by the BNA. The names given by the BNA to the valves, although conventional (like many other terms of orientation applied to parts of the heart), are convenient, particularly from

than the pulmonary; opposite them there are three dilations in the aortic wall, the aortic sinuses [**sinus aortæ**] or sinuses of Valsalva. From the right and left sinuses the right and left coronary arteries, respectively, arise.

After ventricular systole the increased pressure in the great vessels distends the valves with blood. The noduli meet in the center and the lunulæ, coming into mutual contact, produce a triradiate line of contact between the valves.

ARCHITECTURE OF THE MYOCARDIUM

In the adult heart the myocardium of the atria is separate from that of the ventricles. There is, between the atria and ventricles, a fibrous partition, the upper and lower surfaces of which give attachment to the muscle fibers of these cavities, respectively.

The **fibrous partition** (fig. 511) is thickest in the interval between the right and left atrioventricular ostia immediately behind the right end of the posterior circumference of the aorta; this part of it is called the right *trigonum fibrosum.* The *left trigonum fibrosum* is smaller than the right, and occupies the angular interval between the left side of the root of the aorta and the left atrioventricular ostium. Spreading out from the trigona are the *annuli fibrosi* which surround the root of the aorta and the two atrioventricular ostia. A particularly dense and strong portion of the fibrous partition of the heart extends forward from the right trigonum fibrosum; it forms the *septum membranaceum ventriculorum* and blends with the right circumference of the aortic annulus. From the anterior aspect of the aorta it passes forward upon the posterior aspect of the conus arteriosus, where it is known as the *tendon of the conus*, and ends by uniting with the annulus fibrosus of the pulmonary ostium. The tendon of the conus, the sep-

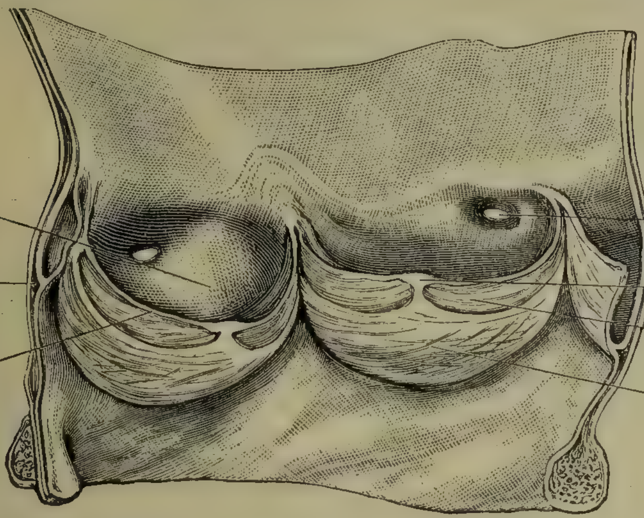


FIG. 510.—INTERIOR VIEW OF THE AORTIC SEMILUNAR VALVES.

tum membranaceum and the greater part of the right trigonum fibrosum are derived from the embryonic aortic septum.

The **atrial musculature** is attached to the trigona and atrioventricular rings. The superficial fibers are attached to both rings and either encircle both atria in one loop, or enter the septum and form a figure 8. The deeper fibers are attached to one ring and encircle one atrium only; some fibers encircle only the auricle.

The **ventricular musculature** is very complex and consists of numerous superimposed layers distinguished from one another by the direction taken by the muscles fibers. In a general way, the fibers of the deepest layer have a direction crossing those upon the surface of the same area at a right angle. The intervening layers of fibers pass through all stages of obliquity.

Recent work upon the origin and distribution of the ventricular fibers has resulted in the recognition of a certain uniformity of behavior, thus:—

1. All fibers arise from, and are inserted into, the fibrous partition at the base. The fibers are either attached directly to the trigona or annuli, or indirectly to them by means of the chordæ tendineæ and atrioventricular valves.

2. The more superficial fibers (fig. 512) tend to encircle the entire heart, passing over the longitudinal sulci. If they enter the septum they do so by passing into the vortex or whorl at the apex of the left ventricle. These fibers have always a definite direction upon the surface, i.e., from right to left upon the sternocostal surface and from left to right on the diaphragmatic (fig. 511).

3. The deeper fibers all enter the septum, and pass across it in a direction oblique or perpendicular to its longitudinal axis. They completely encircle one or both ventricles forming, in the latter case, a double loop (fig. 513).

During systole, as a result of this arrangement:—(1) The papillary muscles and the longitudinal and anteroposterior axes of the ventricles are simultaneously shortened. (2) There is a movement of torsion or 'wringing' which reduces the ventricular cavities to their minimum dimensions.

Conducting system.—Although the ordinary myocardium of the atria is distinct from that of the ventricles there is, at one place, a connection between them. This connection is effected by means of a small band of muscle which differs histologically from ordinary heart muscle. It

a developmental standpoint. The NK recommends velum semilunare dextrum, sinistrum and ventrale for the valvulæ aortæ; and velum semilunare dextrum, sinistrum and dorsale for the valvula arteriæ pulmonalis.

is known as the **atrioventricular bundle** (fasciculus atrioventricularis NK), and serves to transmit the atrial rhythm of contraction to the ventricles.

The atrioventricular bundle begins in the septal wall of the atrium a short distance in front of the coronary orifice (fig. 508). It has an expanded free end, the **atrioventricular node,** from which branches pass to be quickly lost in the atrial myocardium. The bundle passes through the right trigonum fibrosum (in the position marked X) into the musculature of the interventricular septum. In this it passes downward and forward, covered by endocardium

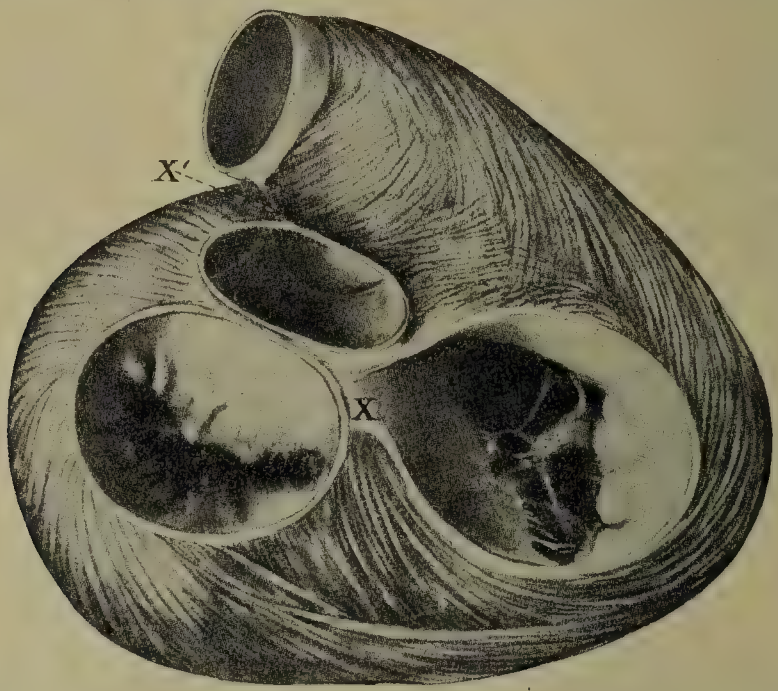


FIG. 511.—BASE OF A WELL DEVELOPED HEART SHOWING THE COURSE OF THE SUPERFICIAL MUSCLE FIBERS.
From X to X′ around the front of the aorta indicates the course of the aortic septum. (Mall, $\times\frac{3}{4}$.)

and by one or two millimeters of myocardium, beneath the medial cusp of the tricuspid valve. The bundle skirts the lower margin of the septum membranaceum, immediately in front of which it divides into a left and right limb. The right limb now passes beneath the crista supraventricularis and above the papillary muscle of the conus, giving off branches to the latter and to other small papillaries on the septum (fig. 508). Bending somewhat toward the apex, it enters the moderator band which conducts it to the large anterior papillary muscle. From here it passes along one of the trabeculæ connected with the sternocostal wall of the ventricle, or in the wall itself, to reach the posterior papillary muscle or muscles. The right limb is compact

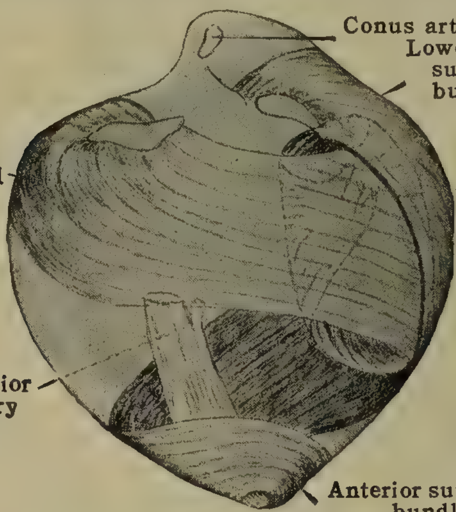


FIG. 512.—DIAGRAM OF ONE ANTERIOR AND ONE POSTERIOR SUPERFICIAL BUNDLE OF CARDIAC MUSCLE FIBERS SEEN FROM BEHIND. (After MacCallum.)

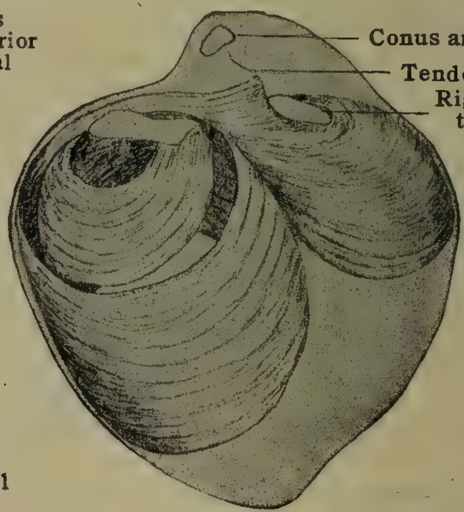


FIG. 513.—DIAGRAM OF A DEEPER BUNDLE OF MUSCLE FIBERS. (After MacCallum.)

and rounded and in the intact heart is usually invisible from the endocardial side except near the root of the moderator band or in the band itself.

The left limb of the bundle pierces the interventricular septum and appears in the left ventricle a little below the septum membranaceum. It forms a flat, wide band immediately beneath the endocardium, which usually cannot be stripped off without injuring the bundle (fig. 509). It passes along the septal wall toward the apex and divides into two parts, which again subdivide to be distributed to the anterior and the posterior papillary muscles. The branches for the papillary muscles may reach them by traversing the trabeculæ carneæ in the neighborhood, or they may form thin strands which, covered by endocardium only, bridge the gap between the septum and the papillary muscles.

In addition to the comparatively distinct branches to the papillary muscles of both ventricles, the bundle gives off finer fibers which form a subendocardial plexus. This plexus, visible to the naked eye (p. 592) is made up of fibers having a structure similar to those of the ventricular portion of the bundle. Its ramifications occupy the entire ventricular part of the heart except an area on the two sides of the interventricular septum below the aortic and pulmonary valves and about the half of each of the papillary muscles toward the chordæ tendineæ. The fibers were described by Purkinje as long ago as 1845 (Arch. f. Anat., Physiol. u. wiss. Med.) but it was not until 1906, thirteen years after the discovery of the bundle by W. His, Jr., that Tawara (Das Leitungssystem des Saügetierherzens, Fischer, Jena) recognized their significance.

There is another node of muscle having characters similar to that of the conducting system, although not connected with it except by myocardium of the ordinary character. This is the sinus-node which is situated at the upper end of the crista terminalis of the right atrium.

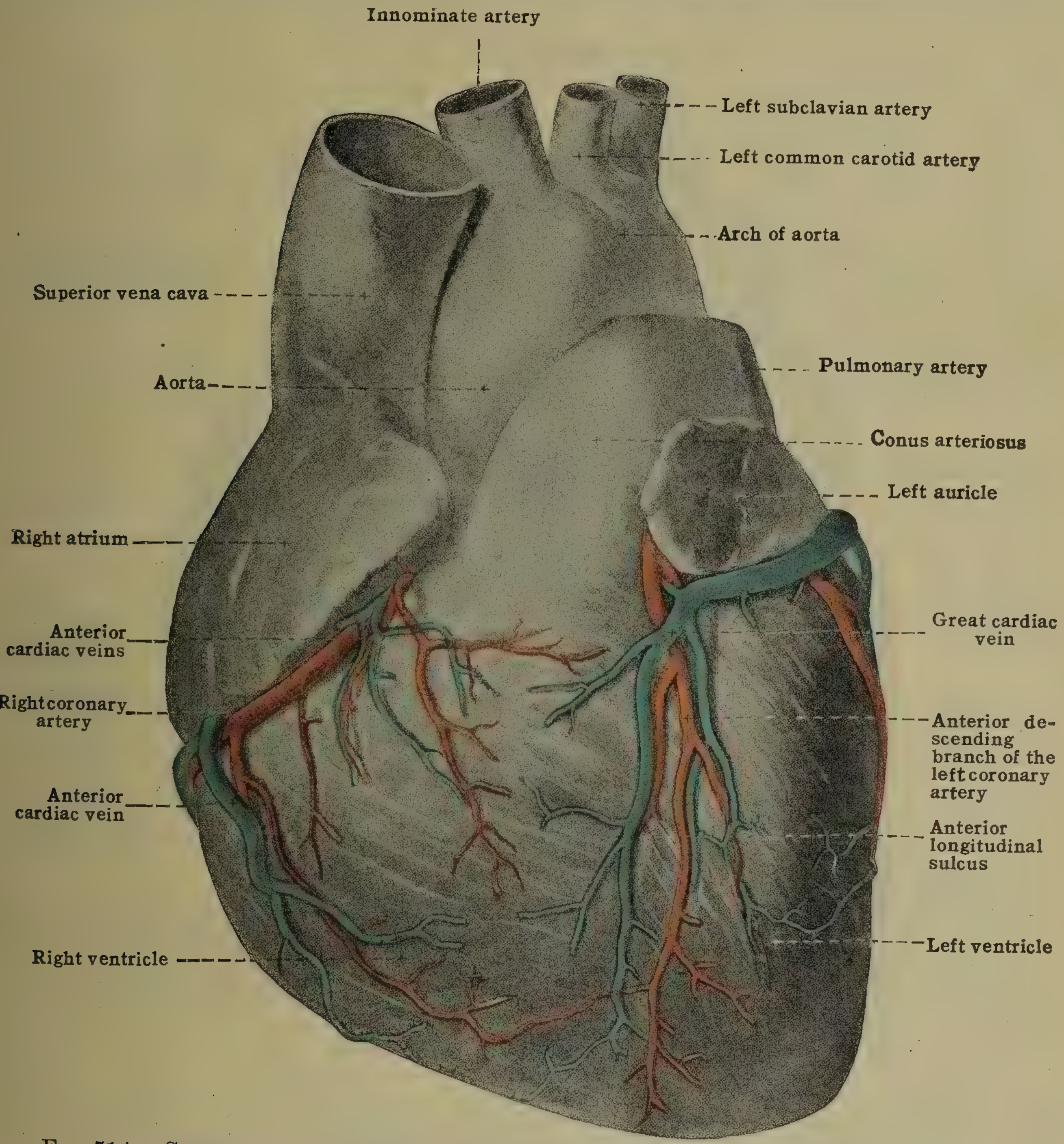


FIG. 514.—STERNOCOSTAL SURFACE OF THE HEART, SHOWING ITS ARTERIES AND VEINS. (After Spalteholz.)

VESSELS AND NERVES OF THE HEART

The arteries.—There are two coronary arteries, the right and left; the former takes origin from the right sinus of the aorta and the latter from the left.

The **right coronary** artery [a. coronaria dextra] passes forward between the pulmonary artery and the right atrium, and then follows the right coronary sulcus to the diaphragmatic surface of the heart (fig. 514), to anastomose with the left coronary artery. The **posterior descending** branch [ramus descendens posterior] arises at the posterior longitudinal sulcus. It passes in the furrow between the ventricles toward the apex, near which it anastomoses with branches derived from the left coronary artery. The right coronary artery supplies branches to the right atrium and to the root of the pulmonary artery and aorta; also a branch that descends near the margo acutus (**right marginal**), and a second (**preventricular**) that runs to the anterior wall of the right ventricle. It supplies both ventricles and the septum.

The **left coronary** artery [a. coronaria sinistra] passes for a short distance forward, between the pulmonary artery and the left auricle, and then divides into two principal branches, one of

which, the **anterior descending branch,** runs in the anterior longitudinal sulcus to the apex of the heart, around which it sends branches to anastomose with the right coronary; while the other, the **circumflex** [ramus circumflexus], winds to the diaphragmatic surface in the coronary groove, to anastomose with the corresponding twigs of the right artery. In this course it gives off a branch which follows the margo obtusus (**left marginal**) as well as smaller branches to the left atrium, both ventricles, and the commencement of the aorta.

Although *anastomoses* occur between the two coronary arteries, these are by no means extensive in the adult, and are not sufficiently free to allow of the establishment of a satisfactory collateral circulation in the case of the blocking of one coronary artery. Interference with the cardiac circulation is apt to produce rapid pathological changes in the heart musculature, provided it is sudden in occurrence. If obliteration of the artery take place gradually, however, some relief may be afforded by the establishment of a collateral circulation through the venæ minimæ, which open out from both the atrial and ventricular cavities and communicate with

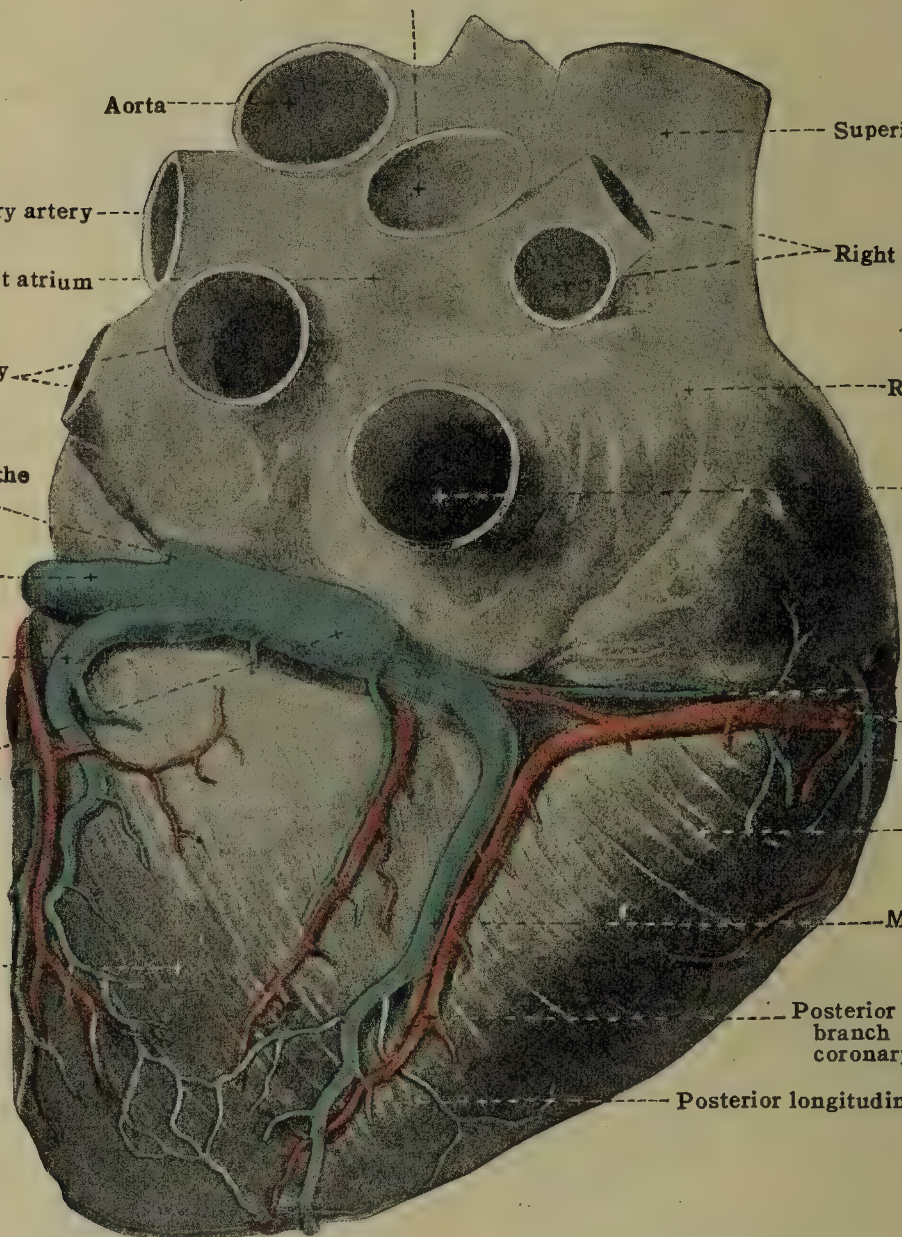


FIG. 515.—BASE AND DIAPHRAGMATIC SURFACE OF THE HEART, SHOWING ITS ARTERIES AND VEINS. (After Spalteholz.)

he finer branches of the cardiac veins, and also with the general capillary network in the cardiac walls. During embryonic life, anastomosis between the two coronary arteries appears to be much freer. Absence of the root of either the right or the left coronary artery has been reported, the remaining root supplying the entire heart. The communicating vessel is usually a large ramus circumflexus of the left coronary.

The **cardiac veins** accompany the coronary arteries and return the blood from the walls of the heart.

The **great cardiac** vein [v. cordis magna], (fig. 514) runs in the anterior longitudinal sulcus, passing round the left side of the heart in the coronary sulcus to terminate in the commencement of the coronary sinus. Its mouth is usually guarded by two valves. It receives small veins from the left atrium and ventricle, all of which are guarded by valves.

The **middle cardiac vein** [v. cordis media] (v. longitudinalis dorsalis cordis NK), sometimes the larger of the two chief veins, communicates with the foregoing at its commencement above the heart apex. It ascends in the posterior longitudinal groove, receiving blood from the ventricular walls, and joins the coronary sinus through an orifice guarded by a single valve, close to its termination.

The **posterior vein of the left ventricle** [v. post. ventriculi sinistri], lies upon the posterior surface of the ventricle and, receiving branches from it, passes upward to terminate directly in the coronary sinus.

The **anterior cardiac** veins [vv. cordis anteriores] consist of several small branches from the front of the right ventricle, which vary in number; they either open separately into the right atrium or join the lesser cardiac vein (fig. 514).

The **small cardiac** vein [v. cordis parva] is a small vessel which receives branches from both the right atrium and ventricle, and winds around the right side of the heart, in the coronary sulcus, to terminate in the coronary sinus. The NK includes both anterior cardiac and small cardiac veins under *vv. cordis minores.*

The **coronary sinus** [sinus coronarius] (fig. 515) may be regarded as a much dilated terminal portion of the great cardiac vein. It is about 2.5 cm. (1 in.) in length, is covered by muscular fibers from the atrium, and lies in the coronary sulcus below the base of the heart. Its cardiac orifice, with the coronary (Thebesian) valve, has already been described. Besides the tributary veins already named, a small **oblique vein** [v. obliqua atrii sinistri] of the left atrium may sometimes be traced, upon the back of the left atrium; it passes from the ligament of the left vena cava (Marshall) to the coronary sinus. This little vein, which is not always pervious or easy of demonstration, never possesses a valve at its orifice. Like the coronary sinus it is a remnant of the left superior vena cava of early fetal life.

The **smallest cardiac** veins [vv. cordis minimæ] drain blood from the septum and lateral walls of the atria, particularly the right; also from the conus arteriosus. They open directly into the right atrium.

The **lymphatic** vessels of the heart pass chiefly through the anterior mediastinal lymph-nodes into the bronchomediastinal trunk. (See Section VII.)

The **cardiac nerves**, derived from the vagus and the cervical sympathetic, descend into the superior mediastinum, passing in front of and behind the arch of the aorta; they unite to form the superficial and deep cardiac plexuses. The superficial plexus lies above the right pulmonary artery as the latter passes beneath the aortic arch. The deep plexus lies between the trachea and the arch of the aorta, above the bifurcation of the pulmonary trunk. For the connections of the plexuses see section on NERVOUS SYSTEM.

2. THE PERICARDIUM

The **pericardium** is a cone-shaped, fibroserous sac which surrounds the heart and contains a small amount of fluid [liquor pericardii]. Its apex is above at the root of the great vessels, and its base below, adherent to the diaphragm. It consists of an outer *fibrous* layer and an inner *serous* layer. The virtual space between the serous pericardium and the epicardium is commonly called the *pericardial cavity.*

The **fibrous layer** is strong and inelastic, made of interlacing fibers. Its connection with the central tendon of the diaphragm is intimate, particularly in the region of the caval opening, but elsewhere it is attached loosely by means of areolar tissue. Above, it is lost on the sheaths of the great vessels, all of which receive distinct investments, with the single exception of the vena cava inferior, which pierces it from below. The aorta, vena cava superior, the pulmonary artery, and the four pulmonary veins, are all ensheathed in this manner. The pericardium is connected above with the deep cervical fascia. Two variable bands of fibrous tissue, the **sternopericardial ligaments** connect the front of the pericardium above and below, with the posterior surface of the sternum.

The **serous layer** is smooth and glistening and consists of connective tissue, rich in elastic fibers, covered by endothelium. It lines the interior of the fibrous layer and is continuous with the epicardium or serous covering of the heart. The reflection of the serous layer from the heart to the fibrous layer of the pericardium occurs both at the arterial and at the venous attachments of the heart. At the arterial attachment a simple tube of epicardium is reflected along the pulmonary artery and aorta. At the venous attachment the serous layer is reflected from the front of the pulmonary veins on the left, and from the front of these and from the roots of the vena cava on the right. This reflection is separated above from that around the aorta and pulmonary artery (figs. 503, 516). Around the lower margin of the left lower pulmonary vein (fig. 516) and the root of the vena cava inferior, this reflection is continuous with an arched reflection from the back of the atria (figs. 503, 516). The latter reflection forms a pocket which extends upward upon the posterior aspect of the atria which is called the *oblique sinus* of the pericardium.

Between the reflections of the epicardium at the arterial and venous attachments of the heart there is a dorsal communication between the right and left sides of the pericardial cavity. This is the **transverse sinus** of the pericardium [s. transversus pericardii]; it passes behind the aorta and pulmonary artery and in front of the superior cava and left atrium. During early embryonic life the sinus transversus is closed by the dorsal mesocardium (see p. 605).

The **ligament of the left superior cava** [lig. venæ cavæ sinistræ] (figs. 503, 516) is a doubling of the serous layer which passes between the left pulmonary artery above and the left superior pulmonary vein below. It contains, besides some fatty and areolar tissue, the shrunken remains of the left vena cava superior.

The ligament is usually connected above with the left superior intercostal vein by means of a small tributary of the latter. Passing from its lower end to the left end of the coronary sinus is the small **vena obliqua atrii sinistri** (oblique vein of Marshall). The root of the left superior intercostal (and the adjacent part of the left innomniate) vein; the vein passing from the superior intercostal to the lig. venæ cavæ sinistræ; the oblique vein of the left atrium, and the coronary sinus all represent parts of the embryonic left vena cava superior.

Relations.—In front of the pericardium are found the thymus gland or its remains, areolar tissue, the sternopericardial ligaments, the left transversus thoracis muscle, the internal mammary vessels, the anterior margins of the pleural sac and lungs, and the sternum. Laterally, it is overlapped by the lungs with their pleural sacs, and it is in contact with the phrenic nerves and their accompanying vessels. Posteriorly, it is in relation with the esophagus and vagus nerves, the descending aorta, the thoracic duct and vena azygos, and the roots of the lungs. Below it is separated by the diaphragm from the stomach and the left lobe of the liver.

Vessels.—The arteries of the pericardium are derived from the pericardiac, esophageal, and bronchial branches of the thoracic aorta and from the internal mammary and phrenic arteries.

RELATIONS OF THE HEART AND PERICARDIUM TO THE THORACIC WALL

Heart (fig. 517 A and B).—The **base** of the heart is opposite the fifth to the ninth thoracic vertebra *posteriorly*. *Anteriorly* the **apex** is in the fifth intercostal space, 7.5 to 8 cm. (3 to

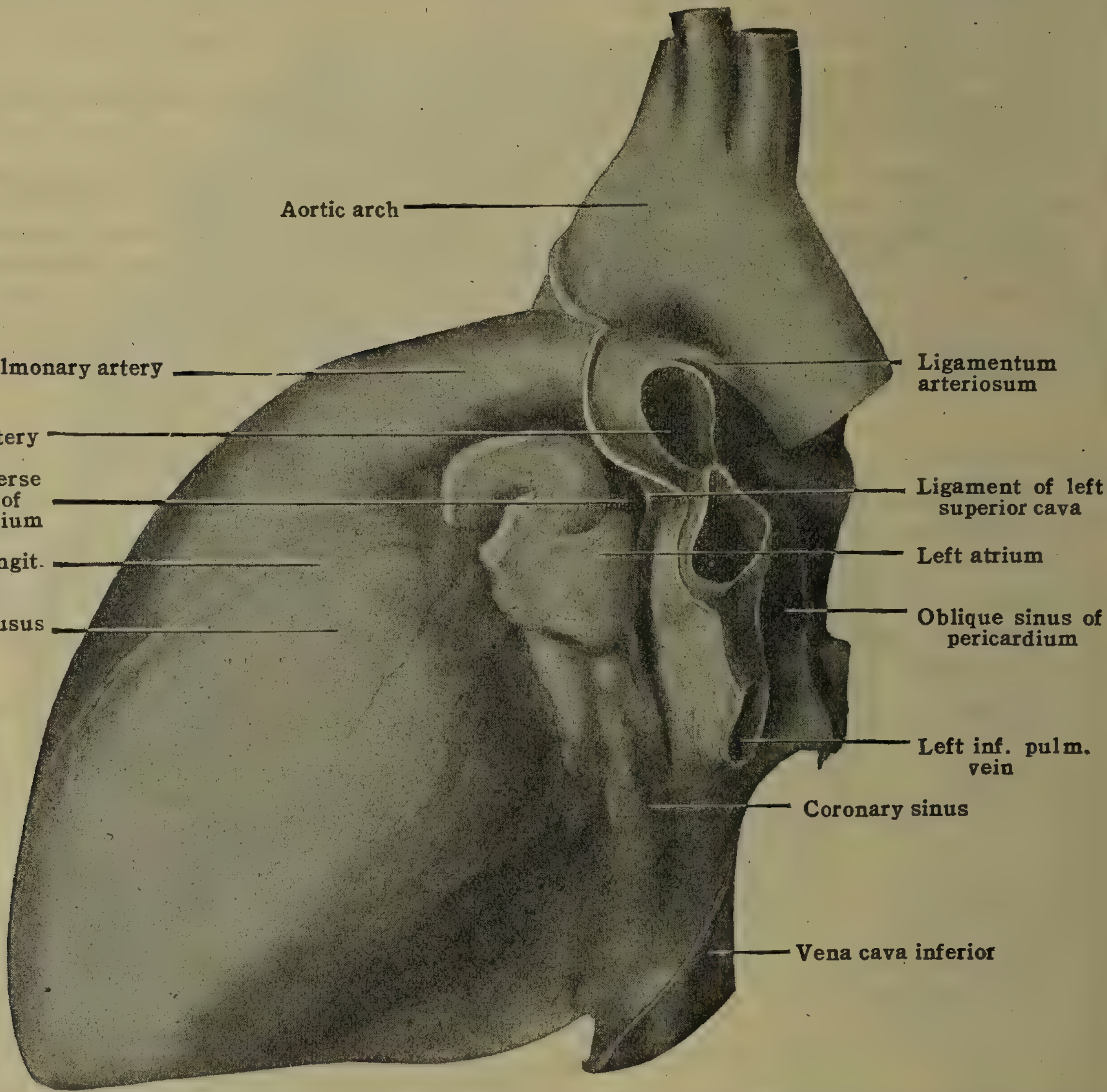


Fig. 516.—Left Posterior View of the Heart to show the Reflections of the Pericardium.

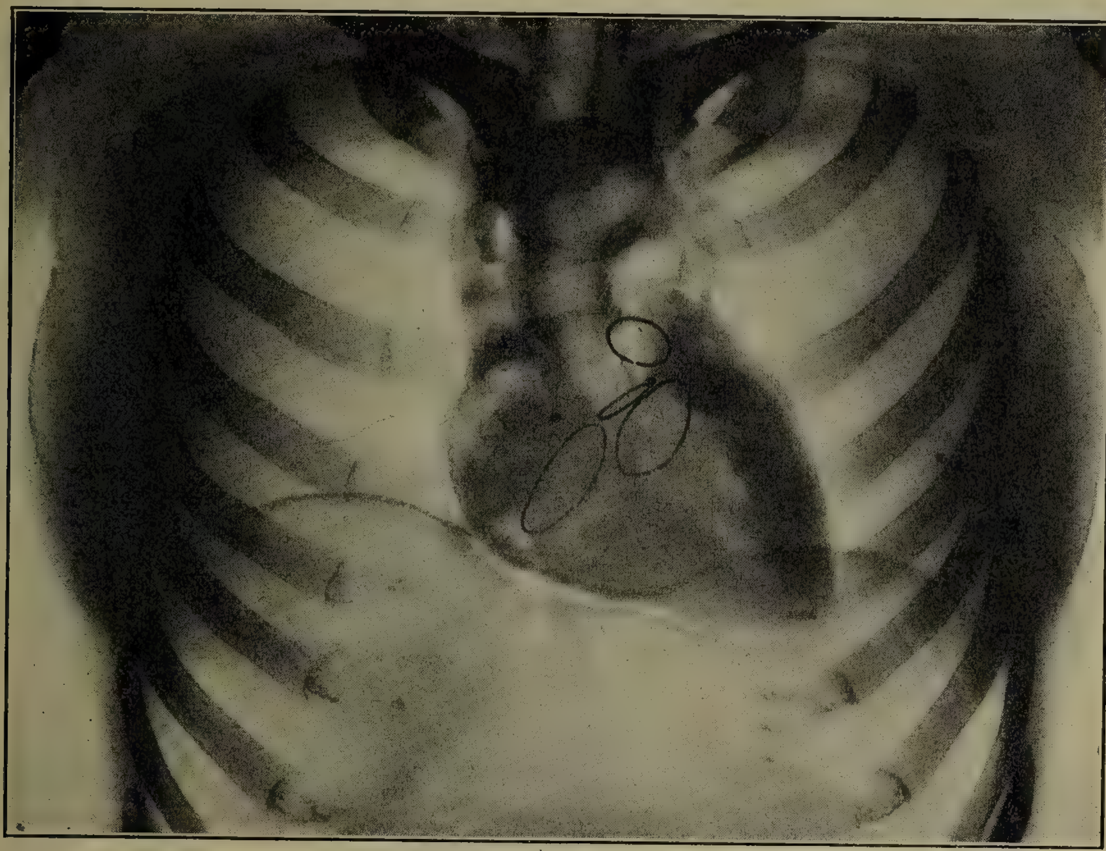
3¼ in.) from the median line. The **base** (above) corresponds to a line (A) drawn from a point 1 cm. (⅖ in.) below the second left chondrosternal articulation, and 3 cm. (1⅕ in. from the median line, to another point (the same distance from the median line) 1 cm. above the right third chondrosternal articulation. The **margo acutus**, or lower border corresponds to a line (B) drawn from the apex through the xiphisternal articulation, to a point on the sixth costal cartilage 2 cm. to the right of the median line. The **right border** of the heart may be indicated approximately by a line (slightly convex to the right) joining the right ends of A and B. The **left border** corresponds to a line (slightly convex to the left) joining the left end of A to the apex.

If a line be drawn from the upper margin of the left third chondrosternal articulation to the right edge of the sternum in the fifth intercostal space, its upper end will lie over the center of the **pulmonary ostium**, and its lower two-thirds (approximately) will overlie the main axis of the **tricuspid ostium.** The **aortic ostium** is immediately to the left of the line mentioned above, with its center at the left edge of the sternum opposite the third space. The **mitral ostium** is very largely behind the third left interspace; its upper end is behind the third cartilage, its lower behind the left margin of the sternum opposite the fourth cartilage and space.

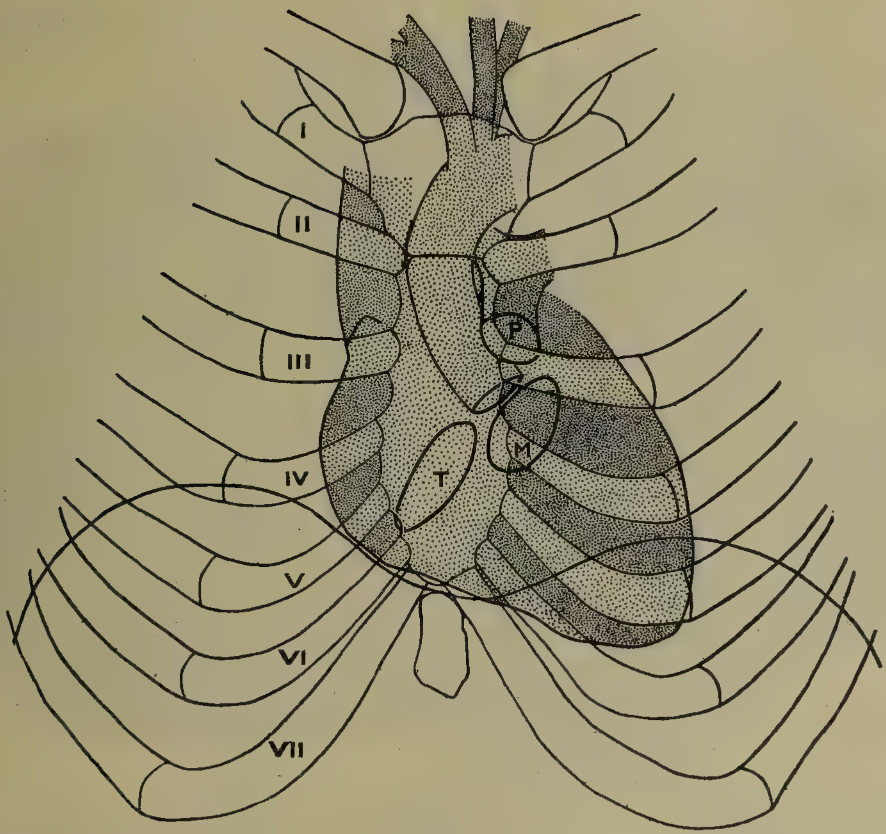
Of the **ostia** of the heart, the pulmonary is nearest the anterior thoracic wall, the aortic is slightly in advance of the tricuspid, and the mitral is the deepest of all.

The **pericardium** follows the heart closely. The upper end (apex) in the subject used in preparing fig. 503 extended up, behind the sternum, to the lower margin of the first costal cartilage on the right and the upper margin of the second on the left. The lower margin (base)

corresponds anteriorly with the line of the margo acutus of the heart. The pericardium is uncovered by pleura in the anterior mediastinum, which is limited on the right by the median line from the level of the fourth chondrosternal to that of the sixth. The limits of the anterior mediastinum to the left and below are subject to some variation (see pleura, p. 1334).



A



B

FIG. 517.—A, TELEROENTGENOGRAM OF A FORMALIN PREPARATION OF THE ANTERIOR THORACIC WALL WITH THE HEART, PERICARDIUM AND DIAPHRAGM IN SITU. (LE WALD, × 1/3) B, EXPLANATORY OUTLINE DRAWING, TRACED FROM THE NEGATIVE AND CONTROLLED BY STEREOSCOPIC VIEWS.

The ostia have been accurately fitted with wire rings. *P*, pulmonary ostium; *M*, mitral, *T*, tricuspid; aortic ostium is unlabelled; I–VII, right costal cartilages.

Paracentesis of pericardium.—While the seat of election must here remain an open question, each case requiring a decision for itself, the one most suitable on the whole is the fifth left space, avoiding injury to the internal mammary artery and the pleura, of which the line of reflection has been shown to vary.

In **incision of the pericardium** to establish free drainage, a portion of the fifth or sixth left costal cartilage should be carefully resected, the internal mammary artery tied, the transversus thoracis (triangularis sterni) scratched through, and the pleural reflection pushed aside.

MORPHOGENESIS OF THE HEART AND PERICARDIUM

The heart is formed by the blending in the median line of two longitudinal endothelial tubes, bounded dorsally by the ventral aspect of the foregut of the early embryo and ventro-

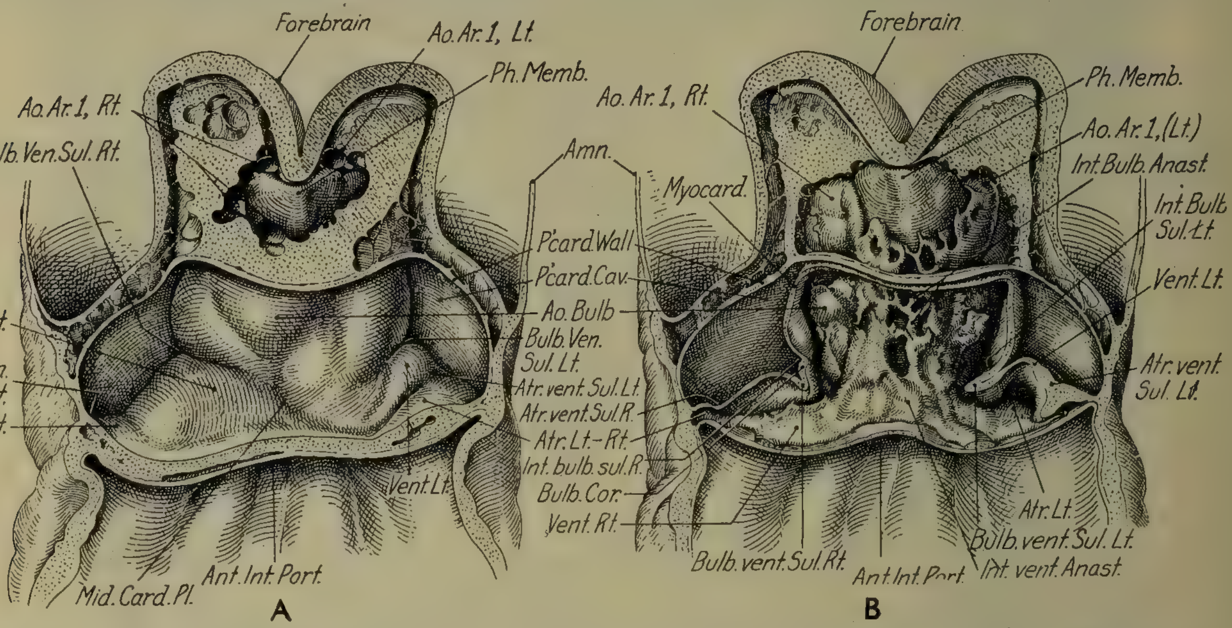


Fig. 518.—The Ventral Surface of a Horizontally Cut Model of the Pericardial Region of a 2.5 mm. Embryo (Univ. of Chicago Coll. No. 3709). (C. L. Davis '27.)

The section opens the amnion, pericardium and the gut and cuts the head in such a way as to expose the blind end of the foregut and the first aortic arches. The first aortic arches have been removed in A and cleared of mesoderm in B. The ventral wall of the myoepicardial mantle has been removed in B.

Abbreviations: Amn., amnion; Ant. Int. Port., anterior intestinal portal; Ao. Ar. 1, Lt. (Rt.), first aortic arch, left (right); Ao. Bulb., aortic bulb; Atr. Lt. (Rt.), atrium, left (right); Atr. vent. Sul. Lt. (Rt.), atrio-ventricular sulcus, left (right); Bulb. Cor., bulbus cordis (conus arteriosus); Bulb. Vent. Sul. Lt. (Rt.), bulbo-ventricular sulcus, left (right).

laterally by splanchnic mesoderm. The endothelial tubes form the **endocardium**; the splanchnic mesoderm in relation with them becomes the **myoepicardium.** The double layer of splanchnic mesoderm which unites the myoepicardium with the somatic mesoderm forms the (temporary) dorsal mesocardium; a ventral mesocardium is never present (Davis). The somatic mesoderm of the heart region becomes the **pericardium.** (See fig. 518.)

The originally straight heart-tube grows rapidly and becomes tortuous, since its length soon exceeds the limit assigned by its fixed arterial and venous ends. Its arterial end is continued into the truncus arteriosus, which is later divided into the pulmonary artery and the ascending

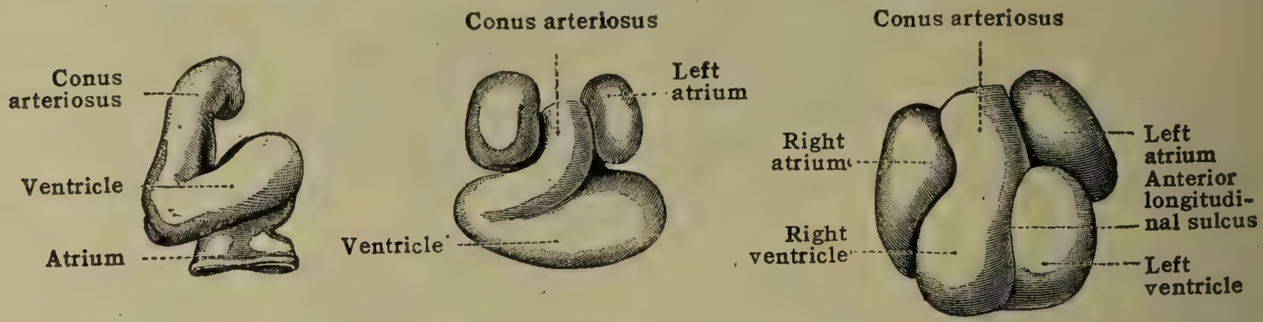


Fig. 519.—Models showing the Development of the Heart. Ventral view. (After His.)

aorta. Its venous end receives the right and left ducts of Cuvier, with the vitelline and umbilical veins. By the formation of a series of alternate bulgings and constrictions the heart becomes differentiated into the sinus venosus, atrium, ventricle and conus arteriosus, counting from the venous to the arterial end. These parts by a process of progressive differentiation and shifting (fig. 519) soon occupy relative positions somewhat approaching those of the adult.

The sinus venosus lies on the dorsal wall of the atrium, and is composed of right and left horns united by a median portion. The sinus is separated from the atrium by a sagitally directed slit-like opening, guarded by right and left lateral valves which project into the atrium. The atrium is wide, being prolonged into a ventrally projecting pouch on either side, the future right and left auricle. The ventricle is situated caudally and somewhat ventrally to the atrium. The right limb of the common ventricle, which leads into the conus arteriosus, is the future right ventricle; the left limb, connected with the atrium, is the future left ventricle. The communication between the atrium and the ventricle, known as the atrial canal (fig. 520), is indicated on the exterior by a constriction; its interior consists of a transversely placed slit.

The conus arteriosus is continued from the ventricle without obvious constriction and passes over into the truncus arteriosus.

The **sinus venosus** early loses its bilateral symmetry owing to the rapid enlargement of the right sinus-horn. This horn soon receives, through the proximal portion of the right vitelline vein (*vena cava inferior*), all the blood from the left vitelline and both umbilical veins. The right common cardinal (duct of Cuvier) eventually gains ascendency over the left and becomes

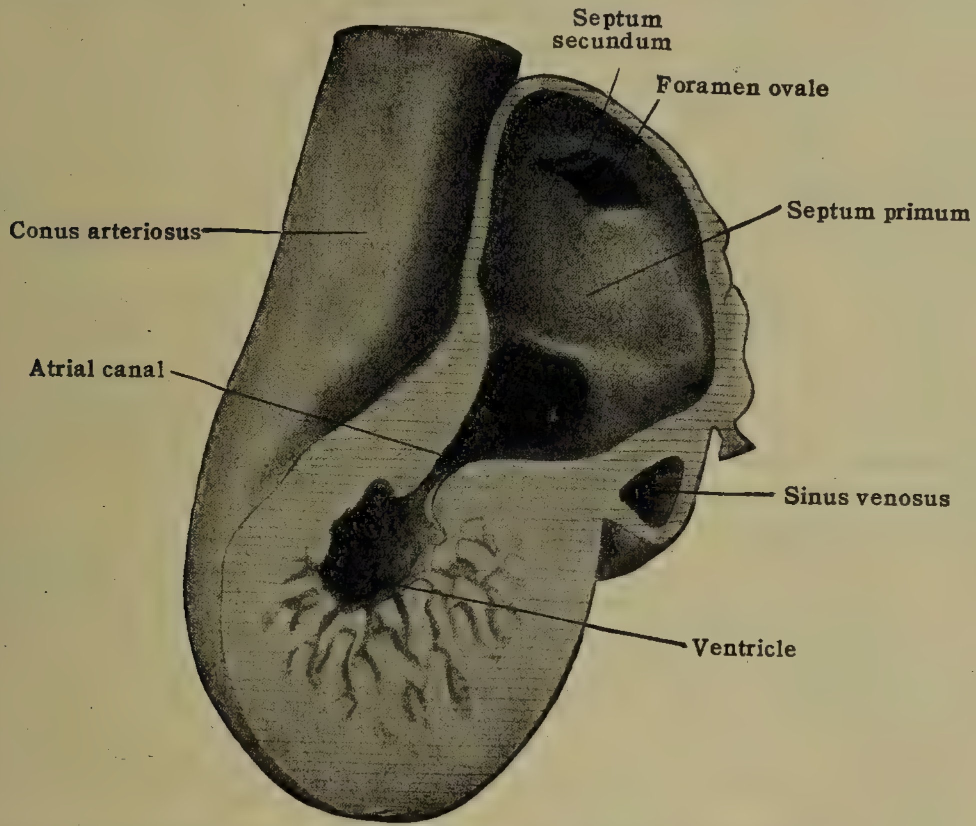


FIG. 520.—SAGITTAL SECTION THROUGH A RECONSTRUCTION OF THE HEART OF A 9 MM. HUMAN EMBRYO SEEN FROM THE LEFT SIDE. (Tandler, ×75.)

FIG. 521.—RECONSTRUCTION OF THE HEART OF AN 11 MM. HUMAN EMBRYO. CAUDAL VIEW (Mall, ×50.)

The lower part of the ventricular portion has been cut off. Connective tissue septa colored yellow. *Ao*, aorta; *Ap*, anterior papillary muscle; *La*, left atrium; *Lo*, left venous ostium; *Lp*, large (anterior) papillary muscle of right ventricle; *Mpm*, medial papillary muscle; *PP*, posterior papillary muscle; *P*, pulmonary artery; *RA*, right astrium; *SV*, septum ventriculorum.

the *vena cava superior*. The left horn of the sinus venosus, which now drains the dwindling left common cardinal (duct of Cuvier) (*left superior cava*) and the coronary veins, become the *coronary sinus*. The right horn gradually becomes absorbed into the right end of the atrial cavity and the superior and inferior cava and the coronary sinus acquire separate openings in that chamber.

In the **atrium** a septum begins early to grow from the ventrocephalic wall of the atrium, toward the atrial canal. As the interatrial communication (ostium primum) around the edge of

the growing septum is becoming narrow a perforation occurs near the attached margin of the septum (ostium secundum); the *septum primum* thus remains incomplete (fig. 520). To the right of the septum primum another septum (s. secundum) is formed later; this never stretches completely across the atrium and is rather a crescentic ridge than a true septum. Until the free edges of the two septa overlap one another there is a direct passage leading from one side of the atrium to the other; when overlapping finally occurs, the interatrial communication (foramen ovale) becomes oblique but persists until birth. (For fetal relations, see p. 37; for adult, see p. 589.) The cavities resulting from the division of the common atrium are the *right and left atria* of the adult. The foramen ovale is bounded on the right side by the septum secundum the free edge of which forms the *limbus fossæ ovalis.* The channel is bounded on the left by the septum primum which slants into the left atrium. The free edge of the septum primum becomes the *valvula foraminis ovalis,* while the remainder becomes the membranous atrial septum of the adult.

The portion of the dorsal wall of the right atrium immediately adjoining the septa is derived from the sinus venosus. This part of the atrium (the *sinus venarum*) receives the venæ cavæ and the coronary sinus. The left sinus-valve is attached to both of the embryonic atrial septa and assists the septum secundum in the formation of the *limbus foraminis ovalis.* The cephalic part of the right sinus-valve disappears along the line of the (adult) *crista terminalis,* which therefore forms the right margin of the portion of the right atrium derived from the sinus venosus. The caudal part of this valve persists as the *inferior caval and coronary valves.*

The left atrium receives, through the dorsal mesocardium, the originally single pulmonary vein. This common stem is absorbed into the atrial wall; later, the primitive right and left tributaries are absorbed in a similar way, leaving the four pulmonary veins of the adult opening separately into the left atrium. The part of the left atrium between the pulmonary veins is, therefore, not part of the original atrial wall.

The **ventricles** are divided by a septum (*s. musculare ventriculorum*) (fig. 521, *SV*) which grows from the caudal wall of the common ventricular cavity toward the atrial canal. The canal moves to the right, and the dorsal part of the septum blends with its dorsal lip. The free ventral edge of the interventricular septum helps to bound the foramen through which blood from the left ventricle must enter the right on its way to the conus arteriosus. The foramen persists until its free margin, having been joined by the aortic septum, becomes the circumference of the *aortic ostium.*

The **aortic septum** is a composite structure formed partly by a septum growing between the fourth and sixth pairs of aortic arches, and partly by endocardial swellings which appear in the interior of the conus and truncus arteriosus. When fully formed it extends spirally along the truncus and conus, and enters the right half of the common ventricular cavity, where it joins the right side of the free edge of the interventricular septum. The septum is spirally curved in such a way that the blood from the left ventricle passes no longer through the right ventricle but traverses a channel (*the aorta*) through the conus and truncus to the first four pairs of aortic arches. The blood from the right ventricle passes through *the pulmonary* division of the conus and truncus arteriosus, anteriorly and to the left of the aorta, into the sixth arches. Further differentiation brings about the external separation of the aorta from the pulmonary artery, but their common covering of epicardium persists as such in the adult. The lower end of the aortic septum persists in the adult as the *septum membranaceum ventriculorum* and the *crista supraventricularis,* the relations of which to the septum musculare are well shown in fig. 507. During the formation of the aortic septum four endocardial swellings appear at the distal part of the interior of the conus. These are arranged as smaller and larger opposite pairs; the smaller and larger swellings, therefore, alternating around the lumen. The larger pair of swellings assists (by partial blending) in the formation of the aortic septum. When the septum is complete, half of each of the larger swellings is contained in the aorta and half of each in the pulmonary artery. One of the smaller swellings remains in the aorta and one in the pulmonary artery, so that there are now three swellings in each vessel. Each of these six swellings becomes undermined to form a *semilunar valve* of the adult.

The atrioventricular valves.—The interior of the ventricular cavity, which is at first smooth, becomes undermined in an irregular way, to form a system of myocardial trabeculæ. The lips of the transversely directed atrial canal become thickened into prominent anterior and posterior endocardial cushions; these project into the ventricular cavity and become involved in its myocardial trabecular system. The atrial canal, which has now moved to the right, becomes divided sagittally, into a right and a left *venous ostium venosum,* by the septum primum. The interventricular septum joins the ventricular side of the posterior endocardial cushion. The anterior and posterior endocardial cushions blend with one another and with the septum primum to form an atrioventricular valve-cusp on either side of the interventricular septum, viz., the anterior cusp of the mitral in the left ostium, and the medial cusp of the tricuspid in the right. The posterior cusp of the mitral and the anterior and posterior cusps of the tricuspid are formed later, partly from endocardial tubercles developing in either ostium, and partly by a process of undermining of the ostia from the ventricular side. The atrial musculature extends into the atrioventricular valves and remains for a while continuous with the trabecular system of the ventricles. This connection between atrial and ventricular musculature eventually becomes non-muscular. Muscle is found at the basal region of the valve-cusps in the adult, and occasionally persists in the chordæ tendineæ.

The connection between the atrial and ventricular musculature is not confined to that of the valvular and trabecular system. The connection between the atrial and ventricular portions of the myocardium remains complete until the embryo has reached the length of about 11 mm. From that time on the myocardium of the atrioventricular junction begins to be replaced by the developing fibrous annuli of the venous ostia. The original connection between the atrial and ventricular musculature persists at one place only, i. e., the site of the *atrioventricular bundle.*

The **pericardial cavity** is the original cephalic end of the intraembryonic celom (see p. 57). The somatic mesoderm of the pericardial region forms the adult *pericardium.* The splanchnic

mesoderm persists only in the part which furnishes the *myoepicardium.* The dorsal mesocardium, formed by the splanchnic mesoderm, is a transitory structure. It persists at the arterial and venous ends of the heart only, and the orifice made by its loss between becomes the *sinus transversus pericardii* of the adult.

During development, the heart and pericardium migrate from a point opposite the cephalic end of the pharynx to the region of the caudal end of the esophagus. This migration is evidenced in the adult by the course of the recurrent and of the cardiac nerves.

B. THE ARTERIES AND VEINS

The **arteries** [arteriæ], proportionately to their size, have much thicker walls than the veins. After death the smaller arteries retain their natural form, but are contracted. The larger arteries are flattened by the pull of the longitudinal elastic fibers in their wall, and contain no clot; except at the orifice of some larger branch, in which a very small clot is usually found. In a very general way the thickness of the wall of an artery is proportional to caliber.

The larger arteries usually take a direct course and branch dichotomously. In descriptive anatomy if dichotomous branches are of nearly equal size it is common for each to take another name; if one branch preponderates in size, it usually retains the name of the parent trunk, while the smaller is regarded as a collateral branch [vas collaterale]. There are numerous exceptions to dichotomous branching; branches may run perpendicularly or recurrently to the vessel from which they arise; or several branches may arise simultaneously.

Anastomosis between large or medium sized arteries occurs less frequently than in veins of corresponding magnitude. Anastomoses do occur, however, particularly in the form of arches, such as the palpebral, plantar and volar arches, or the arches between the intestinal arteries. This form of anastomosis is sometimes called inosculation. Between smaller arteries anastomosis is usually free as in the case, for instance, of the articular retia. In some organs anastomosis (excepting capillary) between neighboring arteries can scarcely be said to exist at all; the a. centralis retinæ affords a good example, as do the arteries of the brain, spleen, and kidney; such arteries are called terminal.

The larger arteries are supplied by *vasa vasorum*, frequently arising from their own recurrent branches.

The **veins** [venæ] have thin walls, and after death are either collapsed or filled with clot or discolored serum. They are characterized by the presence of valves.

Frequent anastomoses occur between veins of all sizes; plexuses are of frequent occurrence. *Venæ comitantes* are veins which, usually in pairs, accompany many of the larger arteries; they communicate with one another, around the artery, very freely. Veins do not primitively accompany arteries. In the case of the extremities the primitive veins ramify upon the surface of the limb. The deep veins of the limbs are of later formation and to them the superficial veins subsequently become tributary.

The veins from the stomach, spleen, pancreas and intestine are collected into a large trunk, the **portal vein.** This does not open into the vena cava inferior directly, but breaks up into numerous capillaries (sinusoids) in the liver. From these the blood is returned, through the hepatic veins, to the inferior cava.

Many veins are provided with **valves,** the free borders of which are directed toward the heart. In the small veins the valves are single; in the larger veins they are usually double, rarely treble. Valves are much more numerous in the veins of infants than those of the adult; their number diminishes progressively with advancing age. Valves are most numerous in the superficial veins, and in the deep veins of the extremities; in many veins of the head and neck valves occur only at the point of termination in a larger trunk.

The cranial *venous sinuses* are modified veins, consisting of intima only which lines channels in the fibrous dura mater. The venous spaces in cavernous tissue, such as occurs in the corpora cavernosa, may be looked upon as specially modified veins. Neither these nor the cranial sinuses are provided with valves.

The larger veins, like the arteries, have *vasa vasorum.*

The section dealing with arteries and veins is divided as follows: 1, pulmonary artery and veins; 2, the systemic arteries; and, 3, the systemic veins. At the ends of the second and third divisions are brief accounts of morphogenesis and variations.

1. THE PULMONARY ARTERY AND VEINS

The **pulmonary artery** [a. pulmonalis] (fig. 522) and its branches differ from all other arteries in the body in that they contain venous blood. It arises as a short, thick trunk from the **conus arteriosus** of the right ventricle, and, after a course of about 5 cm. (2 in.) within the pericardium, divides into a right and a left branch, which pass to the right and the left lung respectively.

The **trunk of the pulmonary artery** at its origin is somewhat anterior to the ascending aorta, and slightly overlaps that vessel. It curves upward, backward, and to the left, around the front and left side of the ascending aorta; having

reached the concavity of the aortic arch, on a plane posterior to the ascending aorta, it divides into its right and left branches, which diverge from each other at an angle of about 130°. The division of the pulmonary artery occurs immediately to the left of the second left chondrosternal articulation.

In the fetus, the pulmonary artery continues its course upward, backward, and to the left under the name of the **ductus arteriosus** (**Botalli**), and opens into the descending aorta just below the origin of the left subclavian artery. Soon after birth, the lumen of the ductus arteriosus becomes obliterated, and its wall is represented in postnatal life by a fibrous cord, the **ligamentum arteriosum** (chorda ductus arteriosi NK) (fig. 522).

Relations.—In front, the trunk of the pulmonary artery is separated from the remains of the thymus gland by the pericardium. The artery lies, at its commencement, behind the upper margin of the third left chondrosternal articulation. The right margin of the artery is behind the second piece of sternum but the greater part of the vessel is behind the medial end of the second intercostal space.

Behind, it lies successively upon the ascending aorta and the left atrium.

To the **right** are the ascending aorta, the right atrium, the right coronary artery, and the cardiac nerves.

To the **left** are the pericardium, the left pleura and lung, the left auricle, the left coronary artery, and the cardiac nerves.

The **right pulmonary artery** [ramus dexter] longer than the left, passes almost horizontally under the arch of the aorta to the root of the right lung, where it divides into two branches, one for the lower lobe and another which subdivides to supply the upper and middle lobes. These branches follow the course of the bronchi, dividing and subdividing for the supply of the lobules of the lung. The terminal branches do not anastomose with each other.

Relations.—In its course to the lung it has **in front** of it the ascending aorta, the superior vena cava, the phrenic nerve, the anterior pulmonary plexus and the reflection of the pleura. **Behind** is the right bronchus, which separates it from the azygos vein. **Above** is the arch of the aorta, and **below** are the left atrium and the upper right pulmonary vein.

At the root of the lung it has the right bronchus **above** and **behind** it; the pulmonary veins **below** and **in front.** Crossing in front of it and the other structures forming the root of the lung are the phrenic nerve and the anterior pulmonary plexus; behind are the azygos vein, the vagus nerve, and the posterior pulmonary plexus.

The **left pulmonary artery** [ramus sinister], shorter and slightly smaller than the right, passes in front of the descending aorta to the root of the left lung, where it divides into two branches for the supply of the upper and lower lobes respectively. These divide and subdivide as on the right side.

Relations.—At the root of the lung it has the left bronchus **behind** and also **below** it, in consequence of the more vertical direction taken by the left bronchus than by the right. **Below** and **in front** are the pulmonary veins, while passing from the artery and the upper left pulmonary vein is the ligament of the left superior cava. Crossing in front of it and the other structures forming the root of the lung are the phrenic nerve and the anterior pulmonary plexus. Crossing behind it are the descending aorta, the left vagus nerve, and the posterior pulmonary plexus.

The **pulmonary veins** [vv. pulmonales] (figs. 516, 522) return the aërated blood from the lungs to the heart. They are usually four in number, superior and inferior, of the right and left sides. Occasionally, however, there are three pulmonary veins on the right side, the result of the vein from the middle lobe of the right lung opening separately into the left atrium instead of joining as usual the upper of the two right pulmonary veins. The relations of the pulmonary veins to the pulmonary arteries and bronchi at the roots of, and within the lungs are given with the anatomy of the lungs (Section X).

The pulmonary veins are about 15 mm. in length. In the pericardium the upper of the **right pulmonary veins** [vv. pulmonales dextræ] passes behind the superior vena cava. The lower crosses behind the right atrium. The superior vein receives the vein from the right middle lobe and runs below and in front of the right pulmonary artery.

The **left pulmonary veins** [vv. pulmonales sinistræ] enter the left atrium about 3 cm. in front of the veins of the right side. The superior vein is below the left pulmonary artery.

2. THE SYSTEMIC ARTERIES

THE AORTA

The **aorta** (fig. 523) is the main systemic arterial trunk, and from it all the systemic arteries are derived. It begins at the left ventricle of the heart, and

ascends near the anterior thoracic wall as high as the second right chondrosternal articulation [**aorta ascendens**]. It then turns backward and to the left forming an arch [**arcus aortæ**] which reaches the posterior thoracic wall at the left side of the fourth thoracic vertebra. From here it runs downward along the vertebral column [**aorta descendens**] through the thorax and abdomen and ends by dividing, opposite the fourth lumbar vertebra, into the right and left common iliac arteries. From the point of bifurcation a small vessel, the middle sacral, is continued down the middle line in front of the sacrum and coccyx. The middle sacral represents the sacrococcygeal aorta.

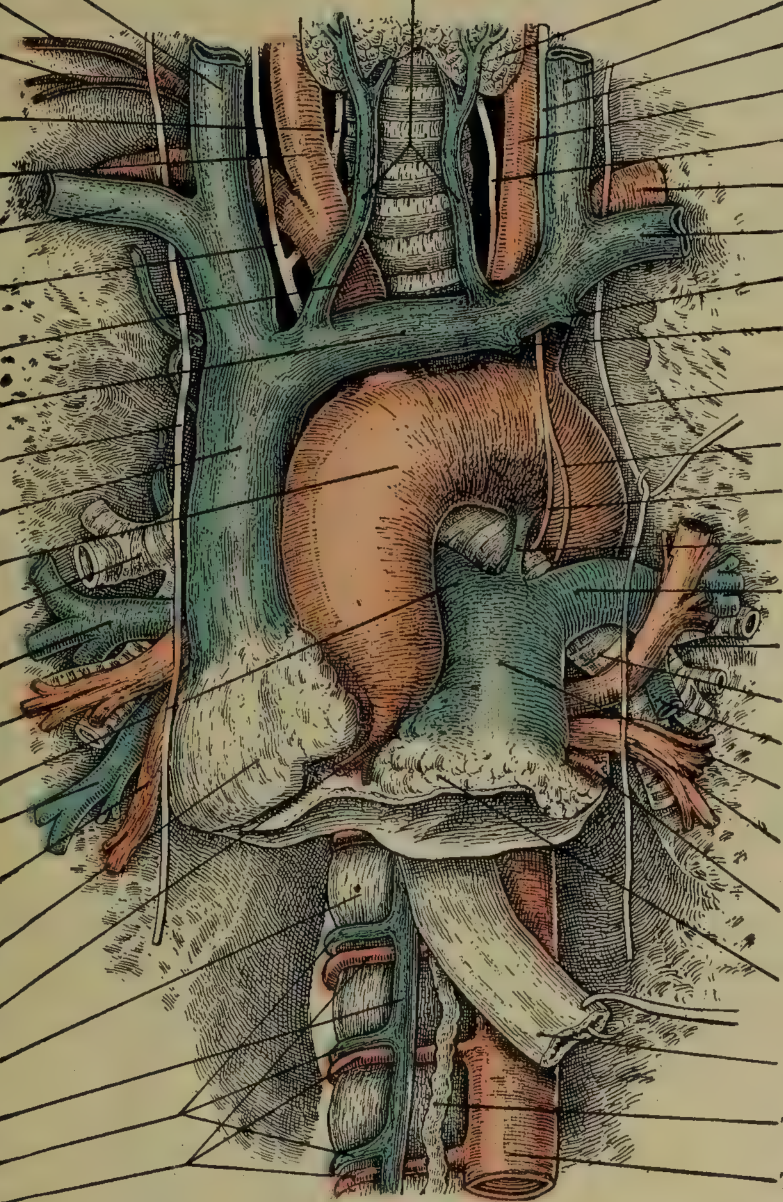


Fig. 522.—The Great Vessels of the Thorax.
(Modified from a dissection in St. Bartholomew's Hospital Museum.)

The Ascending Aorta

The **ascending aorta** [aorta ascendens] (fig. 523) begins at the upper part of the left ventricle, on a level with the third intercostal space, and ascends behind the sternum to the upper border of the right second chondrosternal articulation. It measures about 5 to 5.5 cm. (2 to 2¼ in.), forming, as it ascends, a gentle curve with its convexity to the right. It is enclosed within the pericardium, being invested, together with the pulmonary artery, in a common sheath formed by the serous layer of that membrane. A dilation known as the **bulbus aortæ** occurs immediately above the heart upon which are three localized bulgings, known as the **aortic sinuses** (of Valsalva); they are placed, one to the right, one to the left, and one posteriorly. From the right and left are derived the coronary arteries of the heart. (See Heart.)

Relations.—**In front** the ascending aorta is overlapped at its commencement by the right auricle, conus arteriosus and pulmonary artery. Higher up, as the pulmonary artery and auricle diverge, it is separated from the manubrium by the pericardium, the remains of the thymus

gland, and by the loose tissue and in the superior mediastium. It is here slightly overlapped also by the right pleura and by the edge of the right lung in full inspiration. The root of the right coronary artery is also in front. **Behind** are the left atrium of the heart, the right pulmonary artery, the right bronchus, and the anterior right deep cardiac nerves. On the **right side** it is in contact, below with the right atrium, and above with the superior vena cava. On the **left side** are the pulmonary artery and the branches of the right superficial cardiac nerves.

Branches.—The right and left coronary arteries have already been described (p. 597).

The Arch of the Aorta

The **arch of the aorta** [arcus aortæ] (figs. 522, 523), extends in a gentle curve upward, backward, and to the left, from the level of the upper border of the second right costal cartilage to the lower border of the fourth thoracic vertebra and is thus contained entirely within the superior mediastinum. Attached to the concavity of the arch, just beyond the origin of the left subclavian artery, is the **ligamentum arteriosum** (vestige of the dorsal part of the left sixth arch). Between the left subclavian artery and the ligamentum arteriosum there is sometimes a definite constriction of the arch (**isthmus aortæ**) situated opposite the third thoracic vertebra. When the isthmus is well marked, it is succeeded by a dilation (**aortic spindle**) which begins in the neighborhood of the ligamentum arteriosum and passes over the descending aorta. The arch measures about 4.5 cm. (1⅘ in.) in length.

Relations.—**In front and to the left**, the aortic arch is slightly overlapped by the right pleura and lung, and to a greater extent by the left pleura and lung. It is crossed in the following order from right to left, by the left phrenic nerve, by the cardiac branches of the vagus nerve, the cardiac branches of the sympathetic nerve, by the left vagus nerve, and by the left superior intercostal vein as it passes up to the left innominate vein.

Behind and to the right are the trachea, the esophagus, the thoracic duct, the deep cardiac plexus which is situated on the trachea just above its bifurcation, and the left recurrent (inferior laryngeal) nerve.

Above it are the three chief branches for the head, neck, and upper extremities, namely, the innominate, the left carotid, and the left subclavian arteries, and the left innominate vein.

Below it—that is, in its concavity—are the bifurcation of the pulmonary artery, the left bronchus, the left recurrent (inferior laryngeal) nerve, the ligamentum arteriosum, the superficial cardiac plexus, two or more bronchial lymphatic glands, and the reflection of the pericardium.

Clinical aspects.—Many pressure symptoms may accompany an **aneurysm of the aortic arch**; e.g., pressure on the left innominate vein, the three large arteries, trachea, and left bronchus, recurrent nerve, esophagus, and thoracic duct. In **aneurysm of the thoracic aorta**, pain, usually unilateral, referred to the corresponding intercostal nerves, is a common pressure symptom.

The **branches of the aortic arch** are:—the innominate, the left common carotid, and the left subclavian arteries. The innominate and left carotid arise close together—indeed, so close that, when seen from the interior of the aorta, the orifices appear merely separated by a thin septum. The left subclavian arises a short distance from the left carotid.

THE INNOMINATE ARTERY

The **innominate** [a. anonyma] or brachiocephalic artery (truncus brachiocephalicus NK) (fig. 522), the largest branch of the arch of the aorta, extends upward and a little forward and to the right, as high as the upper limit of the right sternoclavicular joint where it bifurcates into the right common carotid and right subclavian arteries. It lies obliquely in front of the trachea, and measures from 3.7 to 5 cm. (1½ to 2 in.).

Relations.—**In front** of the artery are the manubrium, the origins of the sternohyoid and sternothyroid muscles, the right sternoclavicular joint and the remains of the thymus gland. The left innominate vein crosses the root of the vessel, and the inferior thyroid and thyroidea ima veins descend obliquely over it to end in the left innominate vein. The inferior cervical cardiac branches of the right vagus nerve pass in front of it on their way to the deep cardiac plexus. **Behind**, it lies on the trachea, crossing that tube obliquely from left to right and coming into contact above with the right pleura. To the **right side** are the right innominate vein, the right vagus and the pleura. To the **left side** are the left common carotid, the remains of the thymus gland, the right inferior thyroid vein, and, at a higher level, the trachea.

The **branches of the innominate artery** are:—(1) The right common carotid; and (2) the right subclavian. These are terminal branches. There are usually no collateral branches from this vessel, but at times the thyroidea ima may arise from it.

The **thyroidea ima** artery, which occurs in about 10 per cent. of subjects, ascends on the front of the trachea to the thyroid gland. It may be large, in which case it might complicate the low operation of tracheotomy. It does not always arise from the innominate, but occasionally from the arch of the aorta (see fig. 584) or from the right common carotid.

THE COMMON CAROTID ARTERIES

The **common carotid** arteries [aa. carotides communes] right and left, pass up deeply from the thorax on either side of the neck to about the level of the upper

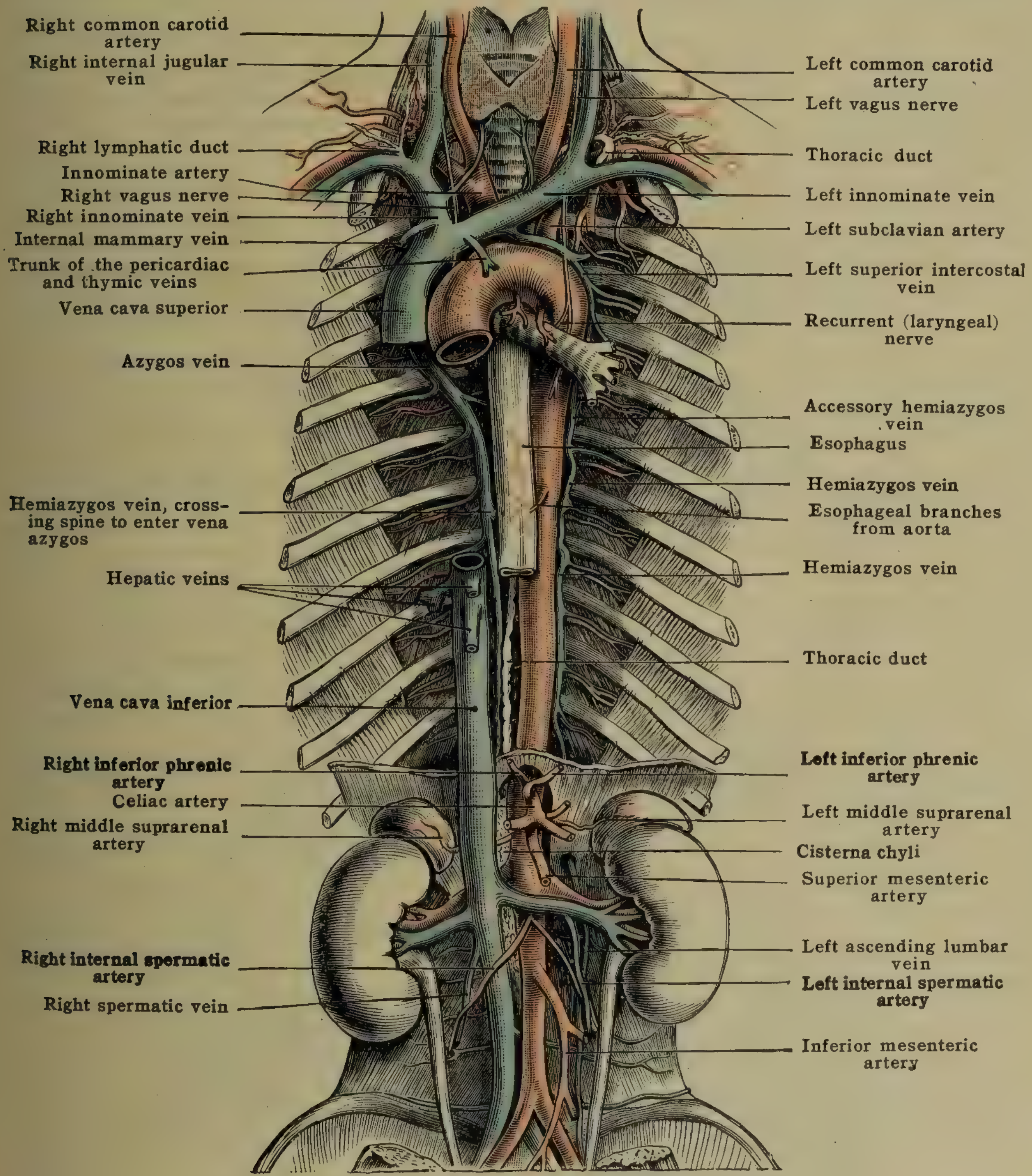


Fig. 523.—The Thoracic and Abdominal Aorta.

border of the thyroid cartilage, where each divides into the external and internal carotid. The **external carotid artery** supplies the structures at the upper part of the neck, the larynx, pharynx, tongue, face, the structures in the pterygoid region, the scalp and the membranes of the brain. The **internal carotid** gives off no branch in the neck, but enters the cranium and supplies the greater part of the brain, the structures contained in the orbit and portions of the membranes of the brain.

The common carotid artery on the right side arises from the bifurcation of the innominate at the upper limit of the sternoclavicular joint; on the left side from the arch of the aorta a little to the left of the innominate artery, and on a plane somewhat posterior to that vessel (fig. 523). The portion of the left common

carotid artery which extends from the arch of the aorta to the upper limit of the sternoclavicular articulation lies deeply in the chest, and requires separate description; but above the level of the sternoclavicular joint the relations of the right and left carotids are practically the same.

THORACIC PORTION OF THE LEFT COMMON CAROTID ARTERY

Within the thorax the left common carotid is deeply placed behind the manubrium of the sternum, and is overlapped by the left lung and pleura. It

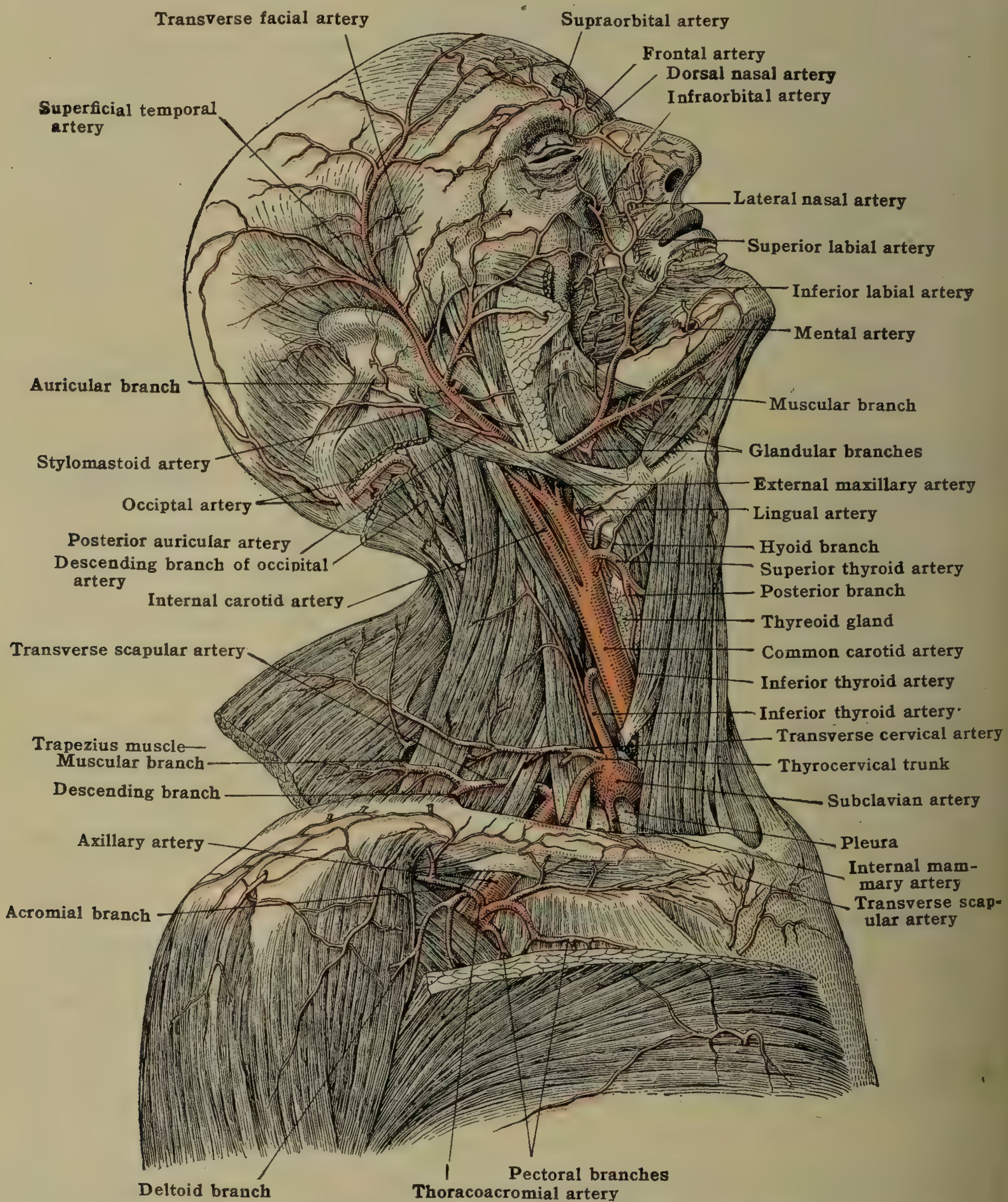


FIG. 524.—ARTERIES OF THE HEAD AND NECK. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

In this case the external maxillary artery ends after having given origin to the lateral nasal branch through which it inosculates with the dorsal nasal artery from the ophthalmic. The angular artery proper is absent. (Cf. fig. 529.)

arises from the middle of the aortic arch, close to the left side of the innominate artery, and a little posterior to the vessel, and ascends obliquely in front of the trachea to the left sternoclavicular articulation, above which its relations are similar to those of the right common carotid (fig. 523).

Relations.—**In front,** but at some little distance, are the manubrium and the origins of the left sternohyoid and sternothyroid muscles. In contact with it are the remains of the thymus gland, and the loose connective tissue and fat of the superior mediastinum. Crossing its root is the left innominate vein. **Behind,** it lies successively upon the trachea, the left recurrent (laryngeal) nerve, the esophagus (which here inclines a little to the left) and the thoracic duct. To its **right side** is the root of the innominate artery, and higher up are the trachea and the inferior thyroid veins. To its **left side,** but on a posterior plane, are the left subclavian artery and the left vagus nerve; and, slightly overlapping it, the edge of the left pleura and lung.

THE COMMON CAROTID ARTERY IN THE NECK

The **common carotid artery in the neck** extends from the sternoclavicular articulation to the upper border of the thyroid cartilage on a level with the fourth cervical vertebra, where it divides into the external and internal carotid arteries. A line drawn from the sternoclavicular joint to a point just behind the neck of the mandible would indicate its course. The artery is at first deeply placed beneath the sternomastoid, sternohyoid, and sternothyroid muscles, and at the level of the top of the sternum is only 2 cm. (¾ in.) distant from its fellow of the opposite side, and merely separated from it by the trachea. As the carotid arteries run up the neck, however, they diverge in the form of a V and become more superficial, though on a plane posterior to that in which they lie at the root of the neck, and are separated from each other by the larynx and pharynx. At their bifurcation they are about 6 cm. (2¼ in.) apart. The common carotid is contained in a sheath of fascia common to it and the internal jugular vein and vagus nerve. The artery, vein, and nerve, however, are not in contact, but separated from one another by fibrous septa, which divide the common sheath into three compartments: one for the artery, one for the vein, and one for the nerve. The vein, which is larger than the artery, lies to the lateral side, and somewhat overlaps it. The vagus nerve lies behind and between the two vessels. The artery on the right side measures about 9.5 cm. (3¾ in.); on the left side, about 12 cm. (4¾ in.) in length (fig. 524).

Relations.—**In front** the common carotid is covered by the skin, superficial fascia, platysma, and deep fascia, and is more or less overlapped by the sternomastoid muscle. At the lower part of the neck it is covered in addition by the sternohyoid and sternothyroid muscles and anteriorly to these is crossed by the anterior jugular vein. In many cases it is overlapped by the thyroid gland. Opposite the cricoid cartilage it is crossed obliquely by the omohyoid muscle, and, above this, by the superior thyroid vein, and the sternomastoid artery. Along the anterior border of the sternomastoid there is sometimes a communication between the facial and anterior jugular veins, which, as it crosses the line of the carotid artery, is in danger of being wounded during the operation for ligature. The ramus descendens n. hypoglossi generally descends in front of the carotid sheath, being there joined by one or two communicating branches from the second and third cervical nerves. At times this nerve runs within the sheath. There are usually two lymphatic glands about the bifurcation of the artery.

Behind, the common carotid lies on the longus colli and scalenus anterior below, and the longus capitis (rectus capitis anterior major) above. Posterior to the artery, but in the same sheath, is the vagus nerve; and posterior to the sheath, the cervical sympathetic and the cervical cardiac branches of the sympathetic and vagus nerves. At the lower part of the neck the inferior thyroid artery courses obliquely behind the carotid, as does likewise the recurrent (inferior laryngeal) nerve.

Medially, from below upward, are the trachea and esophagus, with the recurrent (inferior laryngeal) nerve in the groove between them, the terminal branches of the inferior thyroid artery, the lateral lobe of the thyroid gland, the cricoid cartilage, the thyroid cartilage and the lower part of the pharynx. At the angle of bifurcation is the **carotid gland** [glomus caroticum].

Laterally are the internal jugular vein and the vagus nerve. On the right side, at the root of the neck, the vein diverges somewhat from the artery, leaving a space in which the vagus nerve and vertebral artery are exposed. On the left side the vein approaches and somewhat overlaps the artery, there being no interval corresponding to that on the right side.

Ligature of the common carotid is usually performed at the 'seat of election,' where the vessel is more superficial, *above the omohyoid.* An incision with its center opposite the cricoid is made 7.5 cm. (3 in.) long in the line of the carotid artery. The deep fascia along the anterior border of the sternomastoid having been divided, the cellular tissue beneath is opened up, the omohyoid identified and drawn down or divided. The sternomastoid is next drawn well laterally, and the artery felt for. At this stage, such veins as the communication between the common facial and the anterior jugular and the superior and middle thyroids may give trouble. The sheath is next opened well to the medial side, opposite to the cricoid cartilage, the ascending cervical, when seen, being avoided. If the internal jugular be distended, it may be drawn aside with a blunt hook, or pressure made lightly in the upper angle of the wound. The needle should be passed from the lateral side in very close proximity to the lateral and back part of the artery, as so to avoid the vein and vagus. Ligature *below the omohyoid* is rendered more difficult by the presence of the anterior jugular, the pretracheal muscles, an overlapping thyroid gland, especially if enlarged, the greater depth of the artery, especially on the left side and, here also, the closeness of the internal jugular. **Ligature of the external carotid,** otherwise

difficult, is rendered very simple by first exposing the bifurcation of the common carotid artery, the incision similar to the last being prolonged upward. Here the facial and lingual veins and hypoglossal nerve cross the trunk, over which also lie some of the deep cervical glands. The ligature is usually placed between the superior thyroid and lingual branches.

The **collateral circulation** (fig. 525), after ligature of the common carotid, is carried on chiefly by the anastomosis of the internal carotid with the internal carotid of the opposite side

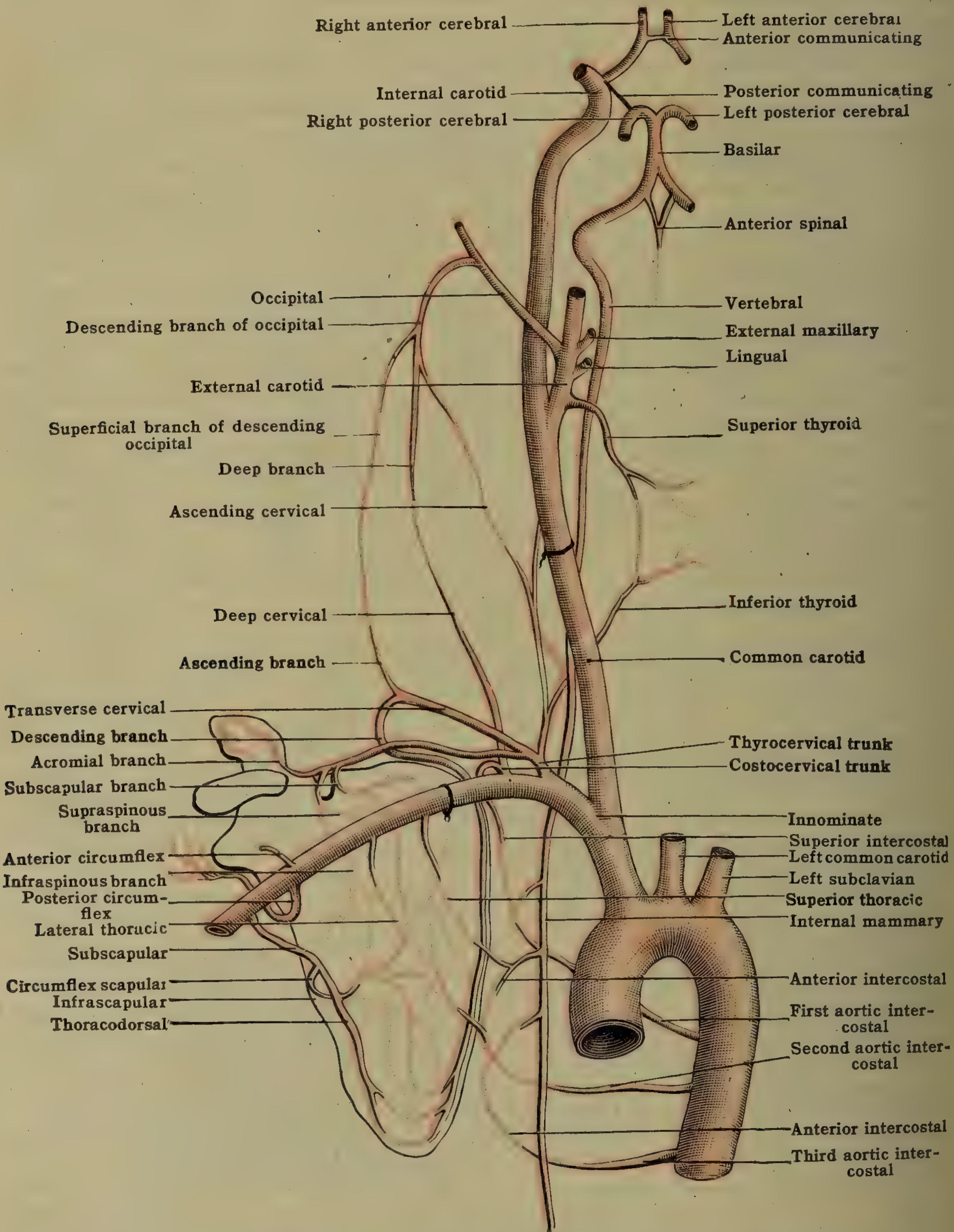


FIG. 525.—THE COLLATERAL CIRCULATION AFTER LIGATURE OF THE COMMON CAROTID AND SUBCLAVIAN ARTERIES.

(A ligature is placed on the common carotid and on the third portion of the subclavian artery.)

and with both vertebral arteries through the circle of Willis; by the inferior thyroid with the superior thyroid; by the deep cervical branch of the costocervical trunk with the descending branch of the occipital; by the superior thyroid, lingual, external maxillary (facial), occipital, and temporal, with the corresponding arteries of the opposite side, and by the ophthalmic with the angular. The anastomosis between the deep cervical branch of the costocervical trunk with the descending branch of the occipital is an important one; it is situated deeply at the back of the neck, between the semispinalis capitis (complexus) and cervicis muscles.

Branches.—The common carotid is unbranched except at its termination, and consequently does not diminish in size as it runs up the neck. It is often a little swollen just below its bifurcation, a condition that should not be mistaken for an aneurismal dilation. Its terminal branches are (1) external and (2) internal carotid arteries.

THE EXTERNAL CAROTID ARTERY

The **external carotid** artery [a. carotis externa] (figs. 524, 526), the smaller of the two branches into which the common carotid divides at the upper border of the thyroid cartilage, is distributed to the anterior part of the neck, the face, and the cranial region, including the skin, the bones, and the dura mater. It is at first medial to the internal carotid; but as it ascends in the neck it forms a

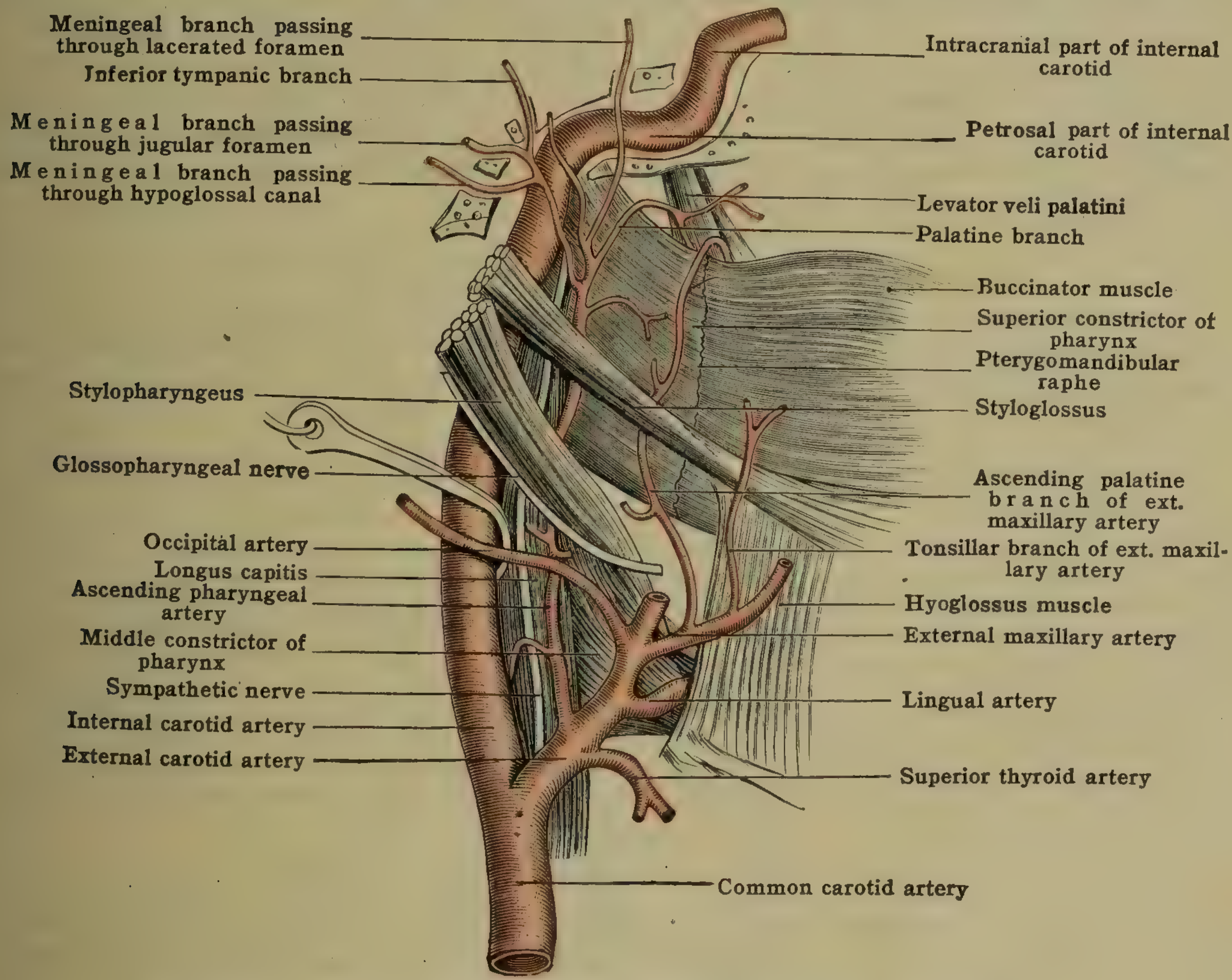


Fig. 526.—Right Ascending Pharyngeal Artery. (Walsham.)
The internal carotid artery is hooked aside.

gentle curve, with its convexity forward, and, running slightly backward as well as upward, terminates opposite the neck of the mandible by dividing into the internal maxillary and superficial temporal arteries. It here lies superficial to the internal carotid from which it is separated by a portion of the parotid gland. At its origin it is overlapped by the anterior margin of the sternomastoid, and is covered by the superficial fascia, platysma, and deep fascia. Higher up the neck it is deeply placed, passing beneath the stylohyoid muscle, the posterior belly of the digastric muscle and the hypoglossal nerve; and finally becomes embedded in the parotid gland, where it divides into its terminal branches. It is separated from the internal carotid artery posteriorly by the stylopharyngeus muscle, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, a portion of the parotid gland, and the stylohyoid ligament. It measures about 6.5 cm. (2⅗ in.) in length.

Relations.—**Laterally,** in addition to the skin, superficial fascia, platysma, and deep fascia, it has the hypoglossal nerve, the lingual, common facial and posterior facial veins, the posterior belly of the digastric and stylohyoid muscles, the superior cervical lymphatic glands, branches of the facial nerve, and the parotid gland. The sternomastoid also overlaps it in the natural state of the parts. **Behind,** it is in relation with the internal carotid, from which it is separated by the stylopharyngeus muscle, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, the stylohyoid ligament, and the parotid gland. The superior laryngeal nerve

crosses behind both the external and internal carotid arteries. **Medially,** it is in relation with the hyoid bone, the pharyngeal wall, the stylomandibular ligament, which separates it from the submaxillary gland, and the parotid gland.

The **branches of the external carotid** are usually given off in the following order, from below upward:—(1) Ascending pharyngeal; (2) superior thyroid; (3) lingual; (4) external maxillary (facial); (5) sternocleidomastoid; (6) occipital; (7) posterior auricular; (8) superficial temporal; (9) internal maxillary.

1. THE ASCENDING PHARYNGEAL ARTERY

The **ascending pharyngeal** artery [a. pharyngea ascendens] (fig. 526) is usually the first or second branch of the external carotid. Occasionally it comes off near the bifurcation of the common carotid from the common carotid itself. It is a long slender vessel, and may be very small if the ascending palatine or the tonsillar branch of the external maxillary artery is large. Deeply seated in the neck it runs to the base of the skull, having the walls of the pharynx and the tonsil **medially,** the internal carotid artery **laterally,** and the vertebral column, the longus capitis (rectus capitis anterior major) and the sympathetic nerve **posteriorly. Laterally** it is crossed by the styloglossus (fig. 526) and the stylopharyngeus muscles and the glossopharyngeal nerve.

Branches of the Ascending Pharyngeal Artery

The branches of the ascending pharyngeal artery are small and variable. They supply the longus and rectus capitis muscles, the upper cervical sympathetic ganglion and adjacent lymph-nodes, as well as the pharynx, soft palate, ear, cranial nerves, and meninges.

The **pharyngeal** branches [rr. pharyngei] supply the superior and middle constrictor muscles and the mucous membrane lining them. These vessels anastomose with branches of the superior thyroid. One branch (the **palatine**) passes over the upper edge of the superior constrictor to the soft palate and its muscles. This branch follows a course similar to that taken by the ascending palatine artery, and when the latter is small may take its place. It generally gives off small twigs to the auditory (Eustachian) tube and tonsil. The **inferior tympanic** artery [a. tympanica inferior] (or cervicalis NK) accompanies the tympanic branch of the glossopharyngeal nerve through the tympanic canaliculus into the tympanum, and anastomoses with the other tympanic arteries. The **posterior meningeal** artery [a. meningea posterior] (a. meningea occipitalis NK) is distributed to the membranes of the brain. Some twigs pass with the jugular vein through the jugular foramen into the cranium, and supply the dura mater in the posterior fossa of the skull. Others occasionally reach the same fossa through the hypoglossal canal while others pass through the cartilage of the lacerated foramen and supply the middle fossa of the skull.

2. THE SUPERIOR THYROID ARTERY

The **superior thyroid** artery [a. thyreoidea superior] (figs. 524, 527) arises from the front of the external carotid a little above the origin of that vessel, and, coursing forward, medially, and then downward, in a tortuous manner, supplies the depressor muscles of the hyoid bone, the larynx, the thyroid gland, and the lower part of the pharynx. The artery at first runs forward and a little upward, just below the greater cornu of the hyoid bone. In this part of its course it lies in the superior carotid triangle, and is quite superficial, being covered only with the integument, fascia and platysma. It next turns downward, and passes beneath the omohyoid, sternohyoid and sternothyroid muscles, and ends at the upper part of the thyroid gland in the terminal glandular branches. The superior thyroid vein passes below the artery on its way to the internal jugular vein. The superior thyroid is the artery most commonly divided in cases of suicidal wounds of the throat.

Branches of the Superior Thyroid Artery

The named **branches of the superior thyroid artery** are:—(1) The hyoid; (2) the sternomastoid; (3) the superior laryngeal; (4) the cricothyroid; (5) anterior; (6) posterior; and (7) glandular.

(1) The **hyoid** branch [r. hyoideus] is usually a small twig which passes along the lower border of the hyoid bone, lying on the thyrohyoid membrane under cover of the thyrohyoid and sternohyoid muscles. It supplies the infrahyoid bursa and the thyrohyoid muscle, and anastomoses with its fellow of the opposite side, and with the hyoid branch of the lingual. When the latter artery is small, the hyoid branch of the superior thyroid is usually comparatively large, and *vice versa.*

(2) The **sternomastoid** branch [r. sternocleidomastoideus] (fig. 527) courses downward and backward across the carotid sheath, and entering the sternomastoid supplies the middle portion of that muscle. It gives off slender twigs to the thyrohyoid, sternohyoid, and omohyoid muscles and to the platysma and integument. It lies usually somewhere in the upper part of the incision for tying the common carotid above the omohyoid muscle.

(3) The **superior laryngeal** artery [a. laryngea superior] (fig. 527) passes medially beneath the thyrohyoid muscle, and, perforating the thyrohyoid membrane along with the internal branch of the superior laryngeal nerve, supplies the intrinsic muscles and mucous lining of the larynx. Its further distribution within the larynx is given with the description of that organ. This branch sometimes arises from the external carotid direct. It may enter the larynx by passing through a foramen in the thyroid cartilage.

(4) The **cricothyroid** [r. cricothyreoideus] passes across the cricothyroid membrane at the lower border of the thyroid cartilage. It anastomoses with its fellow of the opposite side, and usually sends a small branch through the membrane to the interior of the larynx. Occasionally a considerable twig descends over the cricoid cartilage to enter the isthmus of the thyroid gland. The cricothyroid is sometimes of comparatively large size. In order to avoid injuring the cricothyroid artery in the operation of laryngotomy, it is usual, if the operation has to be

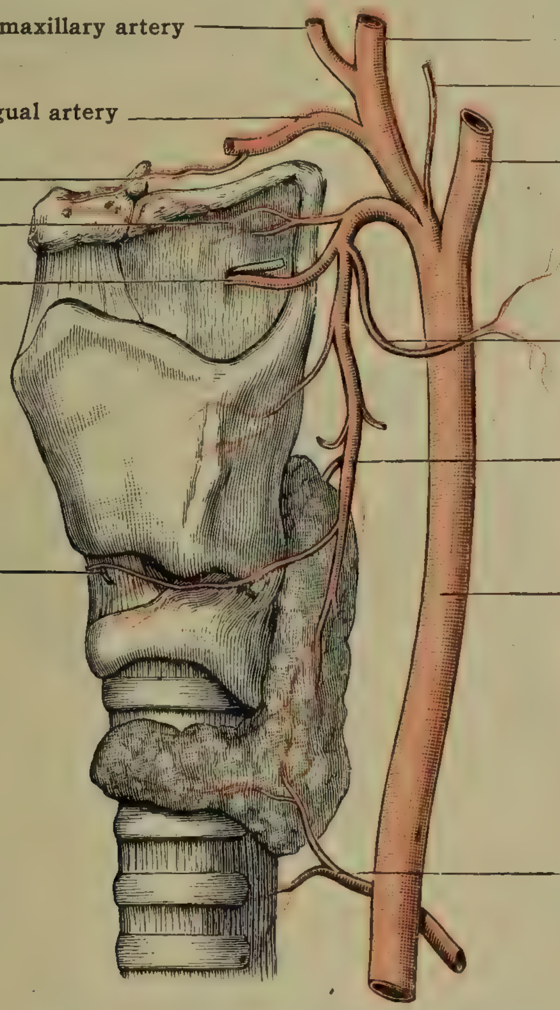


Fig. 527.—Scheme of Left Superior Thyroid Artery. (Walsham.)

done in a hurry to make the incision through the cricothyroid membrane in a transverse direction, and as near to the cricoid cartilage as possible.

(5) The **anterior** branch [r. anterior] is the larger of the terminal branches, supplying the isthmus and the neighboring part of the lateral lobe of the thyroid gland.

(6) The **posterior** branch [r. posterior], also terminal, but much smaller than the anterior, supplies the posterior part of the lateral lobe, and sends branches to the inferior constrictor of the pharynx and to the esophagus. It anastomoses with the ascending branches of the inferior thyroid artery.

(7) The **glandular** branches [rr. glandulares] are the ultimate twigs, arising from the anterior and posterior terminal branches, for the supply of the thyroid gland.

3. THE LINGUAL ARTERY

The **lingual** artery [a. lingualis] (fig. 528) arises from the front of the external carotid, between the superior thyroid and external maxillary (facial) arteries, often as a common trunk with the latter vessel, and nearly opposite or a little below the greater cornu of the hyoid bone. It may, for purposes of description, be divided into two portions: the **first,** or **oblique,** extends from its origin to the posterior edge of the hyoglossus muscle and the **second,** or **horizontal** portion, which lies medially to the hyoglossus and divides at the anterior border of that muscle into its two terminal branches, the sublingual and the deep lingual. The

first or oblique portion is situated in the superior carotid triangle, and is superficial, being covered merely by the integument, platysma, and deep fascia. Here it lies on the middle constrictor muscle and superior laryngeal nerve. After ascending a short distance, it curves downward and forward beneath the hypoglossal nerve, and, in the **second part of its course**, runs horizontally along the upper border of the hyoid bone, beneath the hyoglossus, by which it is separated from the hypoglossal nerve and its vena comitans, and the posterior belly of the digastric and the stylohyoid muscles. It lies successively on the middle constrictor of the pharynx and the genioglossus and is covered posteriorly by the hyoglossus muscle.

The lingual artery is most easily ligated in *Lesser's triangle*, which is found by the hypoglossal nerve above and the two bellies of the digastric muscle below.

Branches of the Lingual Artery

The named **branches of the lingual artery** are:—(1) The hyoid; (2) the dorsal lingual; (3) the sublingual; and (4) the deep lingual (ranine).

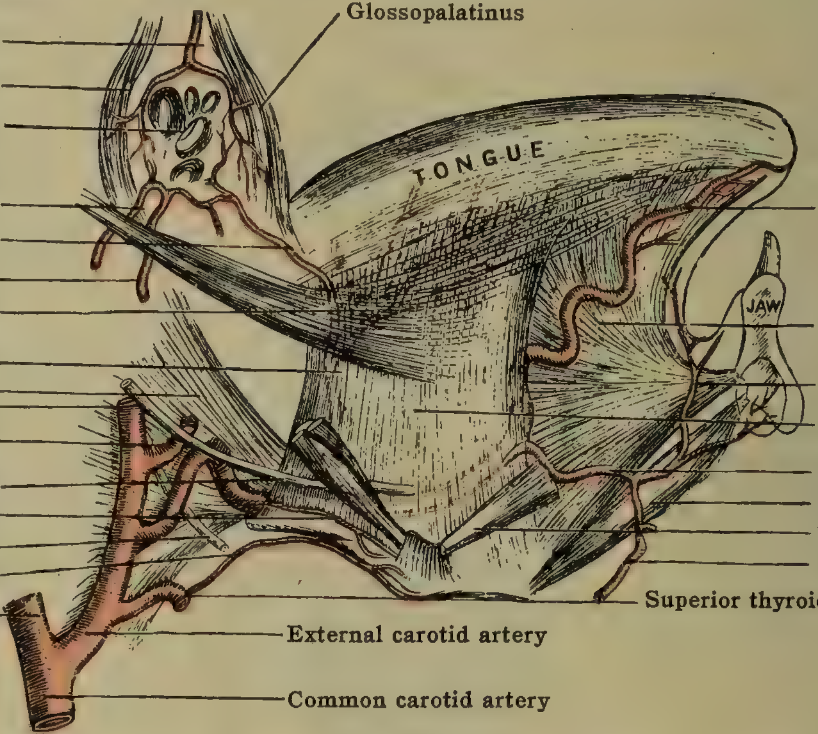


Fig. 528.—Scheme of the Right Lingual Artery. (Walsham.)

(1) The **hyoid** branch [r. hyoideus] (fig. 528) is a small vessel which arises from the first part of the lingual, and courses along the upper border of the hyoid bone, superficial to the hyoglossus, but beneath the insertion of the posterior belly of the digastric and the stylohyoid. It anastomoses with its fellow of the opposite side, and with the hyoid branch of the superior thyroid artery, and supplies the contiguous muscles.

(2) The a. **dorsalis linguæ** (fig. 528) arises from the second portion of the lingual artery, usually under cover of the posterior edge of the hyoglossus muscle. It ascends to the back of the dorsum of the tongue, and dividing into branches, supplies the mucous membrane on each side of the V formed by the vallate papillæ. It also supplies the palatine arches (pillars)and the tonsil, where it anastomoses with the other faucial and tonsillar arteries. Instead of a single artery, as above described, there may be several small vessels running directly to the parts mentioned. The artery anastomoses in the mucous membrane by very small branches with the vessel of the opposite side; but the anastomosis is so minute that when one lingual artery is injected the injection merely passes across to the opposite side at the tip of the tongue; and when the tongue is divided accurately in the middle line, as in the removal of one-half of that organ, practically no hemorrhage occurs.

(3) The **sublingual** artery [a. sublingualis] (fig. 528), one of the terminal branches, arises at the anterior margin of the hyoglossus. It passes beneath the mylohyoid to the sublingual gland, which it supplies, and finally it usually anastomoses with the submental artery, a branch of the external maxillary (facial). It also supplies branches to the side of the tongue, and gives off a terminal twig, which anastomoses beneath the mucous membrane of the floor of the mouth (to which it also gives twigs) with the artery of the opposite side. The **artery of the frenulum** is usually derived from this vessel (fig. 528).

(4) The **deep lingual** [a. profunda linguæ] or ranine artery, the other terminal branch of the lingual, courses forward beneath the mucous membrane, on the lower surface of the tongue, to the tip. It lies upon the lateral side of the genioglossus, between that muscle and the inferior lingualis, and is accompanied by the lingual vein and terminal branch of the lingual nerve. It follows a very tortuous course, so that it is not stretched when the tongue is protruded. Branches are given off from it to the contiguous muscles and mucous membrane. Near the tip of the tongue it communicates with its fellow of the opposite side.

4. THE EXTERNAL MAXILLARY (FACIAL) ARTERY

The **external maxillary** or **facial** artery [a. maxillaris externa] (a. facialis NK) (figs. 529, 533) arises immediately above the lingual from the fore part of the external carotid, sometimes in common with the lingual. It courses forward and upward in a tortuous manner to the mandible and, passing over the body of that bone at the anterior edge of the masseter muscle, winds obliquely upward and forward over the face to the medial angle of the eye, where it anastomoses, under the name of the **angular artery,** with the dorsal nasal branch of the ophthalmic. It is described as having two portions—the cervical and the facial.

The **cervical portion** (fig. 529) ascends tortuously from its origin from the external carotid upward and forward beneath the posterior belly of the digastric, the stylohyoid muscle and the hypoglossal nerve. Then, making a turn, it runs horizontally forward for a short way beneath the jaw, either imbedded in, or lying under the submaxillary gland with the mylohyoid and styloglossus muscles beneath it. On leaving the gland it loops first downward and then upward over the lower border of the jaw immediately in front of the masseter muscle, where it is covered only by the integument and platysma. The vein is separated from the artery by the submaxillary gland, the posterior belly of the digastric muscle, the stylohyoid muscle, and the hypoglossal nerve.

The **facial portion** (fig. 529) of the external maxillary artery ascends tortuously forward toward the angle of the mouth, passing under the platysma (risorius), the zygomatic muscle, the zygomatic head of the quadratus labii superioris (zygomaticus minor), and the zygomatic and buccal branches of the facial nerve. It here lies upon the jaw and the buccinator muscle. Thence it courses upward by the side of the nose toward the medial angle of the eye, passing under the infraorbital head of the quadratus labii superioris, and under the infraorbital branches of the facial nerve. It lies on the caninus (levator anguli oris) and the infraorbital branches of the fifth nerve and its termination is embedded in the angular head of the quadratus labii superioris. The anterior facial vein takes a straighter course than the external maxillary artery and is usually separated from the latter by the zygomatic muscle.

Clinical aspects.—The external maxillary artery crosses the mandible just in front of the masseter; if divided, both ends must be ligated here. It can be felt again a little behind the angle of the mouth, just beneath the mucous membrane (where it gives off the labial branches, which can also be felt, lying deeply, if the lip is taken between the finger and thumb); and again by the side of the nose, as it runs up to the medial angle (canthus) of the eye. The small angular branch is, from its position, always troublesome to secure. To trace the **course of the external maxillary** artery a line should be drawn from a point a little above and lateral to the tip of the great cornu of the hyoid to the lower part of the anterior border of the masseter, and thence to one lateral to and above the angle of the mouth, and so onward, lateral to the angle of the nose, up to the medial angle of the eye.

Branches of the External Maxillary Artery in the Neck

The **branches of the external maxillary artery in the neck** are:—(1) The ascending palatine; (2) the tonsillar; (3) the glandular; (4) the submental.

(1) The **ascending palatine** [a. palatine ascendens] (figs. 526, 529).—the first branch of the external maxillary, but often a distinct branch of the external carotid—ascends between the internal and external carotids, and then between the styloglossus and stylopharyngeus muscles, and on reaching the wall of the pharynx is continued upward between the superior constrictor and internal pterygoid muscles toward the base of the skull as high as the levator veli palatini, where it divides into two branches, a palatine and a tonsillar. One of these branches, the **palatine,** passes with the levator veli palatini over the curved upper margin of the superior constrictor to the soft palate. It anastomoses with its fellow of the opposite side and with the descending palatine branch of the internal maxillary, also with the ascending pharyngeal, which often to a great extent supplies the place of this artery. The other branch, the **tonsillar,** supplies the tonsil and the auditory (Eustachian) tube, anastomosing with the tonsillar branch of the external maxillary (facial) and ascending pharyngeal arteries. The ascending palatine artery supplies the muscles between which it runs on its way to the palate.

(2) The **tonsillar** branch [r. tonsillaris] (fig. 529) ascends between the styloglossus and internal pterygoid muscles to the level of the tonsil, where it perforates the superior constrictor muscle of the pharynx, and ends in the tonsil, anastomosing with the tonsillar branch of the ascending palatine and with the other tonsillar arteries fig. 528). It gives branches also to the root of the tongue.

The ascending palatine artery and the tonsillar tend to vary inversely in size, and either may be small or absent when the ascending pharyngeal is large. There is also a compensatory adjustment between the size of these three arteries and that of the minor palatine branches of the descending palatine.

(3) The **glandular** branches [rr. glandulares] are distributed to the submaxillary gland as the artery is passing through or beneath that structure. A small twig from one of these branches usually supplies the submaxillary (Wharton's) duct.

(4) The **submental** artery [a. submentalis] (fig. 529) comes from the external maxillary as the latter lies under cover of the submaxillary gland and, passing forward on the mylohyoid muscle between the base of the jaw and the anterior belly of the digastricus, supplies these structures and the overlying platysma and integuments. It anastomoses with the sublingual artery.

Branches of the External Maxillary Artery on the Face

From the **lateral** or **concave** side of the artery are given branches which supply the masseter muscle and anastomose with the masseteric and buccinator

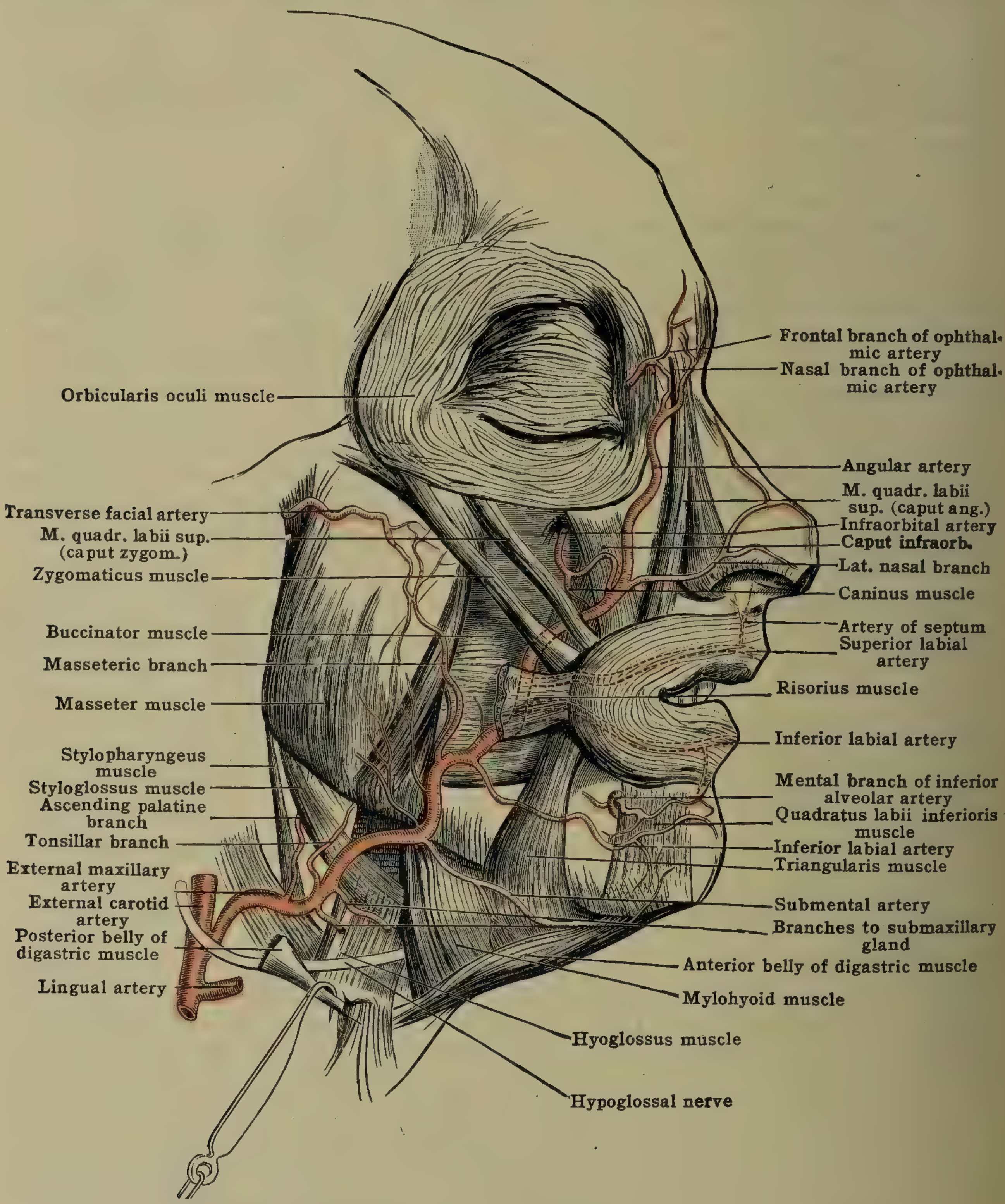


Fig. 529.—Right External Maxillary Artery and Branches. (Walsham.)

branches of the internal maxillary artery and with the transverse facial and infraorbital arteries.

From the **medial** or **convex** side the following larger and named vessels are given:—(1) The inferior labial; (2) the superior labial; and (3) the angular.

(1) The **inferior labial** artery [a. labialis inferior] arises at the angle of the mouth (fig. 533) and runs in the lower lip within the substance of the orbicularis oris, close to the mucous mem-

brane. It anastomoses with the artery of the other side. Frequently an additional branch sepass from the external maxillary to the lower lip.

(2 The **superior labial** artery [a. labialis superior] arising from the external maxillary higher than the inferior (fig. 533), passes forward beneath the zygomaticus, and then, like the inferior labial, courses tortuously along the lower margin of the upper lip between the orbicularis oris and the mucous membrane, about 1.2 cm. (½ in.) from the junction of the mucous membrane and the skin. It is usually larger than the inferior labial. It anastomoses with its fellow of the opposite side, and gives off a small artery to the septum—**arteria septi nasi.** Compression of this vessel will sometimes control hemorrhage from the nose.

(3) The **angular** artery [a. angularis] (fig. 529) is the terminal branch of the external maxillary. It supplies the nose and anastomoses at the medial angle of the eye with the dorsal nasal branch of the ophthalmic. It lies to the medial side of the lacrimal sac and supplies that structure and the lower part of the orbicularis oculi, beneath which a branch anastomoses with the infraorbital artery.

5. THE STERNOCLEIDOMASTOID ARTERY

The **sternocleidomastoid** artery [a. sternocleidomastoidea] arises from the posterior side of the external carotid at the point where the carotid is crossed by the digastric muscle. It hooks over the loop formed by the hypoglossal nerve and follows the accessory nerve into the sternocleidomastoid muscle. It is frequently a branch of the occipital artery.

6. THE OCCIPITAL ARTERY

The **occipital** artery [a. occipitalis] (fig. 530) is usually a vessel of considerable size. It comes off from the posterior part of the external carotid opposite the external maxillary (facial), or else a little higher than that vessel. It then winds upward and backward to the interval between the mastoid process of the temporal bone and transverse process of the atlas, and, after running horizontally backward in a groove on the mastoid portion of the temporal bone, again turns upward, and ends by ramifying in the scalp over the back of the skull, extending as far forward as the vertex.

The vessel may be divided into three parts—viz., that anterior to the sternomastoid muscle; that beneath the sternomastoid; and that posterior to the sternomastoid.

In the **first part of its course** the occipital artery is covered by the integument and fascia, and is more or less overlapped by the posterior belly of the digastric muscle, the parotid gland, and posterior facial (temporomaxillary) vein. It is crossed by the hypoglossal nerve as the latter winds forward over the carotid vessels to reach the tongue. It successively crosses in front of the internal carotid artery, the hypoglossal nerve, the vagus nerve, the internal jugular vein and the accessory nerve.

In the **second part of its course** it sinks deeply beneath the digastric muscle into the interval between the mastoid process of the temporal bone and the transverse process of the atlas. It is here covered by the sternomastoid, splenius capitis, and longissimus capitis muscles and by the origin of the digastric; and lies, first on the rectus capitis lateralis, which separates it from the vertebral artery, then in a groove, the occipital groove, on the mastoid portion of the temporal bone, and then on the insertion of the superior oblique muscle.

In the **third part of its course** it enters the triangular interval formed by the diverging borders of the splenius capitis and the superior nuchal line of the occipital bone. Here it lies beneath the integuments and the aponeurosis uniting the occipital attachments of the sternomastoid and trapezius, and rests upon the semispinalis capitis (complexus) just before the insertion of that muscle into the occipital bone. In company with the greater occipital nerve, it perforates the aponeurosis, or less often the posterior belly of the epicranius (occipitofrontalis), and follows roughly, but in a tortuous course, the line of the lambdoid suture, lying between the integument and the cranial aponeurosis. In the scalp it divides into several large branches, which ramify over the back of the skull and reach as far forward as the vertex. They anastomose with the corresponding branches of the opposite side, and with the posterior auricular and the superficial temporal arteries.

Branches of the Occipital Artery (Fig. 530)

The **branches of the occipital artery** are:—(1) The muscular; (2) the meningeal; (3) the auricular; (4) the mastoid; (5) the descending; (6) the occipital.

(1) The **muscular** branches [rr. musculares] (fig. 530) supply the sternocleidomastoid and adjacent muscles. One of these branches may take the place of the sternomastoid branch of the external carotid. The hypoglossal nerve then loops around it, and not, as a rule, around the occipital.

(2) The **meningeal** branches [rr. meningei] (fig. 532), one or more in number, are long slender vessels which leave the occipital artery as it crosses the internal jugular vein and, ascend with it through the jugular or hypoglossal foramen, and are distributed to the dura mater lining the posterior fossa of the skull.

(3) The **auricular** branch [r. auricularis] ascends over the mastoid process to the back of the ear, and supplies the auricle. It sometimes takes the place of the posterior auricular artery (fig. 530).

(4) The **mastoid** branch [r. mastoideus] is a small twig that passes into the skull through the mastoid foramen, supplying the dura mater, the diploë, the walls of the transverse sinus, and the mastoid cells.

(5) The **descending** or **princeps cervicis** [r. descendens] (fig. 530), the largest of the branches of the occipital, arises from that artery just before it emerges from beneath the splenius, and, descending for a short distance between the splenius and semispinalis capitis (complexus), divides into a superficial and a deep branch. The **superficial branch** perforates the splenius, supplies branches to the trapezius, and anastomoses with the ascending branch of the transverse cervical artery. The **deep branch** passes downward between the semispinalis capitis (complexus) and colli, and anastomoses with the deep cervical branch of the costocervical

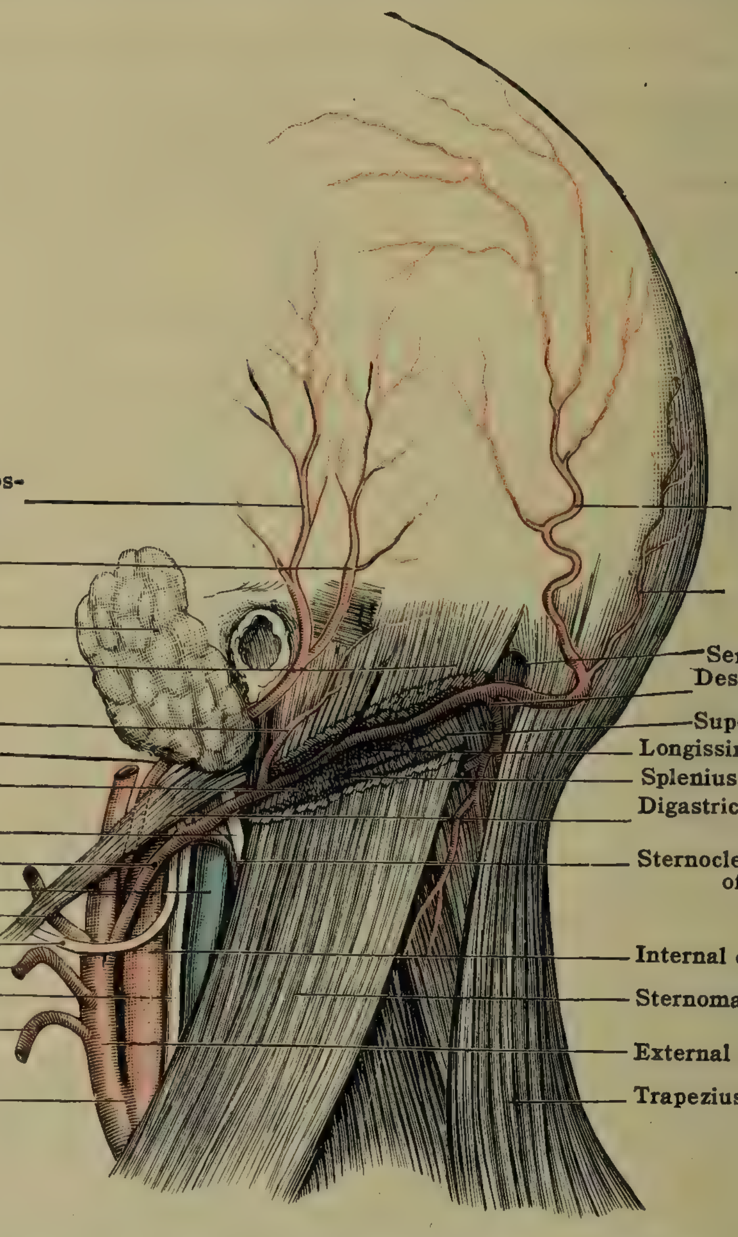


Fig. 530.—Left Occipital and Posterior Auricular Arteries. (Walsham.)

trunk and with branches of the vertebral. The anastomoses between the above-mentioned arteries form important collateral channels after ligature of the common carotid and subclavian arteries (fig. 525).

(6) The **occipital** or **terminal** branches [rr. occipitales] (fig. 530), usually two in number, named from their position medial and lateral, ramify over the scalp, and have already been described. The medial branch generally gives a twig which enters the parietal foramen (parietal artery) and is distributed to the dura mater. The occipital artery may also give off the stylomastoid, the posterior auricular, or the ascending pharyngeal arteries.

7. THE POSTERIOR AURICULAR ARTERY

The **posterior auricular** artery [a. auricularis posterior] (a. retroauricularis NK) (fig. 530) arises from the posterior part of the external carotid artery, usually immediately above the posterior belly of the digastric, about the level of the tip of the styloid process. Occasionally it arises under cover of the digastric, quite close to, or as a common trunk with, or as a branch of, the occipital. It courses upward and backward in the parotid gland to the notch between the margin of the external acoustic meatus and the mastoid process, where it divides

into branches. In this course it rests on the styloid process, crosses the accessory nerve, and is crossed by the facial nerve.

Branches of the Posterior Auricular Artery

The **branches of the posterior auricular artery** are:—(1) the stylomastoid; (2) the auricular; (3) the occipital (fig. 530).

The posterior auricular also gives branches to the parotid gland and to the posterior belly of the digastric, the stylohyoid, and auricularis posterior (retrahens aurem) muscles.

(1) The **stylomastoid** artery [a. stylomastoidea] follows the facial nerve through the stylomastoid foramen into the tympanic cavity. In the facial canal it gives origin to **mastoid** branches (rr. mastoidei) to the mastoid cells and a branch (r. stapedius) to the stapedius muscle and tendon. At the iter chordæ posterius, it gives the **posterior tympanic** artery [a. tympanica posterior]. This artery follows the chorda tympani nerve and gives branches to the posterior part of the tympanic membrane which anastomose with the anterior tympanic artery, a branch of the internal maxillary. It then ramifies on the promontery, giving branches to the stapes and to the secondary tympanic membrane, and ends by anastomosing with the superior tympanic artery from the middle meningeal, with the anterior tympanic branch of the internal maxillary, and with the caroticotympanic branch of the internal carotid.

(2) The **auricular** branch [r. auricularis] passes upward behind the ear and beneath the auricularis posterior (retrahens aurem), supplying the medial surface of the auricle and adjacent skin. It anastomoses with the posterior branch of the superficial temporal artery. The branches to the auricle not only supply the back of that structure, but some perforate the cartilage, and others turn over its free margin to supply the lateral surface; there they anastomose with the anterior auricular branches from the temporal.

(3) The **occipital** branch [r. occipitalis] passes upward and backward, crossing the aponeurotic insertion of the sternomastoid muscle. It gives a branch to the posterior belly of the epicranius (occipitofrontalis), and anastomoses with the occipital artery.

8. THE SUPERFICIAL TEMPORAL ARTERY

The **superficial temporal** artery [a. temporalis superficialis] (fig. 524), is the smaller of the two terminal divisions of the external carotid, though apparently the direct continuation of that vessel. It arises opposite the neck of the mandible and, under cover of the parotid gland, passes upward in the interval between the condyle and the external acoustic meatus to the zygoma, lying on the capsule of the temporomandibular joint. Thence it ascends over the posterior zygomatic root and the temporal aponeurosis for about 4 or 5 cm. (1½ or 2 in.), and there divides into frontal and parietal branches. It is surrounded by a dense plexus of sympathetic nerves, and is accompanied by the auriculotemporal nerve, which lies beneath and generally a little behind it. It is crossed by the temporal and zygomatic branches of the facial nerve, and by the auricularis anterior (attrahens aurem) muscle. As it crosses the zygoma it can be readily felt pulsating immediately in front of the auricle, and in this situation can be compressed against the bone. It is here quite superficial, being merely covered by the integuments and a delicate prolongation from the cervical fascia (fig. 524).

Branches of the Superficial Temporal Artery

The **branches of the superficial temporal** artery are:—(1) The parotid; (2) the transverse facial; (3) the anterior auricular; (4) the zygomatico-orbital; (5) the middle temporal; (6) the frontal; (7) the parietal.

(1) The **parotid** branches [rr. parotidei] are small twigs arising in the substance of the parotid gland.

(2) The **transverse facial** [a. transversa faciei] is the largest branch of the temporal. It sometimes arises from the external carotid as a common trunk with the temporal. It is at first deeply seated in the substance of the parotid gland, but soon emerging from the upper part of the anterior border of the gland, courses transversely across the masseter muscle about a finger's breadth below the zygoma. The parotid duct runs below it, and the zygomatic (infraorbital) branches of the facial nerve about it. It supplies the parotid gland, the masseter muscle, and the skin of the face, and anastomoses with the infraorbital, the buccal, and the external maxillary (facial) arteries.

(3) The **anterior auricular** branches [rr. auriculares anteriores] (rr. praeauriculares NK) are three or four in number and supply the tragus, the pinna, and the lobule of the ear, and to some extent the external acoustic meatus.

(4) The **zygomatico-orbital** artery [a. zygomaticoorbitalis] (fig. 537), in some cases a branch of the deep temporal, passes forward along the upper border of the zygoma in the fat between the superficial and deep layers of the temporal aponeurosis and, after giving branches to the orbicularis oculi, sends one or more twigs into the orbit through foramina in the aygomatic (malar) bone to anatomose with the lacrimal and palpebral branches of the ophthalmic.

(5) The **middle temporal** artery [a. temporalis media] (fig. 533), arises just above the zygoma, and, perforating the temporal aponeurosis and temporal muscle, ascends on the squa-

mous portion of the temporal bone, and anastomoses with the posterior deep temporal artery.

(6) The **frontal** or **anterior terminal** branch [r. frontalis] ramifies tortuously in an upward and forward direction over the front part of the skull. It lies first between the skin and temporal fascia and then between the skin and epicranial aponeurosis. It supplies the anterior belly fo the epicranius (occipitofrontalis) and the orbicularis oculi muscles, and anastomoses with the supraorbital and frontal branches of the ophthalmic and with the corresponding artery of the opposite side. The secondary branches given off from this vessel to the scalp run from bfeore backward.

(7) The **parietal** or **posterior terminal** branch [r. parietalis] ramifies on the side of the head between the skin and temporal fascia. Its branches anastomose in front with the anterior terminal branch; behind with the posterior auricular and occipital arteries and above, across the vertex of the skull, with the corresponding artery of the opposite side.

The arteries of the scalp include the terminal branches of the superficial temporal, together with those of the supraorbital and frontal arteries anteriorly and the posterior auricular and

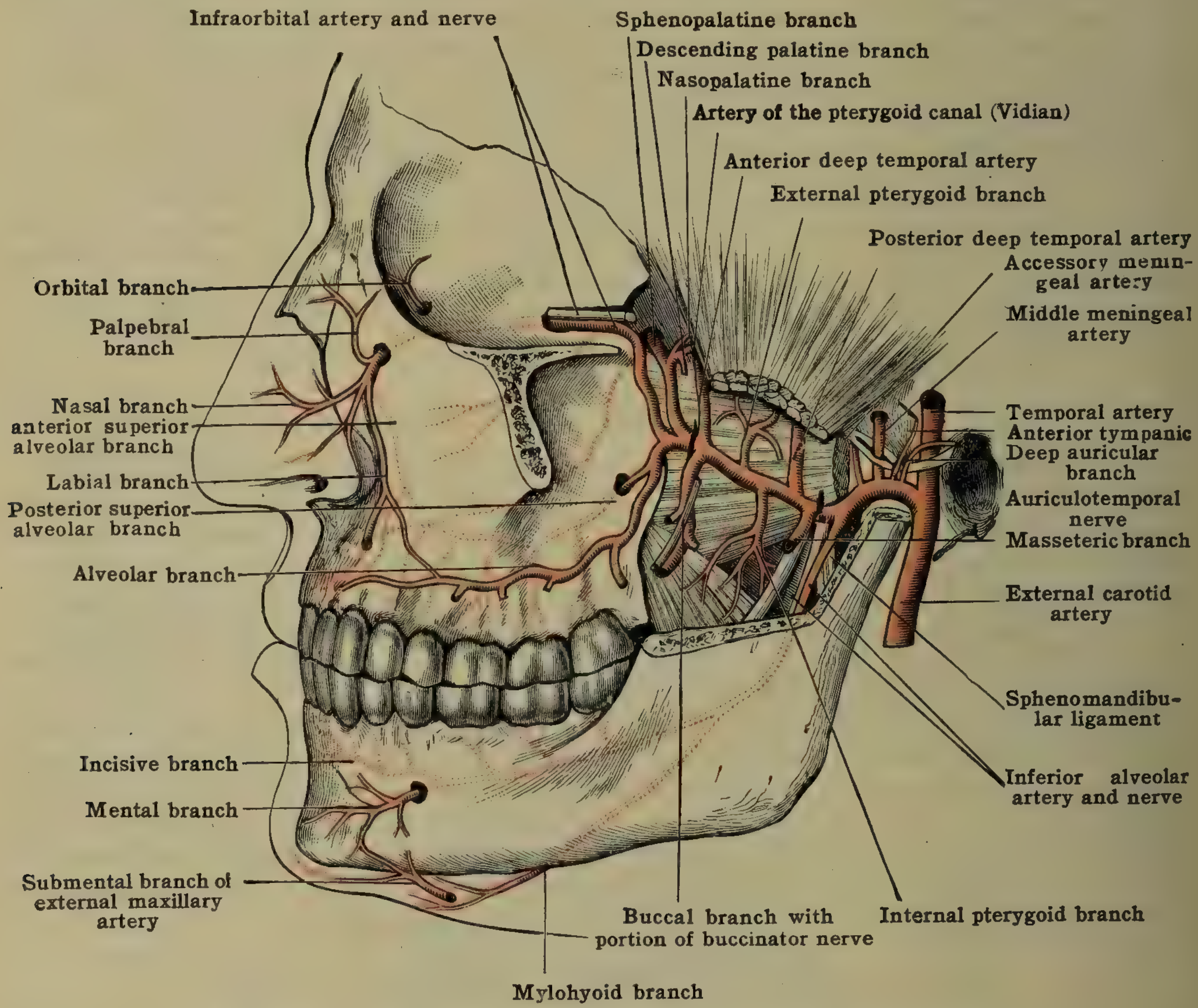


Fig. 531.—Left Internal Maxillary Artery. (Walsham.)

occipital arteries posteriorly. These vessels are peculiar in their location superficial to the deep fascia, which in the scalp is represented by the epicranial aponeurosis. On account of this position of the vessels, a large flap of scalp may be detached above without perishing, as it carries its own vascular supply. From the density of the subcutaneous layer in which the vessels run, they cannot collapse and bleed freely, being difficult to ligate. Finally, on account of their position over adjacent bone, ill-applied pressure may lead to sloughing.

9. THE INTERNAL MAXILLARY ARTERY

The **internal maxillary** artery [a. maxillaris interna] (a. maxillaris NK) (fig. 531) is the larger of the two terminal divisions of the external carotid. It arises opposite the neck of the mandible in the substance of the parotid gland, and, passes forward, between the mandible and the sphenomandibular ligament and then in contact with the external pterygoid muscle, between the heads of origin of which it sinks deeply into the pterygopalatine (sphenomaxillary) fossa, and there breaks up into its terminal branches. It is divided for description into three portions: mandibular, pterygoid, and pterygopalatine.

(1) In the **first part of its course** (the **mandibular portion**) the artery lies between the neck of the mandible and the sphenomandibular ligament, taking a horizontal course forward, nearly parallel to and a little below the auriculo-

temporal nerve and the external pterygoid muscle. It is here embedded in the parotid gland, and usually crosses in front of the inferior alveolar (dental) nerve.

(2) In the **second part of its course** (the **pterygoid portion**) the artery may lie laterally or medially to the external pterygoid muscle. In the first case it passes between the two pterygoid muscles and the ramus of the jaw, and then turns upward over the lateral surface of the external pterygoid, medial to the temporal muscle, to reach the interval between the two heads of the external pterygoid, and sinks into the pterygopalatine fossa. In the second case it is covered by the external pterygoid muscle till it reaches the interval between its two heads, where, forming a projecting loop, it turns into the pterygopalatine fossa.

(3) In the **third part of its course** (the **pterygopalatine portion**) the artery lies in the pterygopalatine fossa beneath the maxillary division of the fifth nerve and in close relationship with the sphenopalatine (Meckel's) ganglion, and there breaks up into its terminal branches.

Branches of the Internal Maxillary Artery

The **branches of the internal maxillary artery** are:—

(A) **From the first part**:—(1) The deep auricular; (2) the anterior tympanic; (3) the middle meningeal; (4) the inferior alveolar (dental); (5) the accessory miningeal (sometimes). All these vessels pass through bony or cartilaginous canals.

(B) **From the second part**:—(1) The masseteric; (2) the posterior deep temporal; (3) the pterygoid; (4) the buccal; and (5) the anterior deep temporal. All these branches supply muscles.

(C) **From the third part**:—(1) The posterior superior alveolar (dental); (2) the infraorbital; (3) the descending palatine; (4) the a. canalis pterygoidei or Vidian; and (5) the sphenopalatine. All these branches pass through bony canals.

Branches of the First Part of the Internal Maxillary Artery

(1) The **deep auricular** artery [a. auricularis profunda] (fig. 531) passes upward in the substance of the parotid gland behind the capsule of the temporomandibular joint, and, perforating the bony or cartilaginous wall of the external acoustic meatus, supplies the skin of that passage and the membrana tympani. It gives a branch to the joint as it passes behind the temporomandibular articular capsule.

(2) The **anterior tympanic** artery [a. tympanica anterior] (a. tympanica maxillaris NK) is a long slender vessel, which runs upward behind the condyle of the jaw to the petrotympanic (Glaserian) fissure, through which it passes to the interior of the tympanum. Here it supplies the lining membrane of that cavity and anastomoses with the other tympanic arteries, forming with the posterior tympanic artery, from the stylomastoid artery a vascular circle around the membrana tympani. This circle is more distinct in the fetus than in the adult.

(3) The **middle meningeal** artery [a. meningea media] (a. meningea temporalis NK) is the largest branch of the internal maxillary artery. It arises between the sphenomandibular ligament and the ramus of the jaw, and under cover of the external pterygoid passes directly upward through the foramen spinosum into the cranium, accompanied by two veins and by filaments of the sympathetic nerve. In this part of its course it is crossed by the chorda tympani nerve; just before it enters the foramen is embraced by the two heads of origin of the auriculotemporal nerve (fig. 531). On entering the skull it ramifies between the bone and dura mater, supplying both structures. It at first ascends for a short distance in a groove on the greater wing of the sphenoid, and then divides into two branches, an anterior and a posterior, both accompanied by venous sinuses.

The **anterior branch** passes upward, in the groove on the greater wing of the sphenoid, on to the parietal bone at its anterior and inferior angle; here the groove becomes deepened and often bridged over by a thin plate of bone, being converted for 6 to 12 mm. (¼ to ½ in.) or more into a distinct canal. The situation of this part of the artery is indicated on the exterior of the skull by a spot 3.7 cm. (1½ in.) behind, and about 2.5 cm. (1 in.) above, the zygomatic process of the frontal bone. The anterior branch continues along the anterior border of the parietal bone nearly as far as the superior sagittal sinus, and gives in its course, but especially posteriorly, large branches which ramify in an upward and backward direction in grooves on the parietal bone (fig. 532). When near the lateral end of the superior orbital fissure, it gives an **orbital** or **lacrimal** branch, which enters the orbit at the outermost part of that fissure, or sometimes through a minute foramen, just lateral to it and anastomoses with the lacrimal branch of the ophthalmic.

The **posterior branch** passes backward over the squamous portion of the temporal bone; and thence on to the parietal bone, behind the anterior branch. This branch and its collaterals extend upward as far as the sagittal sinus, and backward as far as the transverse (lateral) sinus.

In addition to its terminal anterior, and terminal posterior branches, the middle meningeal gives off:—(*a*) **Ganglionic** branches to the semilunar (Gasserian) ganglion and its sheath of

dura mater. (*b*) A **superficial petrosal** branch [r. petrosus superficialis], which enters the hiatus of the facial canal in company with the large superficial petrosal nerve and anastomoses with the terminal branch of the stylomastoid artery. (*c*) A **superior tympanic** artery [a. tympanica superior], which enters the tympanum through the petrosquamous fissure and anastomoses with the other tympanic arteries. (*d*) **Anastomotic** or **perforating** branches which pierce the greater wing of the sphenoid bone, and anastomose with the deep temporal arteries.

(4) The **inferior alveolar** artery [a. alveolaris inferior] (a. alveolaris mandibularis NK) (fig. 531), arising from the internal maxillary as it lies between the sphenomandibular ligament and neck of the jaw, courses downward to the mandibular foramen, which it enters in company with, and a little behind and lateral to, the inferior alveolar nerve. It then passes along the canal in the interior of the bone, giving off branches to the molar, premolar, and canine teeth. On reaching the mental foramen it divides into two branches, the incisive and the mental. The incisive continues its course in the bone, supplies branches to the incisor teeth, and anastomoses with the artery of the opposite side. The **mental** branch [r. mentalis] passes through the mental foramen in company with the mental branch of the inferior alveolar nerve, and emerges on the chin under cover of the quadratus labii inferioris. It anastomoses above with the inferior labial (coronary) artery and below with the submental. Near its origin the artery gives off (*a*) a **lingual** or **gustatory** branch which accompanies and supplies the lingual nerve, and ends

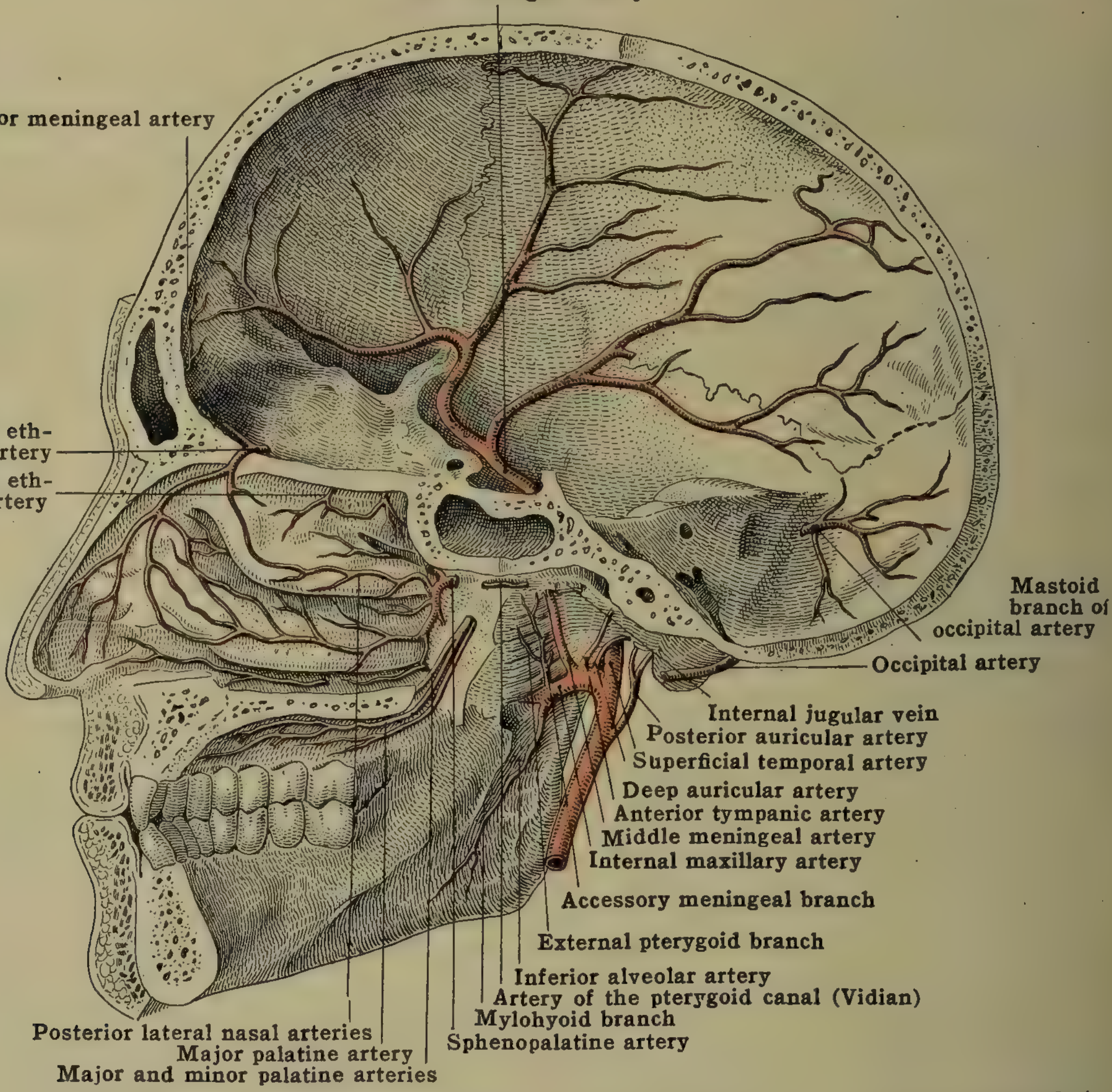


Fig. 532.—The Middle Meningeal Artery within the Skull. (After Spalteholz.)

in the mucous membrane of the mouth; and, just before it enters the mandibular foramen, a (*b*) **mylohyoid** branch [r. mylohyoideus], which accompanies the nerve of that name along the groove in the mandible and after supplying the mylohyoid muscle, anastomoses with the sublingual and submental arteries.

(5) The **accessory or small meningeal** branch [r. meningeus accessorius] arises either from the internal maxillary a little in front of the middle meningeal, or as a branch of the latter vessel. It passes upward along the course of the mandibular division of the fifth nerve, and, entering the skull through the foramen ovale, is distributed to the semilunar (Gasserian) ganglion, to the walls of the cavernous sinus and to the dura mater in the neighborhood.

Branches of the Second Part of the Internal Maxillary Artery

The branches of the second portion of the internal maxillary all supply muscles. They are:—(1) The masseteric; (2) the posterior deep temporal; (3) the pterygoid; (4) the buccal; and (5) the anterior deep temporal

(1) The **masseteric** artery [a. masseterica] comes from the internal maxillary as the latter is passing from between the neck of the jaw and the sphenomandibular ligament. It passes.

with the masseteric nerve through the mandibular (sigmoid) notch in the mandible and supplies the masseter muscle. Some filaments perforate the muscle and anastomose with the transverse facial and with the masseteric branches of the external maxillary (facial).

(2) The **posterior deep temporal** artery [a. temporalis profunda posterior] (a.t.p. aboralis NK) arises, as a rule, from the internal maxillary in common with the masseteric, or a little beyond that branch. It passes upward beneath the temporal muscle in a slight groove on the anterior margin of the squamous portion of the temporal bone, supplying the temporal muscle, the pericranium and the external layer of the bone. It anastomoses with the other temporal arteries.

(3) The **pterygoid** branches [rr. pterygoidei] are short trunks which pass into and supply the internal and external pterygoid muscles.

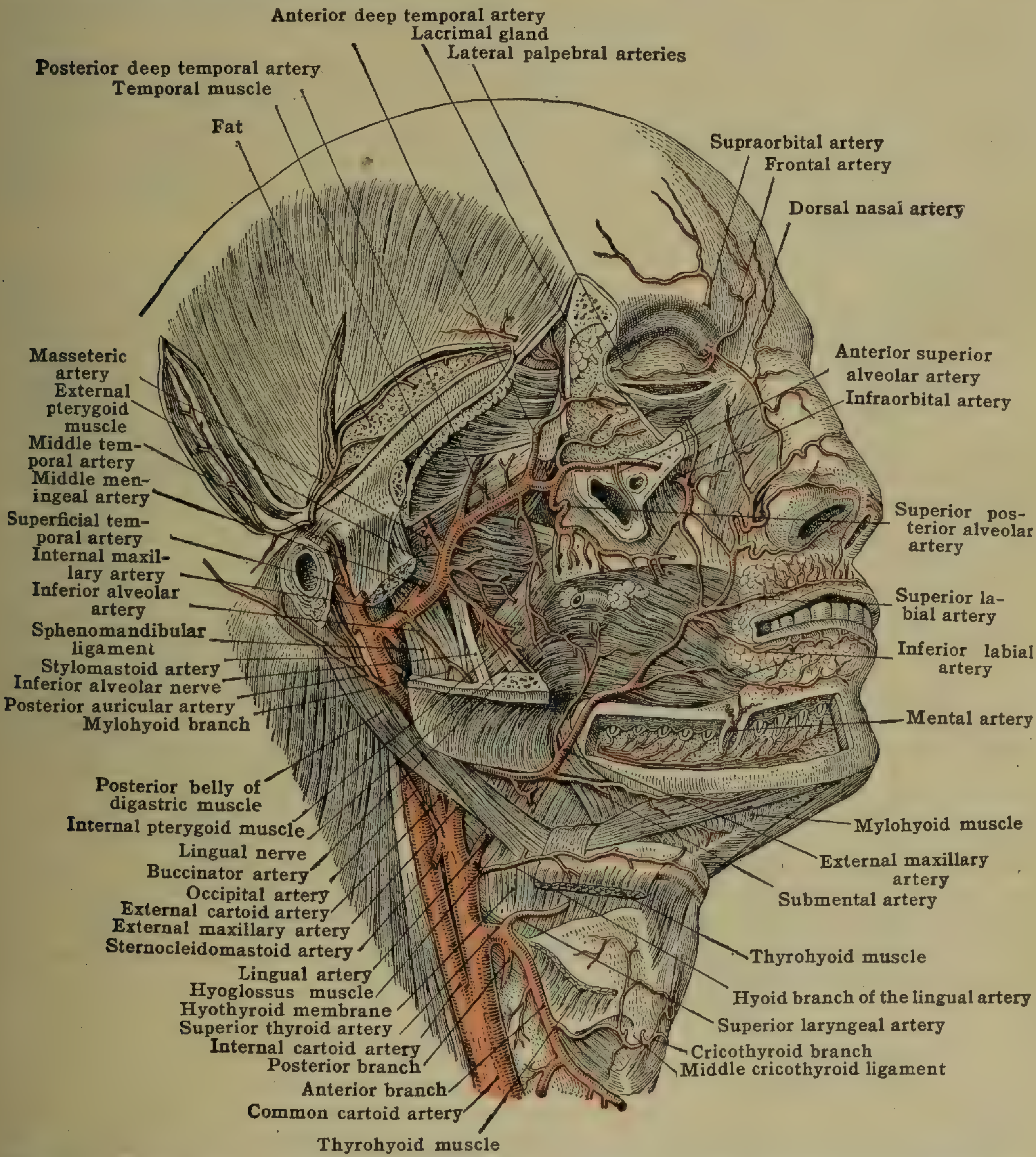


FIG. 533.—THE CAROTID ARTERIES. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

(4) The **buccal** artery [a. buccinatoria] (fig. 533) courses forward and downward with the buccal nerve to the buccinator muscle, lying in close contact with the medial side and anterior margin of the tendon of the temporal muscle and coronoid of the lower jaw. It supplies the buccinator muscle and mucous membrane of the mouth, and anastomoses with the external maxillary (facial), transverse facial, and infraorbital arteries.

(5) The **anterior deep temporal** artery [a. temporalis profunda anterior] (a.t.p. oralis NK) ascends beneath the temporal muscle in a slight groove on the greater wing of the sphenoid bone. It supplies the muscle, pericranium, and subjacent bone, and gives small branches through minute foramina in the zygomatic (malar) bone. Some of these last branches enter the orbit and anastomose with the lacrimal artery; others emerge on the face and anastomose with the transverse facial artery.

BRANCHES OF THE THIRD PART OF THE INTERNAL MAXILLARY ARTERY

The branches of the third part of the internal maxillary artery, like those of the first part, all pass through bony canals. They are the following:—(1) The posterior superior alveolar

(dental); (2) the infraorbital; (3) the descending palatine; (4) the artery of the pterygoid canal (Vidian); and (5) the sphenopalatine.

(1) The **posterior superior alveolar (dental)** artery [a. alveolaris superior posterior] (a. a. maxillaris aboralis NK) arises from the internal maxillary as the latter is passing into the pterygopalatine (sphenomaxillary) fossa, and descends in a tortuous manner in a groove on the back of the body of the maxilla. It gives off branches to the maxillary sinus, to the molar and premolar teeth, the gums, and to the buccinator muscle.

(2) The **infraorbital** artery [a. infraorbitalis] arises from the internal maxillary, generally as a common trunk with posterior alveolar (dental). It then passes forward and a little upward through the pterygopalatine (sphenomaxillary) fossa; then forward in company with the infraorbital branch of the fifth nerve, first along the groove, and then through the canal in the orbital plate of the maxilla; and finally, emerging on the face at the infraorbital foramen, under cover of the quadratus labii superioris, is distributed to the structures forming the upper lip, the lower eyelid, the lacrimal sac, and the side of the nose. It anastomoses with the superior labial (coronary) and angular branches of the external maxillary (facial), with the nasal and lacrimal branches of the ophthalmic, and with the transverse facial. It gives off small branches supplying the fat of the orbit and the inferior rectus and inferior oblique muscles. The **anterior superior alveolar** branch [a. alveolaris superior anterior] (a. a. maxillaris oralis NK) passes downward through a groove in the anterior wall of the maxilla, together with the anterior alveolar branch of the infraorbital nerve, and supplies branches to the incisor and canine teeth and the mucous membrane of the maxillary sinus. It has also **nasal** branches which pass through the foramina in the nasal process of the maxilla.

(3) The **descending palatine** artery [a. palatina descendens] descends in the pterygopalatine canal with the anterior palatine branch of the sphenopalatine ganglion. On emerging on the palate at the greater (posterior) palatine foramen, it divides into the following branches— (*a*) The **major palatine** artery [a. palatina major], which courses forward in the mucoperiosteum at the junction of the hard palate with the alveolar process as far as the incisive (anterior palatine) foramen, where it anastomoses with the sphenopalatine artery; and (*b*) **minor palatine** arteries [aa. palatinæ minores], which pass backward and downward into the soft palate, contributing to the supply of that structure, and anastomosing with the ascending palatine artery, the tonsillar and the ascending pharyngeal. After the operation for cleft palate, serious hemorrhage occasionally occurs from the major palatine artery. The foramen is situated a little behind, and medial to, the last molar tooth, and almost immediately in front of the hamular process (fig. 532).

4) The **arteria canalis pterygoidei or Vidian** artery is a long slender branch which passes backward through the pterygoid (Vidian) canal in company with the nerve of the same name into the cartilage of the lacerated foramen. It gives off branches which supply the roof of the pharynx, and anastomose with the ascending pharyngeal and sphenopalatine arteries; also a branch which is distributed to the auditory (Eustachian) tube; and one which enters the tympanum, and anastomoses with the other tympanic arteries.

(5) The **sphenopalatine** [a. sphenopalatina], the terminal branch of the internal maxillary, passes with the nasopalatine branch of the sphenopalatine ganglion from the pterygopalatine (sphenomaxillary) fossa into the nose through the sphenopalatine foramen. Crossing the roof of the nose in the mucoperiosteum, it passes to the septum, and runs forward and downward in a groove on the vomer toward the incisive (anterior palatine) foramen, where it anastomoses with the major palatine artery, which enters the nose through the lateral compartment of that foramen (the canal of Stenson). In this course it gives branches to the roof and contiguous portions of the pharynx, and to the sphenoidal cells. It gives also the **posterior lateral nasal** arteries [aa. nasales post. laterales], which ramify over the nasal conchæ (turbinate bones) and lateral walls of the nose, and give twigs to the ethmoidal and frontal sinuses and the lining membrane of the maxillary sinus; and the **posterior septal** arteries [aa. nasales post. septi], which run upward and forward, giving small twigs to the mucous membrane covering the upper part of the septum, and which pass through the cribriform plate of the ethmoid and anastomose with the ethmoidal arteries (perforating or meningeal branches).

THE INTERNAL CAROTID ARTERY

The **internal carotid** artery [a. carotis interna] (figs. 533 and 534) arises with the external carotid at the bifurcation of the common carotid, opposite the upper border of the thyroid cartilage, on a level with the fourth cervical vertebra. It is at first placed a little laterally to the external carotid, but as it ascends in the neck it lies medially and slightly posteriorly to the external carotid. The internal carotid passes up the neck, in front of the transverse processes of the upper cervial vertebræ, lying upon the longus capitis (rectus capitis ant. major), to the carotid foramen, thence through the carotid canal in the petrous portion of the temporal bone. It makes at first a forward and medial turn and then a second turn upward, above the cartilage occupying the foramen lacerum. Within the cranium, it makes a sigmoid curve on the side of the body of the sphenoid bone, and terminates, after perforating the dura mater, by dividing opposite the anterior clinoid process, in the lateral fissure (fissure of Sylvius), into the anterior and middle cerebral arteries. For the so-called 'carotid sinus,' see p. 1026.

In its course up the neck it often forms one or more curves, especially in old people. Between the internal and the external carotids, at their angle of divergence, is situated the **carotid body** or gland [glomus caroticum].

1. The Cervical Portion

Relations.—In the neck (fig. 533) the artery is at first comparatively superficial, having laterally to it, as it lies in the superior carotid triangle, the skin, superficial fascia, platysma and deep fascia, and the overlapping edge of the sternomastoid muscle. As it ascends, it becomes deeply placed, beneath the internal jugular vein and the parotid gland. It is crossed by the posterior belly of the digastric and stylohyoid muscles, the hypoglossal nerve, and the occipital and posterior auricular arteries. Still higher it is separated anteriorly from the external carotid artery by the stylopharyngeus muscle, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, and by the stylohyoid ligament.

Behind, it lies upon the longus capitis (rectus capitis anticus major), which separates it from the transverse processes of the three upper cervical vertebræ, on the superior cervical ganglion of the sympathetic nerve, and on the vagus nerve. Near the base of the skull, the hypoglossal, vagus, glossopharyngeal, and accessory nerves cross obliquely behind it, and separate it from the internal jugular vein, which, as the artery is about to enter the carotid canal, also forms one of its posterior relations.

On its **medial side** it is in relation with the pharynx, the superior constrictor muscle separating it from the tonsil. The ascending pharyngeal and ascending palatine arteries, and the auditory (Eustachian) tube and levator veli palatini muscles, are also medial to it.

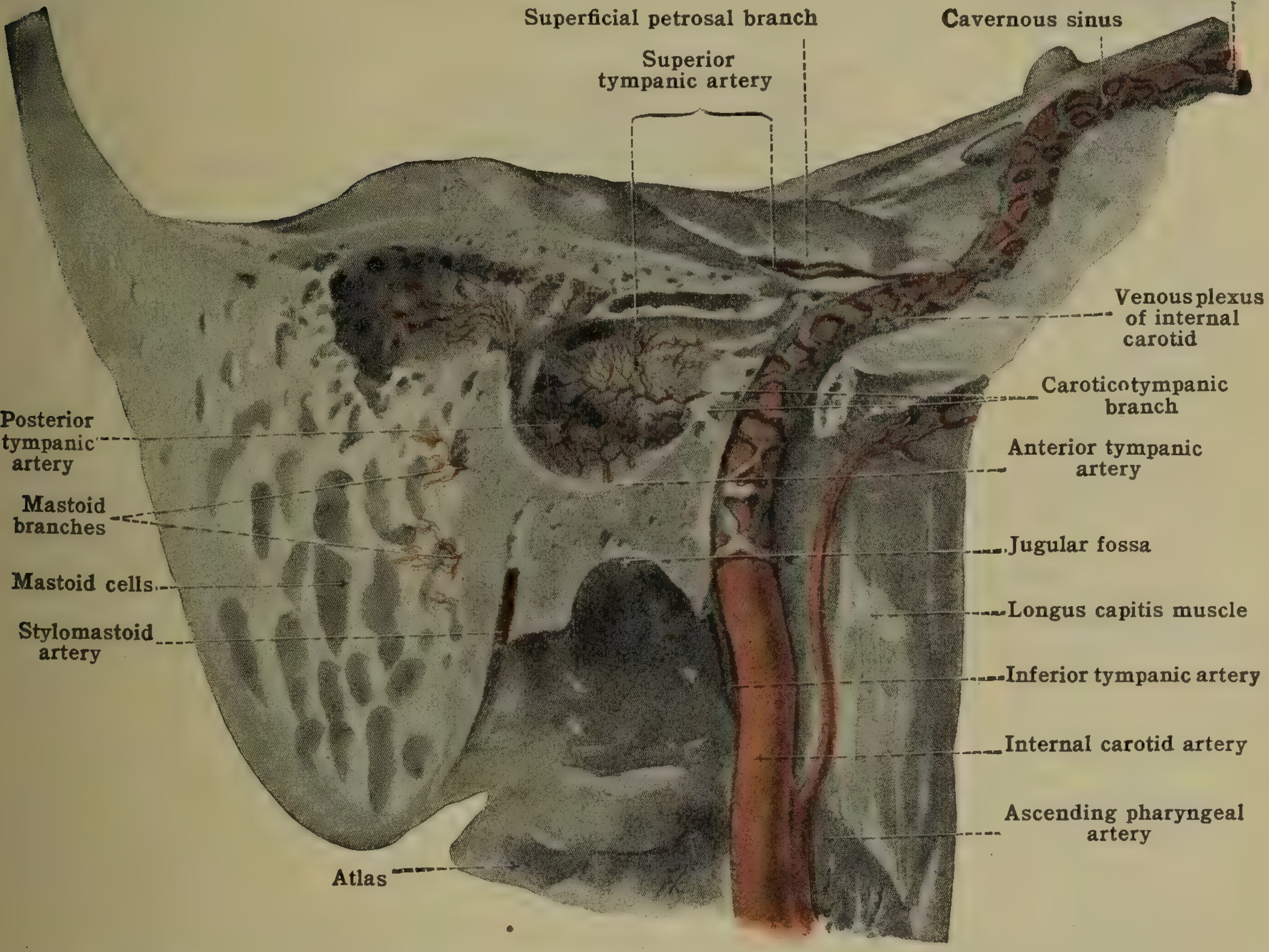


Fig. 534.—The Internal Carotid Artery in the Canal. (After Spalteholz.)

2. The Petrosal Portion

The **petrosal portion** (fig. 534) is situated in the carotid canal in the petrous portion of the temporal bone. It is here separated from the walls of the canal by a prolongation downward of the dura mater. In this part of its course it first ascends in front of the tympanum and cochlea of the internal ear; it then turns forward and medially, lying a little to the medial side of and behind the auditory (Eustachian) tube, and enters the cranial cavity by turning upward above the cartilage filling the foramen lacerum, lying upon the lingula of the sphenoid bone. In this part of its course it is accompanied by the ascending branches from the superior cervical ganglion of the sympathetic. These form a plexus about the artery, but are situated chiefly on its lateral side. It is also surrounded by a number of small veins, which receive tributaries from the tympanum and open into the cavernous sinus and internal jugular vein.

3. The Intracranial Portion

On entering the cranium the internal carotid first ascends upon the medial side of the lingula along the lateral part of the body of the sphenoid. It then follows the carotid sulcus forward and slightly downward along the medial wall of the cavernous sinus (fig. 536). Here it has the sixth nerve immediately lateral to it, and is covered by the lining membrane of the sinus. Again turning upward, it pierces the dura mater on the medial side of the anterior clinoid process, and passes between the second and third nerves to the anterior perforated

substance. At the medial end of the lateral (Sylvian) fissure it pierces the arachnoid and divides into its two terminal branches, the anterior and middle cerebral. As it lies above the foramen lacerum, the artery is crossed on its lateral side by the great superficial petrosal nerve as the latter goes to join the great deep petrosal from the carotid plexus to form the nerve of the pterygoid canal (Vidian).

Branches of the Internal Carotid Artery

The **cervical portion** has no branches. The **petrosal portion** gives off the caroticotympanic. The **branches of the intracranial portion** are:—(2) ophthalmic; (3) posterior communicating; (4) choroid; (5) anterior cerebral; (6) middle cerebral.

As the internal carotid artery lies on the medial side of the cavernous sinus, it also gives off the following small branches—branches to the walls of the cavernous sinus, to the pituitary body, to the semilunar (Gasserian) ganglion and to the dura mater. These anastomose with anterior branches of the middle meningeal.

1. THE CAROTICOTYMPANIC ARTERY

The **caroticotympanic artery** (fig. 534) [ramus caroticotympanicus] enters the tympanum through a small foramen in the posterior wall of the carotid canal,

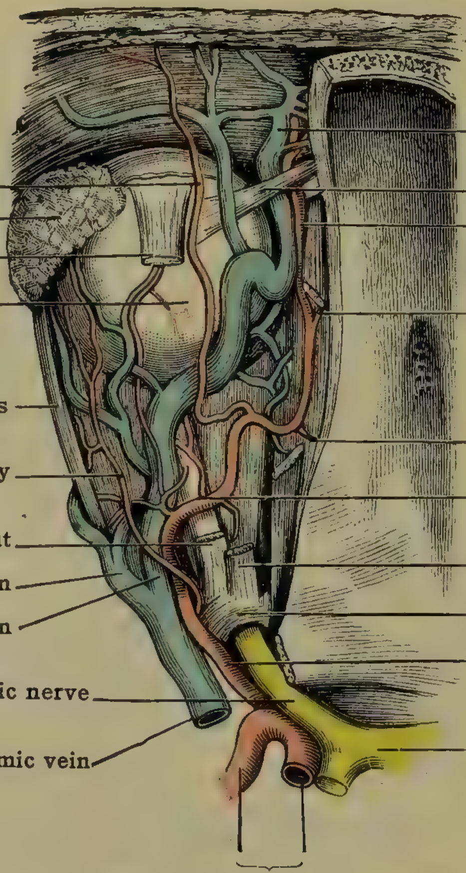


Fig. 535.—The Left Ophthalmic Artery and Vein, Viewed from Above.

and contributes to the blood-supply of that cavity. It anastomoses on the promontery with the tympanic branches of the stylomastoid, internal maxillary, and middle meningeal arteries.

2. THE OPHTHALMIC ARTERY

The **ophthalmic** artery (fig. 535) arises from the internal carotid immediately below the anterior clinoid process just as the latter vessel is passing through the dura mater. Entering the orbit through the optic foramen below and laterally to the optic nerve, it at once perforates the sheath of dura mater which is prolonged through the optic foramen on both artery and nerve. It then runs in a gentle curve with a lateral convexity below the optic nerve and lateral rectus, being here crossed by the nasociliary (nasal) nerve. Turning forward and upward, it passes over the optic nerve, to its medial side. Thence it runs obliquely beneath the superior rectus in front of the nasociliary (nasal) nerve under the lower border and pulley of the superior oblique, but above the medial rectus, and continues its course to the medial palpebral region, where it divides into the frontal and dorsal nasal branches.

BRANCHES OF THE OPHTHALMIC ARTERY

The **branches of the ophthalmic artery** are:—(1) the lacrimal; (2) the supraorbital; (3) the central artery of the retina; (4) the muscular; (5) the ciliary; (6) the posterior ethmoidal; (7) the anterior ethmoidal; (8) the medial palpebral; (9) the frontal; and (10) the dorsal nasal.

(1) The **lacrimal** artery [a. lacrimalis], is usually the first and often the largest branch of the ophthalmic. It arises between the superior and lateral rectus on the lateral side of the optic nerve from the ophthalmic, soon after that vessel has entered the orbit. At times it is given off from the ophthalmic, or from the middle meningeal artery outside the orbit, and then usually passes into that cavity through the superior orbital (sphenoidal) fissure. It runs forward along the lateral wall of the orbit with the lacrimal nerve, above the upper border of the lateral rectus, to the lacrimal gland, which it supplies. In this course it furnishes the following branches:—(*a*) **Recurrent**, one or more branches which pass backward through the superior orbital (sphenoidal) fissure, and anastomose with the lacrimal branch of the middle meningeal artery. The anastomosis is sometimes of large size, and then takes the chief share in the formation of the lacrimal artery. (*b*) **Muscular** branches, distributed chiefly to the lateral rectus. (*c*) **Zygomatic** branches—small twigs, which pass through the zygomatico-orbital (malar) canals, and anastomose with the orbital branch of the middle temporal, and with the transverse facial on the cheek. (*d*) **Lateral palpebral** arteries [aa. palpebrales laterales] which are distributed to the upper and lower eyelids and to the conjunctiva. (*e*) **Ciliary.** See CILIARY ARTERIES below.

(2) The **supraorbital** artery [a. supraorbitalis] (a. frontalis lateralis NK) usually arises from the ophthalmic after the latter vessel has crossed over the optic nerve. Passing upward to the medial side of the superior rectus and levator palpebræ, it runs along the upper surface of the latter muscle with the frontal nerve in the orbital fat, but beneath the periosteum, to the supraorbital notch. On emerging on the forehead beneath the orbicularis oculi, it divides into a superficial and a deep branch, the former ramifies between the skin and epicranius (occipitofrontalis), the latter between the epicranius and the pericranium. Both branches anastomose with the anterior branches of the superficial temporal, the angular branch of the external maxillary (facial), and the transverse facial artery. The branches of the supraorbital are:—(*a*) **periosteal**, to the periosteum of the roof of the orbit; (*b*) **muscular**, to the levator palpebræ and superior rectus; (*c*) **diploic**, given off as the artery is passing through the supraorbital notch, enters a minute foramen at the bottom of the notch and is distributed to the diploë and frontal sinuses; (*d*) **trochlear**, to the pulley of the superior oblique; (*e*) **palpebral**, to the upper eyelid.

(3) The **arteria centralis retinæ**, a small but constant branch, comes off from the ophthalmic close to the optic foramen and, perforating the optic nerve about 6 mm. (¼ in.) behind the globe, runs forward (in the substance of the nerve) to the eyeball, supplying the retina. Its further description is given in the section on the EYE.

(4) The **muscular** branches [rr. musculares] are very variable in their origin and distribution. They may be roughly divided into superior and inferior sets. Those of the superior set supply the superior oblique, the levator palpebræ, and superior rectus. The inferior pass forward, between the optic nerve and the inferior rectus, supplying that muscle, the medial rectus, and the inferior oblique. From the muscular branches are given off the anterior ciliary arteries. (See CILIARY ARTERIES.)

(5) The **ciliary arteries** are divided into three sets:—The **short posterior**, the **long posterior**, and the **anterior.** (i) The **short posterior** [aa. ciliares posteriores breves] (aa. chorioideæ NK), five or six in number, come off chiefly from the ophthalmic as it is crossing the optic nerve. They run forward about the nerve, dividing into twelve or fifteen small vessels, which perforate the sclera around the entrance of the optic nerve, and are distributed to the choroid coat. (ii) The **long posterior** ciliary arteries [aa. ciliares posteriores longæ], usually two, sometimes three, in number, come off from the ophthalmic on either side of the optic nerve, and run forward with the short ciliaries to the sclera. On piercing the sclera, they course forward, one on either side of the eyeball between the sclera and the choriod, to the ciliary processes and iris. Their further distribution is given under the anatomy of the EYE. (iii) The **anterior ciliary** arteries [aa. ciliares anteriores] (ramuli ciliares NK) are derived from the muscular branches and from the lacrimal. They run to the globe along the tendons of the recti, forming a zone of radiating vessels beneath the conjunctiva. Some of them, the **episcleral arteries** [aa. episclerales], perforate the sclera about 6 mm. (¼ in.) behind the cornea, and supply the iris and ciliary processes. It is these vessels that are enlarged and congested in iritis, forming the circumcorneal zone of redness so characteristic of that disease. They then differ from the tortuous vessels of the conjunctiva in that they are straight and parallel. The other branches constitute the **anterior conjunctival** arteries [aa. conjunctivales anteriores].

(6) The **posterior ethmoidal** artery [a. ethmoidalis posterior] (a. ethmoidalis labyrinthica NK) (fig. 535) runs medially between the superior oblique and medial rectus and, leaving the orbit by the posterior ethmoidal canal, together with the posterior ethmoidal branch of the nasociliary (nasal) nerve, enters the posterior ethmoidal cells, whence it passes through a transverse slit-like aperture between the sphenoid bone and cribriform plate of the ethmoid bone into the cranium. It gives off (*a*) **ethmoidal** branches to the posterior ethmoidal cells; (*b*) **meningeal** branches to the dura mater lining the cribriform plate; and (*c*) **nasal** branches, which pass through the cribriform plate to the superior meatus and upper nasal conchæ, and anastomose with the nasal branches of the sphenopalatine artery (fig. 532).

(7) The **anterior ethmoidal** artery [a. ethmoidalis anterior] (a. ethmoidalis olfactoria NK) (figs. 532, 535), a larger branch than the posterior ethmoidal, arises in front of the latter, passes medially between the superior oblique and medial rectus, and, leaving the orbit through the anterior ethmoidal canal, in company with the anterior ethmoidal nerve, enters the cranial cavity. After running a short distance beneath the dura mater on the cribriform plate of the

ethmoidal bone, it passes into the nose through the horizontal slit-like aperture by the side of the crista galli. Its terminal branch passes along the groove on the under surface of the nasal bone, and emerges on the nose between the bone and lateral cartilage, terminating in the skin of that organ. It gives off the following branches in its course:—(i) **Ethmoidal,** to the anterior ethmoidal cells; (ii) **anterior meningeal** artery, [a. meningea anterior] to the dura mater of the anterior fossa; (iii) **nasal** branches to the middle meatus and anterior part of the nose; (iv) **frontal** branches to the frontal sinuses; (v) **cutaneous,** or **terminal** branches to the skin of the nose.

(8) The **medial palpebral** arteries [aa. palpebrales mediales] arise either separately or by a common trunk from the ophthalmic artery opposite the pulley for the superior oblique. They pass, one above and one below, the medial palpebral ligament and then skirt along the upper and

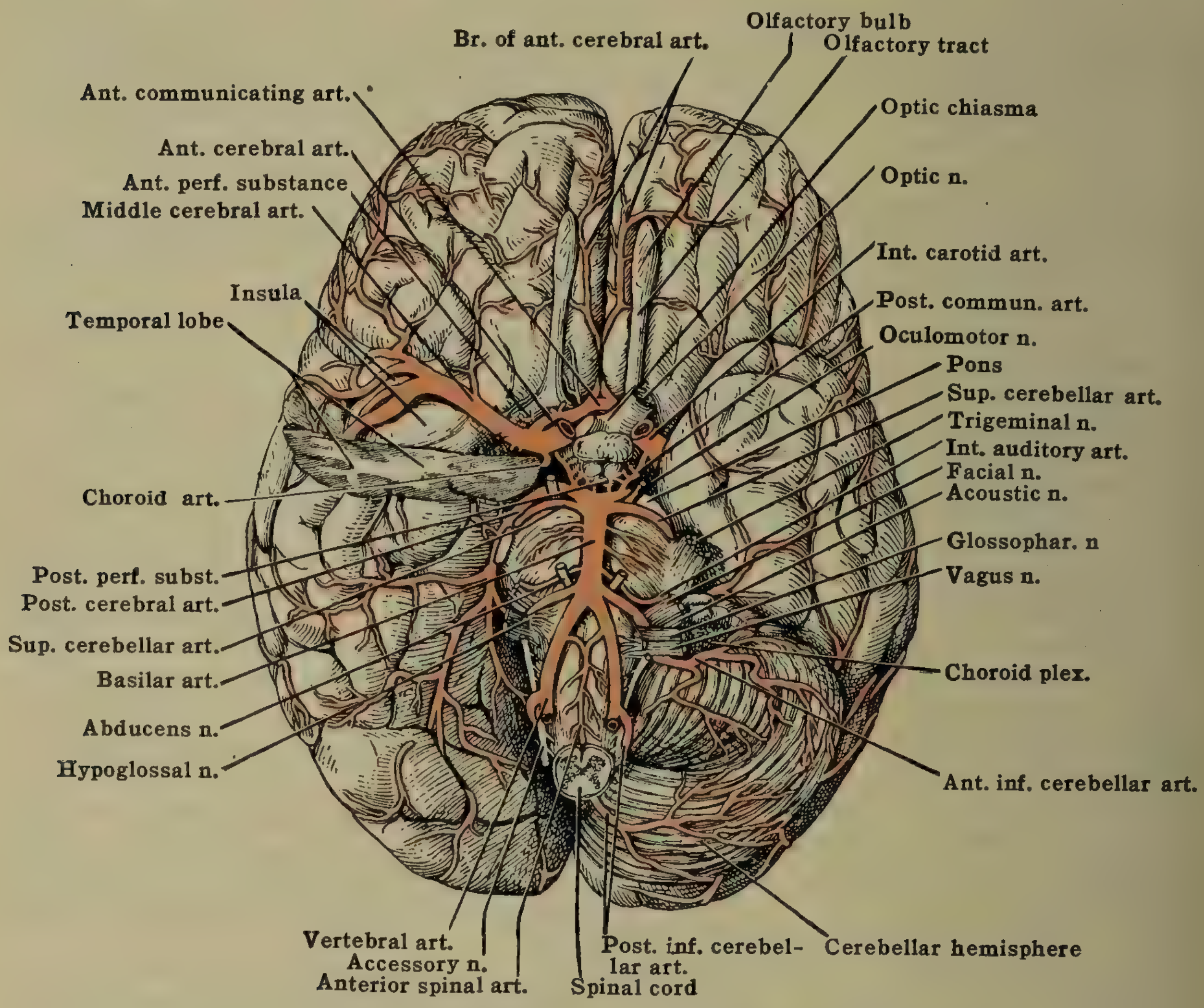


FIG. 536.—THE ARTERIES AT THE BASE OF THE BRAIN.

lower eyelids respectively, near the free margin between the palpebral tarsi and the orbicularis muscle, and form a **superior** and an **inferior tarsal arch** [arcus tarseus superior, inferior] (arcus tarseus frontalis, maxillaris, NK) by anastomosing with the lateral palpebral branches of the lacrimal. The upper medial palpebral arch anastomoses with the supraorbital artery and orbital branch of the temporal artery; the lower with the infraorbital, the angular branch of the external maxillary (facial), and the transverse facial arteries. A branch from the lower medial palpebral artery passes with the ductus nasolacrimalis as far as the inferior meatus. Small twigs, the **posterior conjunctival** arteries [aa. conjunctivales posteriores] (ramuli conjunctivales NK) are also given to the caruncula lacrimalis and conjunctiva.

(9) The **frontal** artery [a. frontalis] the upper of the terminal branches of the ophthalmic, pierces the superior tarsus at the medial angle of the orbit, passes upward over the frontal bone beneath the orbicularis oculi, supplies the structures in its neighborhood. It anastomoses with its fellow of the opposite side, with the supraorbital, and with the anterior division of the superficial temporal artery.

(10) The **dorsal nasal** [a. dorsalis nasi], the lower of the terminal branches of the ophthalmic, leaves the orbit at the medial angle by perforating the tarsus above the medial palpebral ligament. It then descends along the dorsum of the nose, beneath the integuments, and anastomoses with the angular and lateral nasal branches of the external maxillary (facial). It gives off a **lacrimal branch** as it crosses the lacrimal sac.

3. THE POSTERIOR COMMUNICATING ARTERY

The **posterior communicating** artery [a. communicans posterior] (a. com. aboralis NK) (fig. 536) arises from the internal carotid just before the division of that vessel into the anterior and middle cerebral arteries; occasionally it arises from the middle cerebral.

It is a slender vessel which runs backward over the optic tract and pedunculus cerebri along the side of the hippocampal gyrus to join the posterior cerebral. It may be of considerable size, the portion of the posterior cerebral between the basilar and posterior communicating being then as a rule reduced to a mere rudiment. It gives off the following branches:—(*a*) the **hippocampal,** to the gyrus of that name; and (*b*) the **middle thalamic,** to the optic thalamus.

4. THE CHOROID ARTERY

The **choroid** artery [a. chorioidea] is a small but constant vessel (fig. 536) which arises from the back of the internal carotid just laterally to the origin of the posterior communicating.

It passes backward on the optic tract and the pedunculus cerebri, at first lying parallel to and on the lateral side of the posterior communicating artery. It then dips under the edge of the uncinate gyrus and, entering the choroid fissure at the lower end of the inferior cornu of the lateral ventricle, ends in the choroid plexus and supplies the hippocampus and fimbria.

5. THE ANTERIOR CEREBRAL ARTERY

The **anterior cerebral** artery [a. cerebri anterior] (a. cerebri oralis NK) (figs. 536, 539), one of the terminal branches into which the internal carotid divides in the lateral fissure (fissure of Sylvius), supplies a part of the cortex of the frontal and parietal lobes of the brain and a small part of the basal ganglia. It passes at first anteriorly and medially across the anterior perforated substance between the olfactory and optic nerves to the longitudinal fissure where it approaches its fellow of the opposite side and communicates with it by a short transverse trunk, about five mm. long, known as the **anterior communicating** artery [a. communicans anterior] (a. com. oralis NK) (fig. 536). Onward from this point it runs side by side with its fellow in the longitudinal fissure round the genu of the corpus callosum; then, turning backward, it continues along the upper surface of that commissure, and, after giving off large branches to the frontal and parietal lobes, anastomoses with the posterior cerebral artery.

6. THE MIDDLE CEREBRAL ARTERY

The **middle cerebral** artery [a. cerebri media] (figs. 536, 540), the larger of the terminal divisions of the internal carotid, supplies the basal ganglia and part of the cortex of the frontal and parietal lobes. It passes obliquely upward and lateralward into the lateral (Sylvian) fissure, and opposite the insula divides into cortical branches.

Circulus Arteriosus

The four arteries that supply the brain, namely, the two internal carotid arteries and the two vertebrals (which unite to form the basilar), inosculate at the base of the brain to form the circle of Willis [circulus arteriosus (Willisi)]. This so-called circle or heptagon is formed **in front** by the anterior communicating artery, uniting the anterior cerebral arteries of opposite sides; **laterally** by the internal carotids, and by the posterior communicating arteries stretching between these and the posterior cerebrals; **behind** by the two posterior cerebrals, diverging from the bifurcation of the basilar artery (fig. 536).

The free anastomosis between the two internal carotid and the two vertebral arteries serves to equalize the flow of blood to the various portions of the brain. Thus, if one carotid or one vertebral were obstructed, the parts supplied by that vessel would receive their blood through the circle from the remaining pervious vessels. One vertebral artery alone has indeed been found equal to the task of carrying sufficient blood for the supply of the brain after ligature of both the carotids and the other vertebral artery. Further, the circulus arteriosus is the only medium of communication between the ganglionic or central and the peripheral or cortical branches of the cerebral arteries, and between the various ganglionic branches themselves. The ganglionic and the cortical branches form separate and distinct systems, and do not anastomose with each other; the ganglionic arteries, moreover, are so-called end-vessels, and do not anastomose with the neighboring ganglionic branches. The three cerebral arteries, anterior, middle, and posterior may be regarded as branches of the circulus arteriosus (circle of Willis). (For details concerning the distribution of the cerebral arteries see pp. 637, 981.)

THE SUBCLAVIAN ARTERY

The **subclavian artery** on the right side [a. subclavia dextra] arises at the bifurcation of the innominate opposite the upper limit of the right sternoclavicular articulation. On the left side it arises from the arch of the aorta and, as far as the medial border of the scalenus anterior, is situated deeply in the chest.

Beyond the medial border of the scalenus anterior the artery has the same relations on both sides. It courses from this point beneath the clavicle in a slight curve across the root of the neck to the lateral border of the first rib, there to end in the axillary artery. The height to which the artery rises in the neck varies. It is perhaps most commonly about 1.2 cm. (½ in.) above the clavicle. If

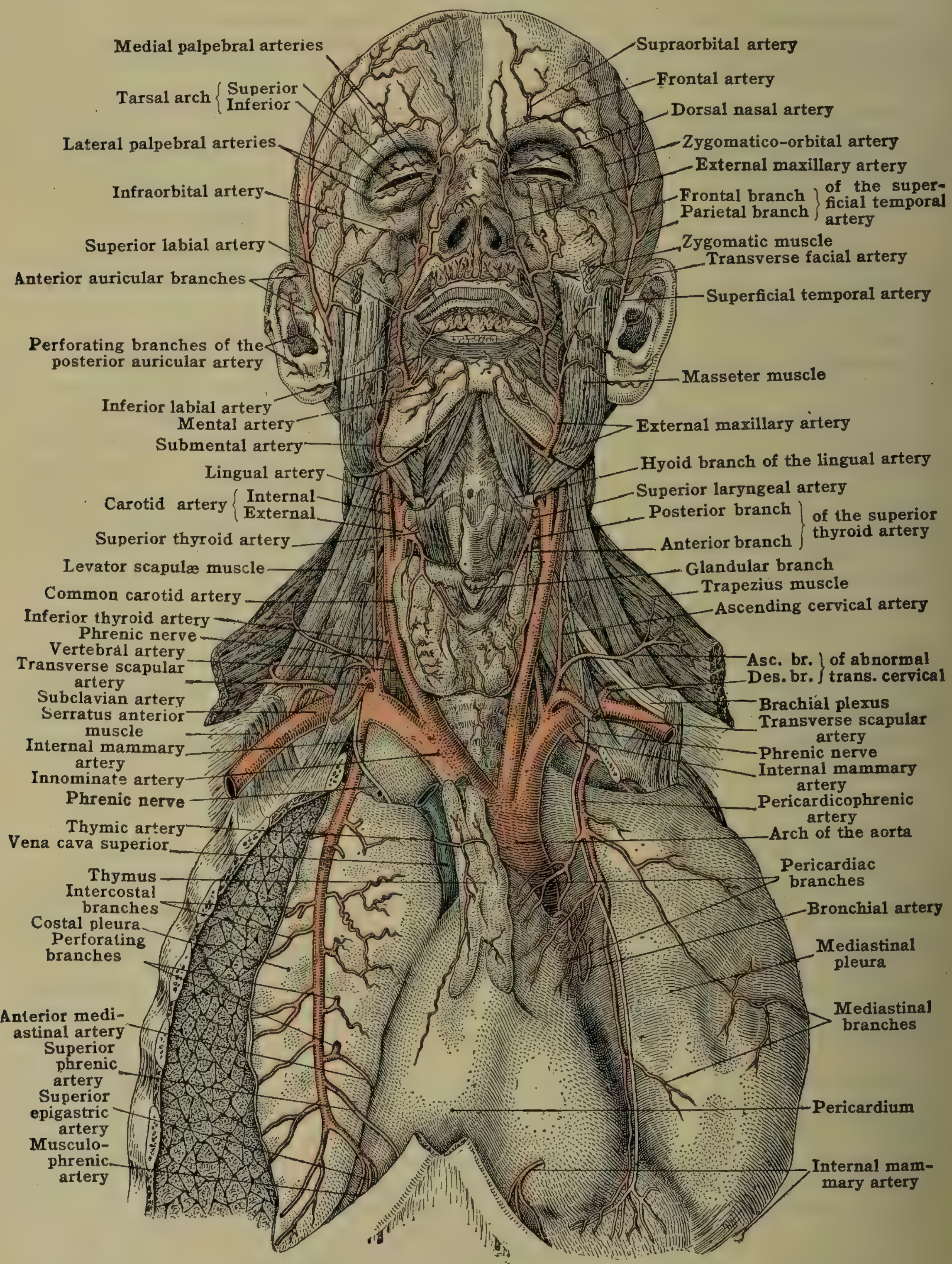


FIG. 537.—THE SUBCLAVIAN ARTERY. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

curved line drawn to represent part of the circumference of a circle having its center at a point on the lower margin of the clavicle 3.7 cm. (1½ in.) from the sternal end of that bone, the line of the artery will be sufficiently well indicated for all practical purposes. In its course the artery arches over the dome of the pleura and gains the groove on the upper surface of the first rib by passing otsteriorly to the scalenus anterior and behind the scalenus medius. Laterally pot he internal jugular veins, each artery is accompanied by the corresponding

vein, the latter lying in front of the scalenus anterior and on a slightly lower plane.

The subclavian artery is divided into three portions—as it lies medial to, posterior to, or lateral to, the scalenus anterior muscle.

THE FIRST OR THORACIC PORTION OF THE LEFT SUBCLAVIAN ARTERY

The **left subclavian** artery [a. subclavia sinistra] (fig. 537) arises from the left end of the arch of the aorta. The first part of the left subclavian is consequently longer than the first part of the right, which arises at the bifurcation of the innominate artery. The artery at its origin is situated deeply in the thorax; as it arises from the aorta it is on a plane posterior to and a little to the left of the thoracic portion of the left common carotid. It first ascends almost vertically and at the root of the neck curves laterally over the apex of the left pleura and lung to the interval between the anterior and middle scalene muscles. Beyond the medial border of the scalenus anterior—that is, in the second and third portions of its course—its relations are similar to those of the right subclavian artery.

Relations.—In front the left subclavian artery is covered by the left pleura and lung, and more superficially by the sternothyroid, sternohyoid, and sternomastoid muscles. It is crossed a little above its origin by the left innominate vein, and higher in the neck near the scalenus anterior by the internal jugular and vertebral veins and by the medial end of the subclavian. The phrenic nerve crosses the artery medially to the scalenus anterior, and then descends parallel with it, but on an anterior plane, to cross the arch of the aorta. The vagus nerve descends parallel with the artery between it and the left common carotid, coming into contact with its anterior surface just before crossing the arch of the aorta. The left cervical cardiac nerves of the sympathetic also descend in front of it on their way to the cardiac plexus. The left *ansa subclavia* also loops in front of the subclavian artery. The left common carotid is situated anteriorly and to its right. The thoracic duct arches over the artery just medially to the scalenus anterior, to empty its contents into the confluence of the internal jugular and subclavian veins (fig. 523).

Behind and somewhat medial to it are the esophagus, thoracic duct, inferior cervical ganglion of the sympathetic, longus colli muscle, and vertebral column. To some extent it is overlapped posteriorly by the left pleura and lung. On its **right side** are the trachea and the recurrent (laryngeal) nerve, and, higher up, the esophagus and thoracic duct. On its **left side** are the left pleura and lung.

Branches.—The vertebral, internal mammary, and thyrocervical trunk (thyroid axis) usually arise from the first portion on the left side. (See p. 642.)

THE FIRST PORTION OF THE RIGHT SUBCLAVIAN ARTERY

The **first portion of the right subclavian artery** (fig. 537) extends from its origin at the bifurcation of the innominate, behind the upper margin of the right sternoclavicular joint, upward and laterally in a gentle curve over the apex of the right lung and pleura to the medial border of the scalenus anterior. It measures about 3 cm. (1¼ in.). In this course it ascends in the neck a variable distance above the clavicle, deeply placed and surrounded by important structures.

Relations.—In front it is covered by the integument, the superficial fascia, the platysma, the deep fascia, by the clavicular origin of the sternomastoid and by the sternohyoid and sternothyroid muscles. It is crossed by the commencement of the innominate, by the internal jugular, and by the vertebral veins; and, in a mediolateral direction, by the vagus and phrenic nerves, and the superior cardiac branches of the sympathetic nerve. A loop of the sympathetic nerve itself also crosses the artery, and forms with the trunk of the sympathetic a ring around the vessel known as the **ansa subclavia** (annulus of Vieussens).

Behind, but separated from the artery by a cellular interval, are the longus colli muscle, the transverse process of the seventh cervical or first thoracic vertebra, the main chain of the sympathetic nerve, the inferior cardiac nerves, the recurrent (laryngeal) nerve, and the apex of the right lung and pleura.

Below, it is in contact with the pleura and lung and the loop of the recurrent (laryngeal) nerve, which winds round the artery from the vagus and ascends behind it to the larynx. The medial end of the subclavian vein is anterior to the lateral end of this part of the artery but on a lower plane.

Branches.—The vertebral, internal mammary, costocervical trunk, and thyrocervical trunk (thyroid axis) arise from this part of the vessel on the right side.

Not uncommonly a small aberrant branch descends from this portion of the right subclavian artery behind the esophagus to join a branch of the aorta opposite the third or fourth thoracic vertebra. This vessel is a vestige of the right dorsal aorta.

THE SECOND PORTION OF THE SUBCLAVIAN ARTERY

The **second portion of the subclavian artery** lies behind the scalenus anterior muscle. It measures about 2 cm. (¾ in.) in length and here reaches highest in the neck. The subclavian vein is separated from the artery by the scalenus anterior, and lies on a lower and anterior plane (fig. 537).

Relations.—**In front** it is covered by the skin, superficial fascia, platysma, the deep fascia, the clavicular origin of the sternomastoid and by the scalenus anterior. The phrenic nerve—which, in consequence of its oblique course medially downward, crosses a portion of both the first and second part of the subclavian—is separated from the second portion by the scalenus anterior muscle, as is also the subclavian vein which courses on a somewhat lower plane. **Behind** the artery are the apex of the pleura and lung, and a portion of the scalenus medius; also the scalenus minimus (partially or entirely fibrous, known as Sibson's fascia, see p. 421). **Above** is the brachial plexus. **Below** are the pleura and lung.

One **branch** only—the costocervical trunk (superior intercostal)—is, as a rule, given off from this portion of the subclavian; occasionally the transverse cervical or the descending branch of the transverse cervical (posterior scapular artery) arises from it.

THE THIRD PORTION OF THE SUBCLAVIAN ARTERY

The **third portion of the subclavian artery** extends from the lateral margin of the scalenus anterior muscle to the lateral border of the first rib. It is more superficial than either the first or second portion and is in relation with less important structures. It is the longest of the three portions of the subclavian artery, and lies in a triangle—the subclavian triangle—bounded by the sternomastoid, the omohyoid, and the clavicle (fig. 524).

As a rule it gives off no branches. The descending branch of the transverse cervical artery arises from it sometimes however, in which case the ascending branch arises from the thyrocervical trunk. (See fig. 537.)

Relations.—**In front** it is covered by skin, superficial fascia, platysma, supraclavicular nerves of the cervical plexus, and the anterior and the posterior layer of the deep cervical fascia. Close to the lateral margin of the sternomastoid, the external jugular vein pierces the anterior layer of the deep cervical fascia and, as this vein lies between the two layers of fascia, it receives on its lateral side the transverse scapular (suprascapular), transverse cervical, and other veins of the neck, which together form a plexus of large veins in front of the artery. The nerve to the subclavius and, when present, the accessory branch from this nerve to the phrenic, also cross in front of the artery beneath the posterior layer of fascia.

Behind, the artery is in contact with the scalenus medius, and with the lower trunk of the brachial plexus.

Below, the artery rests in the posterior of the two grooves on the upper surface of the first rib.

Above it is separated by the deep fascia from the posterior belly of the omohyoid. The trunk formed by the fifth and sixth cervical nerves is also above the artery, but on a somewhat anterior plane. The seventh cervical nerve is close to the vessel, and has been mistaken for the artery in the application of a ligature.

The **branches of the subclavian artery** will be described in the following order:—(1) The vertebral artery; (2) the thyrocervical trunk; (3) the internal mammary artery; (4) the costocervical trunk.

1. THE VERTEBRAL ARTERY

The **vertebral** artery [a. vertebralis] (fig. 538) the first, largest and most constant branch, arises from the upper and posterior part of the first portion of the subclavian; on the right side, about 2 cm. (¾ in.) from the origin of the latter vessel from the innominate, on the left side, from the most prominent part of the arch of the subclavian, close to the medial edge of the scalenus anterior muscle. It first ascends vertically to the foramen transversarium of the sixth cervical vertebra and, having passed through that foramen and those of the next succeeding cervical vertebræ as high as the epistropheus (axis), it turns laterally and then ascends to reach the foramen in the transverse process of the atlas; after passing through that foramen it turns backward behind the articular process, lying in the groove on the posterior arch of the atlas. It next pierces the posterior occipitoatlantoid membrane and the dura mater, and enters the cranium through the foramen magnum. Here it passes upward, at first lying by the side of the medulla, then in front of that structure, and terminates at the lower portion of the pons by anastomosing with the vertebral of the opposite side to form the basilar.

The vertebral artery may be divided for purposes of description into four parts: the **first,** or **cervical,** extending from its origin to the transverse process of the sixth cervical vertebra; the **second,** or **vertebral,** situated in the **foramina** transversaria; the **third,** or **occipital,** contained in the suboccipital triangle; and the **fourth,** or **intracranial,** within the cranium.

The first or cervical portion.—The artery here lies between the scalenus anterior and longus colli muscles. **In front** it is covered by the vertebral and internal jugular veins, and is crossed by the inferior thyroid artery, and on the left side, in addition, by the thoracic duct, which runs over it mediolaterally. **Behind,** the artery lies on the transverse process of the seventh cervical vertebra and the sympathetic nerve. To its **medial side** is the longus colli. To its **lateral side** is the scalenus anterior. It gives off as a rule no branch in this part of its course. Occasionally, however, a small branch passes into the foramen transversarium of the seventh cervical vertebra.

The second or vertebral portion.—As the artery passes through the foramina transversaria, it is surrounded by a plexus of veins and by branches of the sympathetic nerve. The cervical nerves lie behind it. Between the transverse processes it is in contact with the intertransverse muscles.

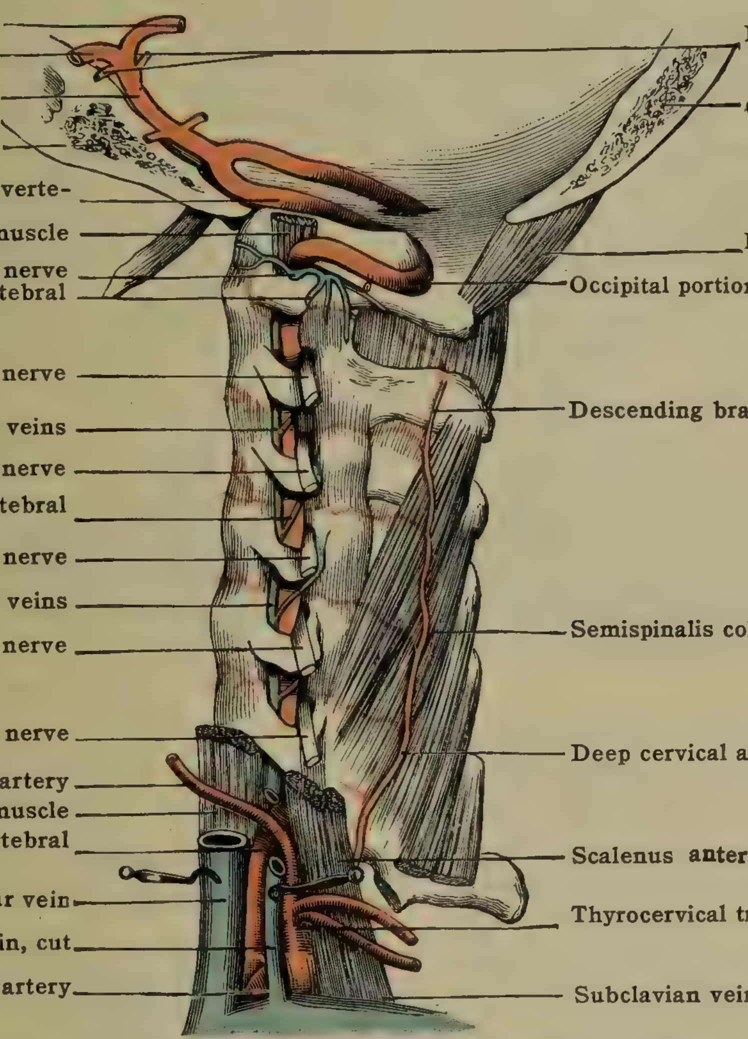


Fig. 538.—The Left Vertebral Artery. (Walsham.)
The internal jugular and vertebral veins are hooked aside to expose the artery.

The third or occipital portion.—The artery here lies in the suboccipital triangle, bounded by the superior oblique, inferior oblique, and rectus capitis posterior major muscles. As it winds round the groove on the atlas, it has the rectus capitis lateralis, the articular process, and the posterior occipitoatlantoid membrane **in front** of it; the superior oblique, the rectus capitis posterior major, and the semispinalis capitis (complexus) **behind** it. Separating it from the arch of the atlas, is the first cervical or suboccipital nerve.

The **fourth** or **intracranial portion** extends from the aperture in the dura mater to the lower border of the pons, where it pierces the arachnoid and unites with its fellow to form the basilar artery. It here winds round from the side to the front of the medulla, lying in the vertebral groove on the basilar part of the occipital bone. In this course it passes beneath the first process of the ligamentum denticulatum, and between the hypoglossal nerve in front, and the anterior roots of the suboccipital nerve behind.

Branches of the Vertebral Artery

The first part of the vertebral artery has no named branches. The second and third parts give off *muscular* branches to the semispinalis and posterior recti and oblique muscles. The second part also gives off five or six, (1) Spinal

branches. The fourth part gives off the following: (2) Posterior meningeal; (3) posterior spinal; (4) anterior spinal; and (5) posterior inferior cerebellar.

(1) The **spinal** branches [rr. spinales] run through the intervertebral foramina into the vertebral canal, and there divide into two branches: one of which ramifies on the backs of the bodies of the cervical vertebræ; while the other runs along the spinal nerves, supplies the cord and its membranes, and anastomoses with the arteries above and below.

(2) The **meningeal** [r. meningeus] is a small branch given off as the vertebral artery pierces the dura mater to enter the cranium. It supplies the bone and dura mater of the posterior fossa of the skull, and anastomoses with the posterior meningeal branches derived from the occipital and ascending pharyngeal arteries. It gives branches to the falx cerebelli.

(3) The **posterior spinal** artery [a. spinalis posterior] runs downward obliquely along the side of the medulla to the back of the cord, down which it passes behind the roots of the spinal nerves, being reinforced by spinal branches accompanying these nerves, in the neck, the thoracic, and in the lumbar region. It can be traced as low as the end of the spinal cord.

(4) The **anterior spinal** artery [a. spinalis anterior] comes off from the vertebral a little below its termination in the basilar artery. Descending with a medial slant in front of the medulla, it unites on a level with the foramen magnum with its fellow of the opposite side. The single vessel thus formed runs downward in front of the spinal cord beneath the pia mater as far as the termination of the cord, being reinforced by the spinal branches on the way down. The spinal arteries are described in detail with the anatomy of the spinal cord.

(5) The **posterior inferior cerebellar** [a. cerebelli inferior posterior] (a. cerebelli caudalis NK) (fig. 536)—the largest branch of the vertebral—arises from that vessel just before it joins its fellow to form the basilar artery; it may come off from the basilar itself. It runs, at first laterally across the restiform body between the origin of the vagus and hypoglossal nerves, and, descending toward the vallecula, there divides into two branches, medial and lateral. (*a*) The *medial branch* runs backward between the vermis and the lateral hemisphere of the cerebellum. It supplies the vermis, and anastomoses with the artery of the opposite side, and with the superior vermian of the superior cerebellar. (*b*) The *lateral branch* runs laterally and, ramifying over the under surface of the cerebellar hemisphere, supplies its cortex and anastomoses along its lateral margin with the superior cerebellar arteries.

From the undivided trunk of the posterior inferior cerebellar artery branches are given to the medulla oblongata, supplying the choroid plexus and the fourth ventricle.

THE BASILAR ARTERY

The **basilar** artery [a. basilaris] is formed by the confluence of the right and left vertebral arteries, which meet at an acute angle at the lower border of the pons. It runs forward and upward in a slight groove in the middle line of the pons, and divides at the upper border of that structure at the level of the tentorial notch into the two posterior cerebral arteries, which take part in the formation of the circle of Willis (fig. 536).

Branches of the Basilar Artery

The **branches of the basilar artery** are:—(1) Pontine; (2) internal auditory; (3) anterior inferior cerebellar; (4) superior cerebellar; (5) posterior cerebral.

(1) The **pontine** branches [rami ad pontem] are numerous small vessels which come off at right angles on either side of the basilar artery, and, passing laterally over the pons, supply that structure and adjacent parts of the brain.

(2) The **internal auditory** artery [a. auditiva interna], a long slender vessel, accompanies the auditory nerve into the internal acoustic meatus (figs. 536, 591). It here lies between the facial and auditory nerves, and at the bottom of the meatus passes into the internal ear, and anastomoses with the other auditory arteries. (See Internal Ear.)

(3) The **anterior inferior cerebellar** [a. cerebelli inferior anterior] (a. cerebelli oralis NK) arises from the basilar soon after its origin, passes laterally and backward across the pons, and then over the brachium pontis to the front part of the under surface of the cerebellum. It anastomoses with the posterior inferior cerebellar artery (fig. 536).

(4) The **superior cerebellar** [a. cerebelli superior] (a. cerebelli dorsalis NK) comes off from the basilar immediately behind its bifurcation into the posterior cerebral arteries. It courses laterally and backward over the pons, in a curve roughly corresponding to that of the posterior cerebral artery, from which it is separated by the third cranial nerve; but, soon sinking into the groove between the pons and the pedunculus cerebri, it curves round the latter onto the upper surface of the cerebellum, lying nearly parallel to the fourth nerve. Here it divides into two branches, medial and lateral. (*a*) The *medial branch* courses backward along the superior vermis, anastomosing with its fellow of the opposite side, and, at the posterior notch of the cerebellum, with the inferior vermian branch of the posterior inferior cerebellar artery. (*b*) The *lateral* runs to the circumference of the cerebellum, anastomosing with the lateral branch of the inferior posterior cerebellar artery.

Branches are given off from the main trunk of the superior cerebellar artery, or from its medial branch to the anterior velum (valve of Vieussens), the corpora quadrigemina, the pineal body, and the choroid plexus.

(5) The **posterior cerebral** arteries [aa. cerebri posteriores] (a. cerebri aboralis NK) are the two terminal branches into which the basilar bifurcates at the upper border of the pons, immediately behind the posterior perforated substance. Each artery runs at first laterally and a little forward across the pedunculus cerebri immediately in front of the third nerve, which separates

it from the superior cerebellar artery. After receiving the posterior communicating artery, which runs backward from the internal carotid, the posterior cerebral turns backward onto the lower surface of the cerebral hemisphere, where it breaks up into branches for the supply of the temporal and occipital lobes (fig. 539).

The **branches of the posterior cerebral artery** are described below in connection with those of the other cerebral arteries.

Distribution of the Cerebral Arteries

Although the brain receives its blood-supply from two distinct sources, namely, from the internal carotids and from the vertebrals, it is convenient to consider together the distribution of the various cerebral branches derived from these stems. The formation of the circulus arteriosus (circle of Willis) and the origin of the anterior, middle and posterior cerebral arteries have already been described (pp. 631, 636). The detailed distribution of these vessels will now be considered. In general, their branches may be divided into *central* or *ganglionic* and *peripheral* or *cortical*.

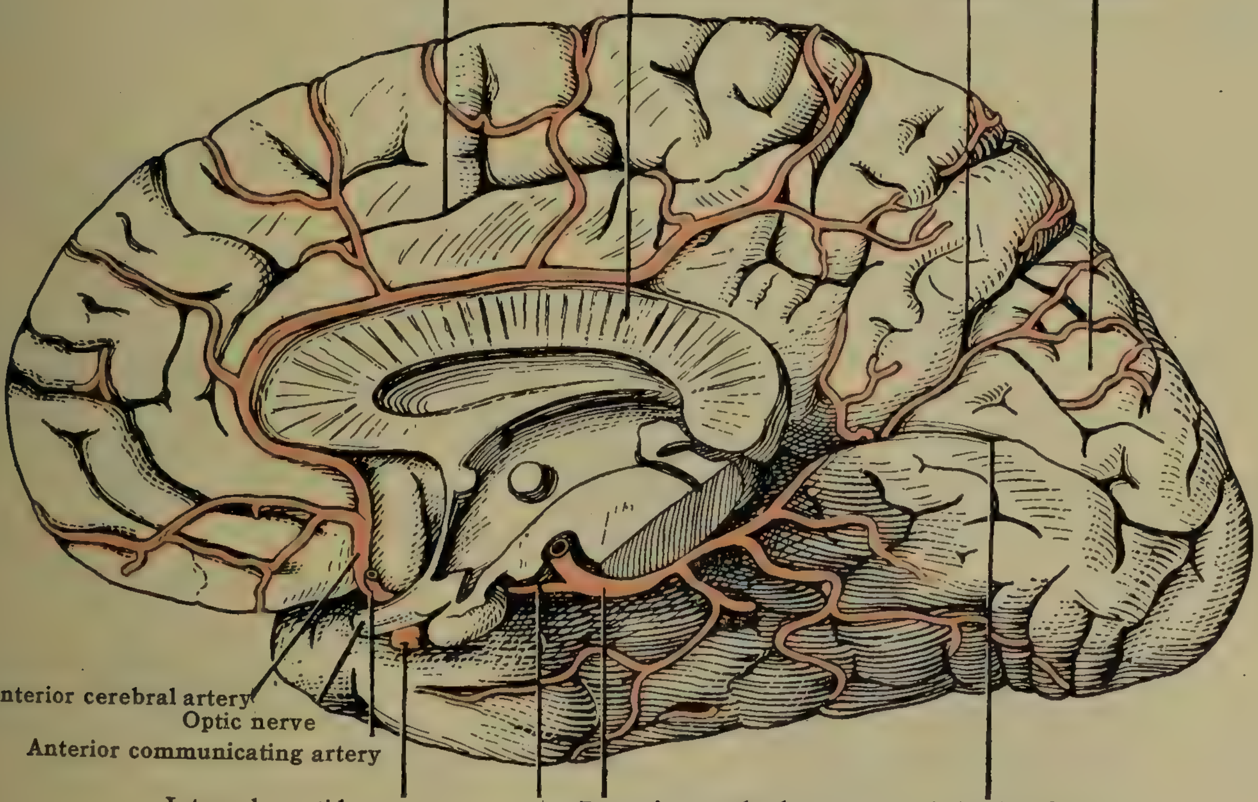


Fig. 539.—The Arteries of the Medial Surface of the Brain. (After Spalteholz.)

The **anterior cerebral artery** has but a limited **central** distribution. It gives off a few inconstant branches which enter the anterior perforated substance and supply the anterior end of the caudate nucleus. One or two of these run to the corpus callosum and septum pellucidum. The **anterior communicating** branch is a transverse trunk which connects the two arteries and thereby completes the circulus arteriosus in front. It lies in front of the optic chiasm, and varies considerably in length and size. It may give off some of the branches to the anterior perforated substance. The **cortical branches** supply the gyrus rectus, the olfactory lobe and a part of the orbital gyri on the ventral surface. On the medial surface branches supply the cortex as far back as the parieto-occipital fissure. These branches are given off as the artery curves around the corpus callosum and some of them curve over onto the lateral surface and supply the superior and middle temporal convolutions. Branches from the anterior cerebral artery also supply the corpus callosum (fig. 539).

The **middle cerebral artery** gives off most of the branches to the basal ganglia and supplies the greater part of the lateral surface of the brain. It runs through the lateral fissure (fissure of Sylvius) (fig. 540). The *branches* of the middle cerebral include the following:

The **central branches** are:—(i) The **caudate**, two or three small branches, which arise from the medial aspect of the artery and pass through the medial part of the floor of the lateral fissure (fissure of Sylvius) to the head of the caudate nucleus. (ii) The **anterolateral** are numerous small arteries which pass through the anterior perforated substance and supply the caudate nucleus (except its head), the internal capsule, and part of the optic thalamus. (iii) The **lenticulostriate**, a larger branch of the anterolateral set, passes through a separate aperture in the lateral part of the anterior perforated substance, runs upward between the lenticular nucleus, which it supplies, and the external capsule, perforates the internal capsule, and terminates in the caudate nucleus. It has been so frequently found ruptured in apoplexy that it was called by Charcot the 'artery of cerebral hemorrhage.' (iv) Sometimes a more or less distinct branch, called **lenticulo-optic**, is distributed to the lateral and hinder portion of the lenticular nucleus and the lateral portion of the optic thalamus.

The **cortical branches** come off opposite the insula. They supply the insula, the inferior frontal gyri, the central gyri (anterior and posterior), the parietal lobules, superior and inferior, the supramarginal, angular, and superior temporal gyri.

The **posterior cerebral** give off both central and cortical branches. The **central branches** are the posteromedial, posterior choroid, and the posterolateral. The **posteromedial** enter the posterior perforated substance and supply the medial portion of the optic thalamus, and the walls of the third ventricle; the **posterior choroid** pass through the transverse fissure to the tela chorioidea (velum interpositum) and chorioid plexus; the **posterolateral** run to the posterior part of the optic thalamus and give branches to the cerebral peduncles and the corpora quadrigemina.

The **cortical branches** of the posterior cerebral supply the entire occipital lobe and all of the temporal lobe except the superior temporal gyrus (fig. 539).

In regard to the cerebral arteries in general it may be said that there is no anastomosis between the cortical and central branches, the two forming distinct and separate systems. The cortical may or may not anastomose with each other, but the communication between the neighboring cortical branches is seldom sufficient to maintain the nutrition of an area when the vessel that normally supplies it is obstructed. The central branches are so-called end-vessels and rarely anastomose with each other. Hence obstruction of the middle cerebral artery leads to softening of the area supplied by its central branches, but not always to softening of the region supplied by its cortical branches. Indeed, the cortical region may escape completely, although the central area is irreparably disorganized. The gross anastomosis of the posterior cerebral with the anterior cerebral arteries through the circulus arteriosus has already been described (p. 631). To sum up the distribution of the cerebral arteries, the branches of

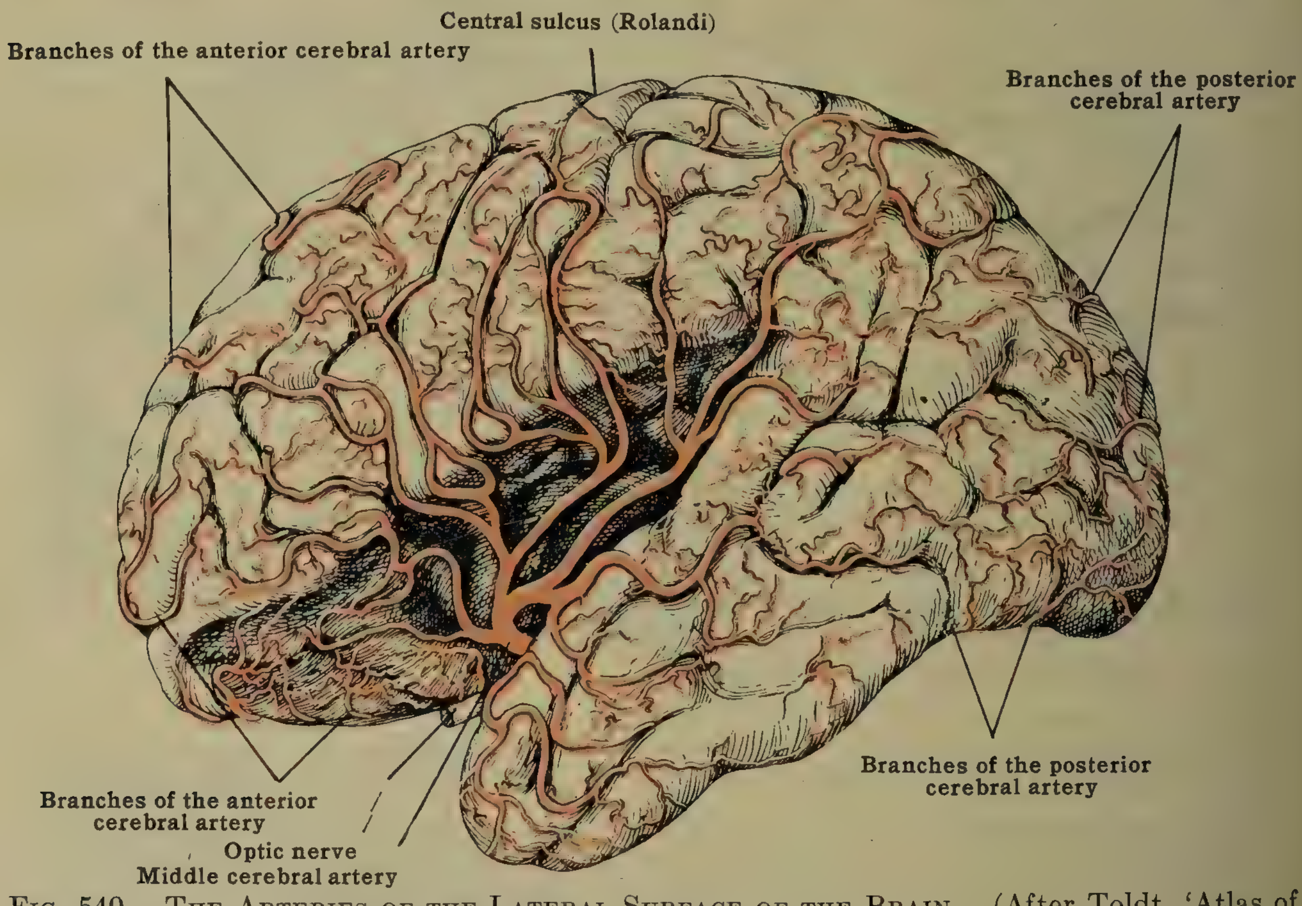


Fig. 540.—The Arteries of the Lateral Surface of the Brain. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

each are divided into the central, or ganglionic and the peripheral or cortical. The central branches arise at the commencement of the cerebral arteries about the circulus arteriosus while the cortical are derived chiefly from the termination of these vessels.

(A) The **central branches** are divided into four sets—two medial and two lateral. 1. The **two medial** are—(1) The **anteromedial**, which arise from the anterior cerebral and the anterior communicating, and supply the fore end of the caudate nucleus, and (2) the **posteromedial**, which arise from the posterior cerebral and supply the medial part of the optic thalamus and neighboring wall of the third ventricle. (2). The **two lateral** are—(1) the **anterolateral**, which arise from the middle cerebral, and, passing through the anterior perforated substance, supply the lenticular nucleus, the posterior part of the caudate nucleus, the internal and external capsules and the lateral part of the optic thalamus; and (2) the **posterolateral**, which arise from the posterior cerebral and supply the hinder part of the optic thalamus, the pedunculus cerebri and the corpora quadrigemina.

(B) The **cortical branches** ramify in the pia mater, giving off branches to the cortical substance, some of which extend through it to the underlying white substance.

It will be seen that the middle cerebral supplies the somesthetic area of the cortex. It also supplies the cortical auditory center, and, in part, the higher visual center. The anterior cerebral supplies only a small part of the somesthetic area, namely, the part of the leg center that occupies the paracentral lobule and the highest part of the anterior central gyrus. The posterior cerebral supplies the visual path from the middle of the tract backward, and the half vision center in the occipital lobe. It supplies also the corpora quadrigemina and the sensory part of the internal capsule.

The branches which supply the cerebellum and brain stem are described in connection with the vertebrals on page 636.

2. THE THYROCERVICAL TRUNK

The **thyrocervical trunk** [truncus thyreocervicalis] or **thyroid axis** arises from the upper and front part of the subclavian artery, usually opposite the internal mammary, and near the medial margin of the scalenus anterior. It is a short thick trunk, and divides almost immediately into three radiating branches—namely, the **inferior thyroid,** the **transverse scapular,** and the **transverse cervical** (figs. 524, 537). It may give off also the **ascending cervical.**

THE INFERIOR THYROID ARTERY

The **inferior thyroid** artery [a. thyreoidea inferior] is the largest of the three branches into which the thyrocervical trunk (thyroid axis) divides, and may arise in a common trunk with the transverse scapular, or as a direct branch of the subclavian. It ascends tortuously passing medially in front of the vertebral artery, the recurrent (laryngeal) nerve and the longus colli muscle, and behind the common carotid and the sympathetic nerve or its middle cervical ganglion, to the thyroid gland, where it anastomoses with the superior thyroid artery and the inferior thyroid of the opposite side.

The branches of the inferior thyroid artery are:—(1) Muscular; (2) esophageal and pharyngeal; (3) tracheal; (4) inferior laryngeal; (5) glandular; and (6) ascending cervical.

(1) The **muscular** branches supply the scalenus anterior, longus colli, sternohyoid, sternothyroid, and omohyoid muscles, and the inferior constrictor muscle of the pharynx.

(2) The **esophageal and pharyngeal** branches [rr. œsophagei et pharyngei] supply the esophagus and pharynx and anastomose with the other arteries supplying those structures.

(3) The **tracheal** branches [rr. tracheales] ramify on the trachea, where they anastomose with the tracheal branches of the superior thyroid and bronchial arteries.

(4) The **inferior laryngeal** artery [a. laryngea inferior] passes along the trachea to the back of the cricoid cartilage in company with the recurrent (laryngeal) nerve. It enters the larynx beneath the inferior constrictor. Its further distribution in that organ is described under Larynx.

(5) The **glandular** branches [rr. glandulares], are distributed almost entirely to the posterior surface of the thyroid gland.

(6) The **ascending cervical** artery [a. cervicalis ascendens] (figs. 525, 537) is given off from the thyrocervical trunk or from the inferior thyroid as that vessel is passing beneath the carotid sheath. It ascends between the scalenus anterior and the longus capitis (rectus capitis anterior major), lying parallel and medial to the phrenic nerve and behind the internal jugular vein. It anastomoses with the vertebral, ascending pharyngeal and occipital arteries, and supplies branches to the deep muscles of the neck [rr. musculares], to the spinal canal [rr. spinales], and to the phrenic nerve. Two veins accompany the ascending cervical artery and end in the innominate vein.

THE TRANSVERSE SCAPULAR ARTERY

The **transverse scapular** or suprascapular [a. transversa scapulæ] artery passes laterally across the root of the neck, lying first beneath the sternomastoid, and then in the subclavian triangle behind the clavicle and subclavius muscle. At the lateral angle of this space it is joined by the suprascapular nerve, sinks beneath the posterior belly of the omohyoid, and passes over the ligament bridging the scapular notch, the nerve passing through the notch (fig. 545). It then ramifies in the supraspinous fossa of the scapula and, winding downward round the base of the spine over the neck of the scapula, enters the infraspinous fossa. It terminates by anastomosing with the circumflex (dorsal) scapular artery and the descending branch of the transverse cervical (posterior scapular) artery.

As it lies under cover of the sternomastoid muscle, it crosses the phrenic nerve and the scalenus anterior; and as it courses through the subclavian triangle, it is separated by the cervical fascia which descends from the omohyoid to the first rib, from the subclavian artery and brachial plexus of nerves. It is one of the chief vessels by which the collateral circulation is carried on after ligature of the subclavian in the third part of its course. At the lateral part of the subclavian triangle it is covered by the trapezius, and after passing over the transverse scapular ligament it pierces the supraspinous fascia and passes beneath the supraspinatus muscle, ramifying between it and the bone. In the infraspinous fossa it lies between the infraspinatus and the bone. The artery is accompanied by two veins.

The **branches of the transverse scapular** are:—(1) the **nutrient,** to the clavicle; (2) the **acromial** [r. acromialis] to the arterial rete or plexus on the acromial process, to reach which it pierces the trapezius; (3) the **articular,** to the acromioclavicular joint and shoulder-joint; (4) the **subscapular,** given off as the artery is passing over the transverse scapular ligament, descends to the subscapular fossa between the subscapularis and the bone, and anastomoses with the infrascapular branch of the circumflex (dorsal) scapular artery, and with the sub-

scapular and transverse cervical arteries; (5) the **supraspinous** branches, which ramify in the supraspinous fossa, and supply the supraspinatus muscle and the periosteum, and the nutrient artery to the bone; (6) the **infraspinous** branches, which ramify in a similar way in the infraspinous fossa, giving off twigs to the infraspinatus muscle, the periosteum, and the bone.

THE TRANSVERSE CERVICAL ARTERY

The **transverse cervical** artery [a. transversa colli], somewhat larger than the transverse scapular (suprascapular), runs like the latter vessel laterally and transversely across the root of the neck, but on a slightly higher plane, and a little above the clavicle. At its origin from the thyrocervical trunk it lies under the sternomastoid; on leaving the cover of this muscle, it crosses the upper part of the subclavian triangle, lying here only beneath the platysma and cervical

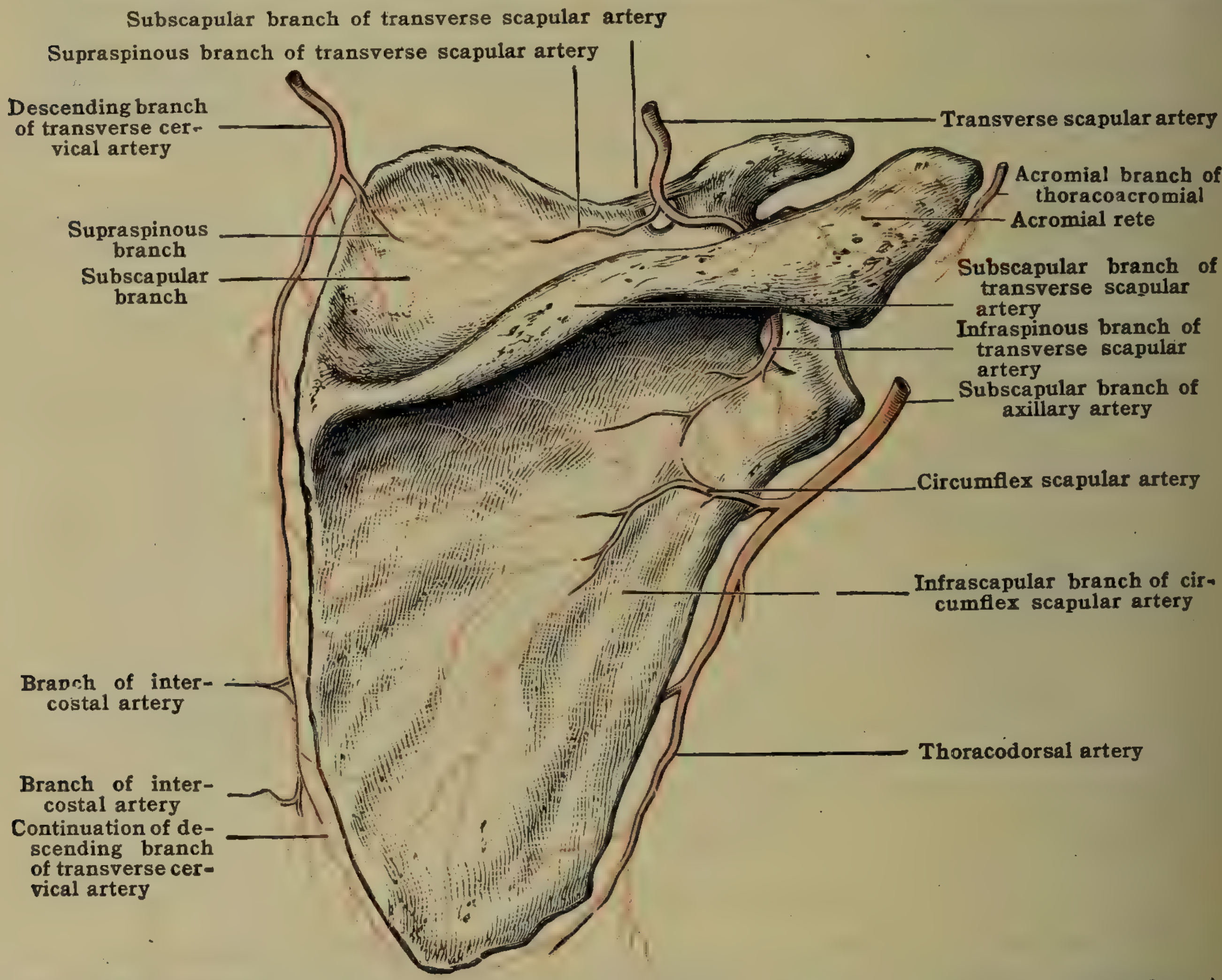


Fig. 541.—Scheme of Anastomoses of the Right Scapular Arteries. (Walsham.)

fascia; further laterally, it passes beneath the anterior margin of the trapezius and omohyoid muscle and, at the lateral margin of the levator scapulæ, divides into a descending (posterior scapular) and an ascending (superficial cervical) branch. In this course it crosses the phrenic nerve, the scalenus anterior, the brachial plexus, and the scalenus medius. Sometimes it passes between the cords of the brachial plexus.

The **branches of the transverse cervical artery** are:—(1) a descending (posterior scapular); and (2) an ascending (or superficial) cervical. The descending branch occasionally arises from the third portion of the subclavian artery.

(1) The **descending branch, or posterior scapular** [r. descendens] the apparent continuation of the transverse cervical artery, begins at the lateral border of the levator scapulæ, and, continuing its course beneath this muscle to the medial angle of the scapula, turns downward and skirts along the vertebral border of the bone, between the serratus anterior (magnus) in front and the levator scapulæ and rhomboideus minor and major behind, to the inferior angle, where it anastomoses with the subscapular artery. It gives off the following branches:—(*a*) **Supraspinous**, which ramifies between the supraspinous muscle and the trapezius, and sends branches through the muscle into the fossa, to anastomose with the transverse scapular artery. (*b*) **Infraspinous** branches, one or more of which enter the infraspinous fossa, and anastomose with the circumflex (dorsal) scapular. (*c*) **Subscapular** branches, which enter the subscapular fossa, and anastomose with the branches of the transverse scapular and subscapular arteries. (*d*) **Muscular** branches, to the muscles between which it runs and to the latissimus dorsi. These branches anastomose with muscular branches of the intercostal arteries.

(2) The **ascending branch** or **superficial cervical artery** [r. ascendens], smaller than the descending branch, ascends under the anterior margin of the trapezius, lying upon the levator scapulæ and splenius muscles. It supplies branches to the trapezius, levator scapulæ, and splenius muscles and to the posterior chain of lymphatic glands. It anastomoses with the superficial ramus of the descending branch of the occipital between the splenius and semispinalis capitis (complexus). It is accompanied by two veins. This artery may arise directly from the thyrocervical trunk or from the third part of the subclavian (fig. 537).

3. THE INTERNAL MAMMARY ARTERY

The **internal mammary** artery [a. mammaria interna] (a. thoracica interna NK) (figs. 537, 542) comes off from the lower part of the first portion of the subclavian, usually opposite the thyrocervical trunk (thyroid axis), close to

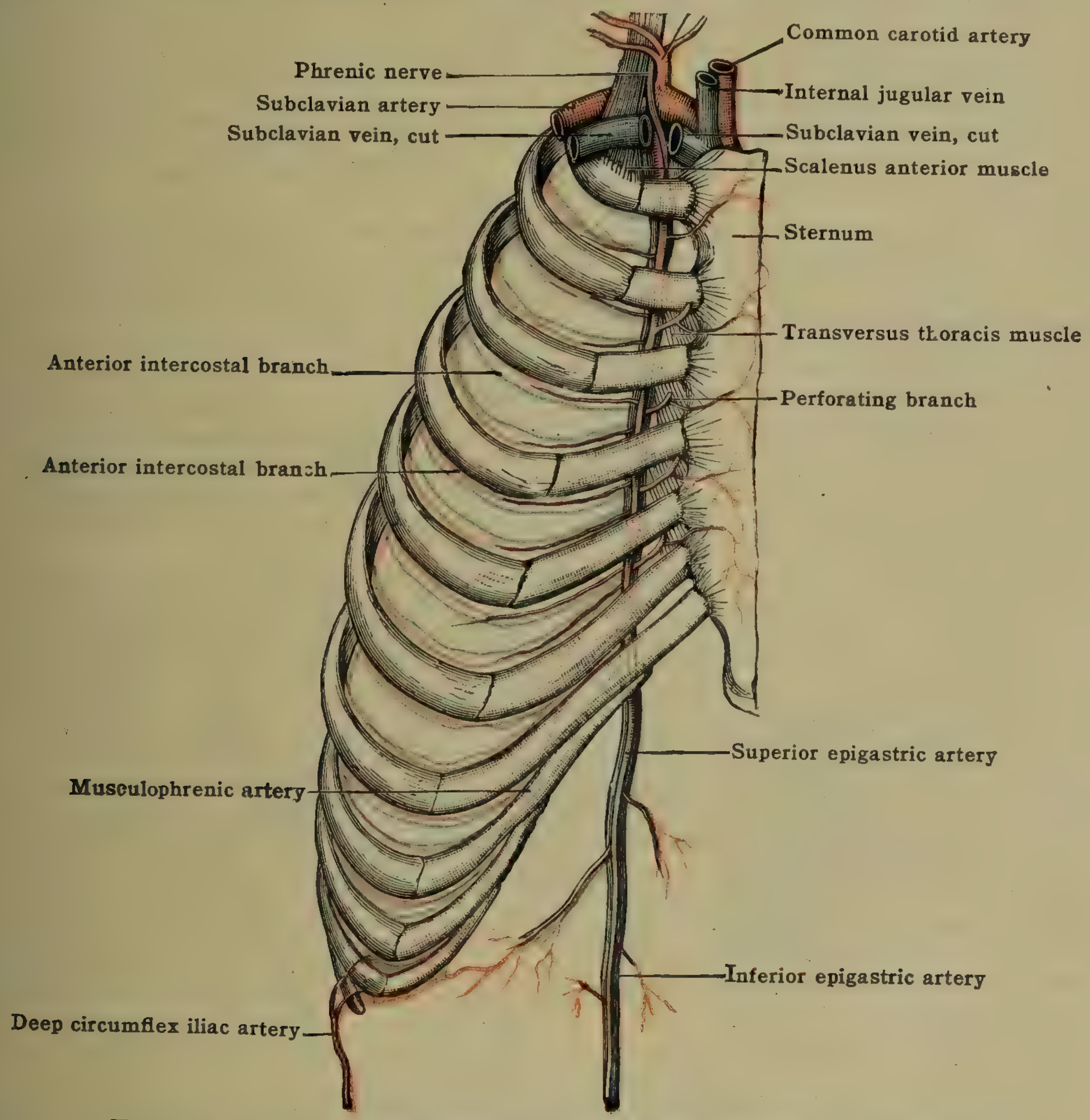


FIG. 542.—THE RIGHT INTERNAL MAMMARY ARTERY. (Walsham.)

the medial edge of the scalenus anterior. It descends with a slight inclination forward and medialward, under cover of the clavicle, and enters the thorax behind the cartilage of the first rib, and thence passes down behind the cartilages of the next succeeding ribs, about 1.2 cm. (½ in.) from the lateral margin of the sternum, to the sixth interspace, where it divides into the **superior epigastric** and the **musculophrenic.** It is accompanied by two veins, which unite into one trunk behind the first intercostal muscle; this passes to the medial side of the artery to open into the corresponding vena innominata, or occasionally on the right side into the vena cava superior. The artery may be divided into two portions, the *cervical* and the *thoracic*.

The **cervical portion** is covered by the sternomastoid muscle, subclavian vein, and internal jugular vein, and is crossed obliquely, in the lateromedial direction, by the phrenic nerve. It rests upon the pleura and courses around the upper part of the innominate vein. There is no branch from this part of the artery.

The **thoracic portion** lies behind the cartilages of the six upper ribs, and in the interspace between the ribs has in front of it the pectoralis major and the internal intercostal muscles and anterior intercostal membranes. Behind, it is in contact above with the pleura, but it is

separated from it lower down by slips of the transversus thoracis (triangularis sterni). On the left side, the artery between the fourth and sixth ribs may be said to be in the anterior mediastinum, the pleura here forming a notch for the heart. In the second and third spaces the artery, if wounded, can easily be tied; but in the fourth space the operation is attended with more difficulty. The remaining spaces are so narrow that a portion of the cartilage would have to be removed to expose the vessel.

The **branches of the internal mammary artery** (fig. 537) are:—(1) The pericardiophrenic; (2) the anterior mediastinal and thymic; (3) the bronchial; (4) the pericardiac; (5) the sternal; (6) the anterior intercostals; (7) the perforating; (8) the lateral costal; (9) the superior epigastric; and (10) the musculophrenic.

(1) The **pericardiophrenic** artery [a. pericardiophrenica], is a long slender vessel which comes off from the internal mammary just after it has entered the chest, and descends with the phrenic nerve, at first between the pleura and innominate vein; then (on the right side) between the pleura and the vena cava superior; and lastly, between the pleura and the pericardium to the diaphragm, where it anastomoses with the other diaphragmatic arteries. It gives branches both to the pleura and pericardium.

(2) The **anterior mediastinal** and **thymic** arteries [aa. mediastinales anteriores et thymicæ] come off irregularly from the internal mammary. They are of small size, and supply the connective tissue, fat, and lymphatics in the superior and anterior mediastina and the remains of the thymus gland.

(3) The **bronchial** branches [rr. bronchiales] are often wanting. When present they are supplied to the bronchi and the lower part of the trachea.

(4) The **pericardiac** branches are distributed to the anterior surface of the pericardium.

(5) The **sternal branches** [rr. sternales] enter the nutrient foramina in the sternum, and also supply the transversus thoracis (triangularis sterni).

(6) The **anterior intercostal** branches [rr. intercostales] (figs. 537, 542)—two in each of the five or six upper intercostal spaces—run laterally from the internal mammary artery, along the lower border of the rib above and the upper border of the rib below, and anastomose with the corresponding anterior and collateral branches of the aortic intercostals. The pair of branches for each intercostal space sometimes arises by a common trunk. The branches lie at first between the internal intercostal muscles and the pleura; afterward between the external and internal intercostal muscles. They supply the contiguous muscles, the pectoralis major, and the ribs.

(7) The **perforating** or **anterior perforating** branches [rr. perforantes] (aa. perforantes NK)—five or six in number, one corresponding to each of the five or six upper spaces—come off from the front of the internal mammary, and, perforating the internal intercostal muscles, pass forward between the costal cartilages to the pectoralis major, which they supply [*rr. musculares*]. The terminal twigs perforate the muscle close to the sternum, and are distributed to the integument [*rr. cutanei*]. The **second, third,** and **fourth perforating** supply the medial and deep surfaces of the mammary gland, and become greatly enlarged during lactation [*rr. mammarii*].

(8) The **lateral costal** branch [r. costalis lateralis] is given off close to the first rib, and descends behind the ribs laterally to the costal cartilages. It anastomoses with the upper intercostal arteries. This vessel is often of insignificant size, or absent.

(9) The **superior epigastric** artery [a. epigastrica superior] (fig. 542), or medial terminal branch of the internal mammary artery, leaves the thorax behind the seventh costal cartilage by passing through the costoxiphoid space in the diaphragm. It is the direct prolongation of the internal mammary downward. In the abdomen it descends behind the rectus muscle, between its posterior surface and its sheath, and, lower, entering the substance of the muscle, anastomoses with the inferior epigastric, a branch of the external iliac. It gives small branches to the diaphragm, the rectus muscle, the skin, the peritoneum, and a small branch which follows the falciform ligament toward the liver.

(10) The **musculophrenic** artery [a. musculophrenica], or lateral terminal branch of the internal mammary artery, skirts laterally and downward behind the costal cartilages of the false ribs along the costal attachments of the diaphragm, which it perforates opposite the ninth rib. It terminates, much reduced in size, at the tenth or eleventh intercostal space by anastomosing with the ascending branch of the deep circumflex iliac artery. It gives off in its course the following small branches:—(*a*) the **phrenic** for the supply of the diaphragm; (*b*) the **anterior intercostals,** two in number for each of the lower five or six intercostal spaces, which are distributed like those to the upper spaces, already described, and anastomose like them with the corresponding anterior branches of the lower aortic intercostals; (*c*) the **muscular** for the supply of the oblique muscles of the abdomen.

4. THE COSTOCERVICAL TRUNK

The **costocervical trunk** [truncus costocervicalis] (figs. 525, 543) is a short stem which arises usually from the back part of the second portion of the subclavian artery, behind the scalenus anterior on the right side, but commonly just medial to that muscle on the left side. Its course is upward and backward above the dome of the pleura and then downward to the thorax, before entering which it divides into its two terminal branches.

The **branches of the costocervical trunk** are:—(1) the superior intercostal and (2) the deep cervical.

(1) The **superior intercostal** [a. intercostalis suprema] (fig. 543) continues the direction of the costocervical trunk, passing downward into the thorax in front of the neck of the first rib.

It sometimes terminates opposite the first intercostal space by becoming the first intercostal artery. Usually, however, it is prolonged downward over the neck of the second rib and supplies the second intercostal space in addition. It communicates with the highest aortic intercostal artery. As it crosses the neck of the first rib the superior intercostal lies upon the ventral side of the first intercostal nerve and to the lateral side of the superior thoracic ganglion of the sympathetic. The branches to the first and second intercostal spaces resemble in course and distribution the succeeding intercostals derived from the thoracic aorta (see p. 661). Like the aortic intercostals they give off **dorsal** [rr. dorsales] and **spinal branches** [rr. spinales]. A small branch representing the right dorsal aorta may arise from the right superior intercostal, costocervical or subclavian artery (see p. 633).

(2) The **deep cervical** artery [a. cervicalis profunda] passes directly backward, first between the seventh and eighth cervical nerves, and then between the transverse process of the seventh cervical vertebra and the neck of the first rib, having the body of the seventh cervical vertebra to its medial side, and the intertransverse muscle to its lateral side. It then turns upward in the groove between the transverse and spinous processes of the cervical vertebræ lying upon the semispinalis colli and covered by the semispinalis capitis (complexus). Between these muscles it anastomoses with the deep branch of the descending branch (princeps cervicis) of the occipital artery. It gives off a spinal branch which enters the vertebral canal through the intervertebral foramen with the eighth cervical nerve.

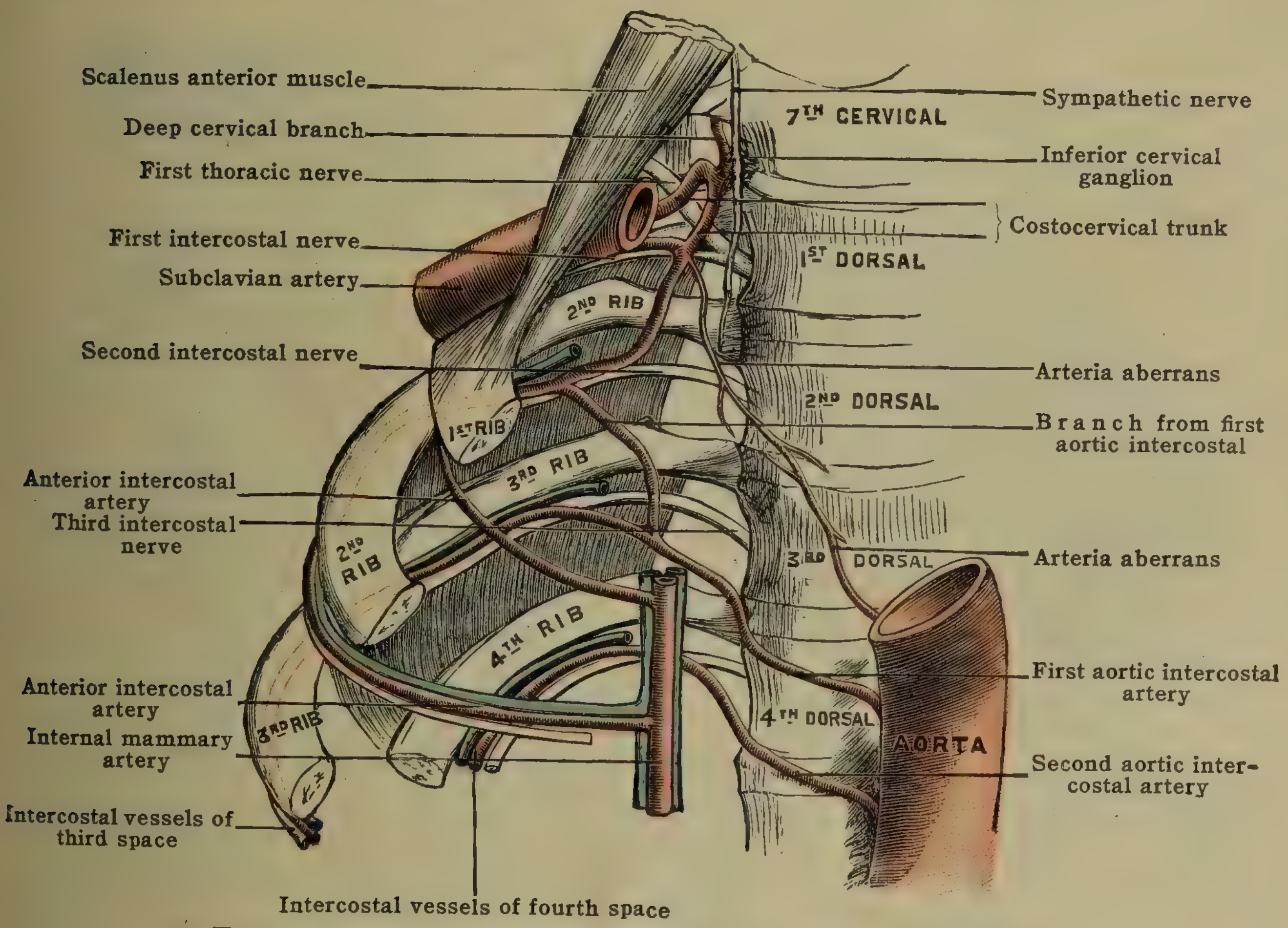


FIG. 543.—THE RIGHT COSTOCERVICAL TRUNK. (Walsham.)

Ligature of the third part of the subclavian artery is best performed by an angular incision, the horizontal portion along the center of the clavicle, and the vertical one along the posterior border of the sternomastoid, with partial division of this and the trapezius when closely adjacent. The chief points to bear in mind are the venous plexus into which the external jugular, transverse cervical, transverse scapular, and cephalic veins enter; the omohyoid and division of the fascia which ties this to the clavicle; identification of the lateral margin of the scalenus anterior and the scalene tubercle; care of the transverse scapular artery and the descending branch of the transverse cervical. The needle is passed from above downward so as not to include the lowest cord of the brachial plexus, the vein, if distended, being depressed with a blunt hook. If the nerve to the subclavius be seen, it must be uninjured, as it occasionally forms an important part of the phrenic. In aneurism of the axillary artery the transverse scapular and transverse cervical vessels may form the main part of the collateral circulation and in exposing the subclavian artery for purposes of ligation they should be carefully preserved.

Collateral circulation after ligature of the second and third parts of the subclavian.—Here the following three sets of vessels are those chiefly involved (fig 525):—

The transverse scapular, the transverse cervical,	with	The thoracoacromial, infra- and subscapular, and circumflex scapular.
The superior intercostal, the aortic intercostals, and the internal mammary,	with	The lateral thoracic and subscapular arteries
Numerous unnamed branches passing through the axilla from branches of the subclavian,	with	Branches of the axillary.

THE AXILLARY ARTERY

The term axillary is applied to that portion of the main arterial stem of the upper limb that passes through the axillary fossa. The **axillary** artery [a. axillaris] (fig. 544) therefore is continuous with the subclavian above and with the brachial below. It extends from the lateral border of the first rib to the lower edge of the teres major muscle, and has the shoulder-joint and the neck of the humerus to its lateral side. When the arm is placed close to the side of the body, the artery forms a gentle curve with its convexity upward; but when the arm is at right angles to the trunk in the ordinary dissecting position, the vessels takes a nearly straight course, which will then be indicated by a line drawn from the middle of the clavicle to the groove on the medial side of the coracobrachialis and biceps muscles. The axillary artery is at first deeply placed beneath the pectoral

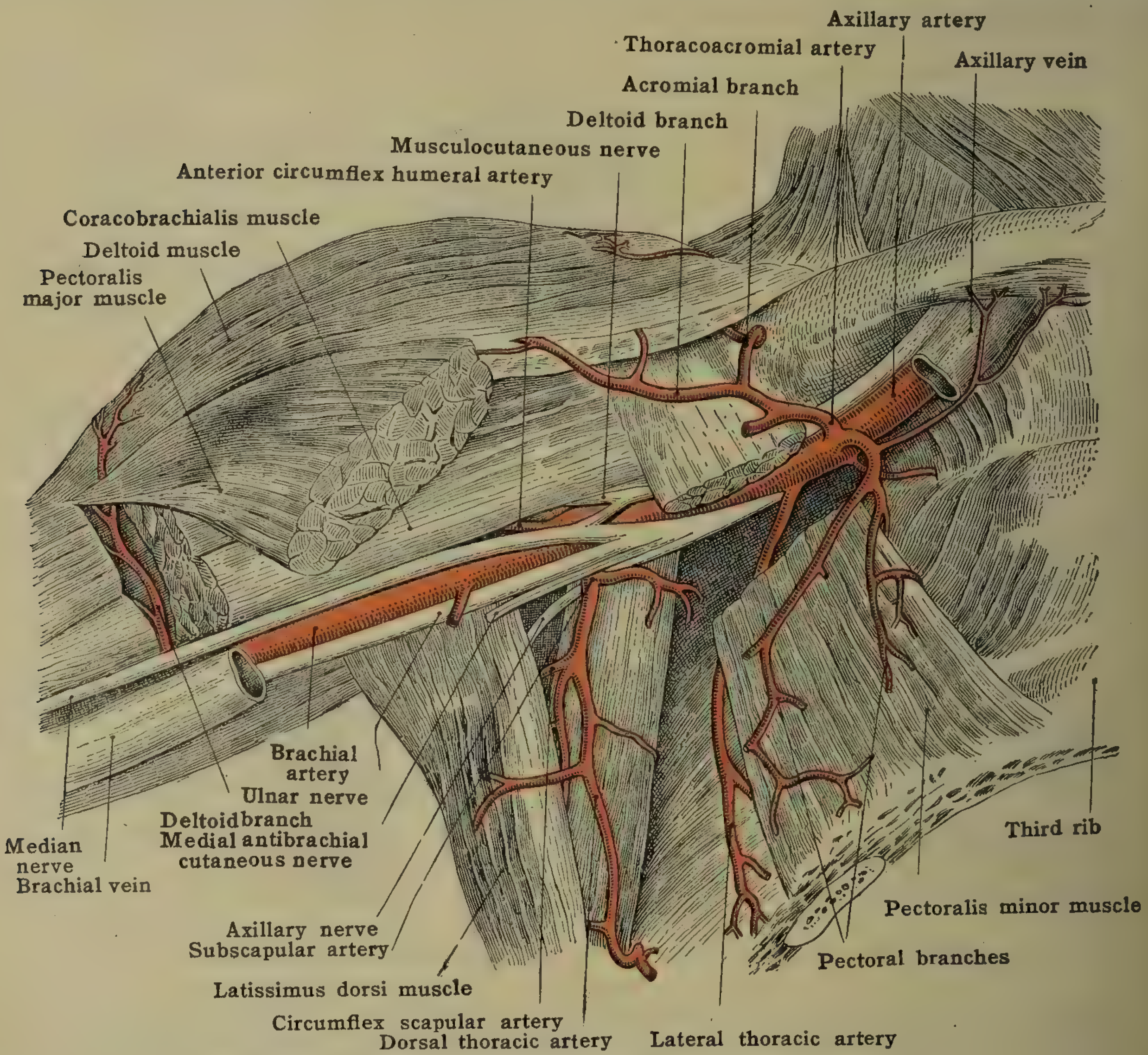


Fig. 544.—The Axillary Artery. (After Spalteholz.)

muscles, but its distal end is superficial, being covered only by the skin and the superficial fascia and deep fascia. It is described as having three parts, first, second, and third, which lie respectively above, behind, and below the pectoralis minor.

The First Part of the Axillary Artery

The **first part of the axillary artery** extends from the lateral border of the first rib to the upper border of the pectoralis minor. It measures about 2.5 cm. (1 in.) in length.

Relations.—**In front** it is covered by the skin, superficial fascia, the lower part of the platysma, the deep fascia, the pectoralis major, the coracoclavicular (costocoracoid) fascia, the subclavius muscle, and by the clavicle when the arm hangs by the side. The cephalic and thoracoacromial veins and the lateral anterior thoracic nerve and the axillary lymphatic trunk, cross over it. A layer of the prevertebral fascia which has passed under the clavicle also descends in front of it.

Behind, it rests upon the first intercostal space and first intercostal muscle, the first digitation and sometimes a portion of the second digitation of the serratus anterior (magnus) muscle and a part of the second rib. The medial cord of the brachial plexus and the long thoracic nerve, on its way to the serratus anterior muscle, pass behind it. To its **lateral side,** and somewhat on a higher plane, are the lateral and posterior cords of the brachial plexus. To its **medial side,** and on a slightly anterior plane, is the axillary vein. The medial anterior thoracic nerve courses between the vein and the artery.

The Second Part of the Axillary Artery

The **second part of the axillary artery** (fig. 544) lies behind the pectoralis minor deep in the axilla. It measures 3 cm. (a little more than 1 in.) in length.

Relations.—In front, in addition to the pectoralis minor, it is covered by the pectoralis major and the integument. **Behind** it is separated by a considerable interval, containing loose connective tissue and fat, from the subscapularis muscle; the posterior cord of the brachial plexus lies immediately behind it. To the **medial side,** but separated from the artery by the medial cord of the brachial plexus, is the axillary vein. To the **lateral side** is the lateral cord of the brachial plexus, and at some little distance the coracoid process.

It is thus seen that the second portion of the axillary artery is surrounded on three sides by the cords of the brachial plexus.

The Third Part of the Axillary Artery

The **third part of the axillary artery** (fig. 544) extends from the lower border of the pectoralis minor to the lower border of the teres major. Its upper half lies deeply placed within the axilla, beneath the lower edge of the pectoralis major muscle, but its lower half is not covered anteriorly by muscle. It measures about 7.5 cm. (3 in.) in length.

Relations.—In front it has, in addition to the skin and superficial fascia, the pectoralis major above, and lower down the deep fascia of the arm. It is crossed obliquely by the medial root of the median nerve and by the lateral brachial vena comitans. **Behind,** it lies successively upon the subscapularis, the latissimus dorsi, and teres major muscles. From the first-named muscle it is separated at first by a considerable mass of fat and cellular tissue. The radial (musculospiral) and axillary (circumflex) nerves intervene between the artery and the muscles. On its **lateral side** it is separated from the bone by the coracobrachialis, by which it is partly overlapped, this muscle and the short head of the biceps serving as a guide to the artery in ligature. For a part of its course it has also the musculocutaneous nerve and the lateral root of the median nerve to its lateral side.

To the **medial side** it has the axillary vein, the ulnar nerve, the medial antibrachial (internal) and brachial (lesser internal) cutaneous nerves, and the medial root of the median nerve. The ulnar nerve is between the artery and the vein. The medial antibrachial (internal) cutaneous nerve is a little in front of the artery as well as medial to it.

Branches of the Axillary Artery

The **branches of the axillary artery,** with the exception of those arising from the third part of the artery, display great variability in number and site of origin. The chief branches in their most common order are listed below.

The **first part** gives off:—(1) The superior thoracic; and (2) the thoracoacromial.

The **second part** gives off:—(3) The lateral thoracic.

The **third part** gives off:—(4) The subscapular; (5) the anterior humeral circumflex; and (6) the posterior humeral circumflex.

1. The **superior thoracic** [a. thoracalis suprema] is variously given off either directly from the axillary artery, or by a trunk common to it and to the thoracoacromial (see fig. 544). It passes behind the axillary vein across the first intercostal space, supplying the intercostal muscles and the upper portion of the serratus anterior, and anastomoses with the intercostal arteries. At times it sends a branch between the pectoralis major and minor, which then, as a rule, takes the place of the pectoral branch of the thoracoacromial.

2. The **thoracoacromial** or acromiothoracic axis [a. thoracoacromialis] arises from the first part of the axillary just above the upper border of the pectoralis minor. It is a short trunk, and, coming off from the front of the artery, pierces the coracoclavicular fascia, and then divides into three or four small branches, named from their direction:—(*a*) the acromial; (*b*) the deltoid; (*c*) the pectoral, and (*d*) the clavicular.

(*a*) The **acromial** branch [r. acromialis] passes laterally across the coracoid process, frequently through the deltoid muscle, which it supplies, and to the acromion. Here it forms by anastomosing with the anterior and posterior circumflex and transverse scapular (suprascapular) arteries, the so-called acromial rete, or plexus of vessels on the surface of the acromion (fig. 541).

(*b*) The **deltoid** branch [r. deltoideus] runs downward with the cephalic vein in the interval between the pectoralis major and the deltoid, and, supplying lateral offsets to these muscles and the adjacent integument, anastomoses with the anterior and posterior circumflex humeral arteries.

(*c*) The **pectoral** branch [r. pectoralis] passes between the pectoralis major and minor muscles, both of which it supplies. In the female, the branches which perforate the pectoralis major are often of large size, and supply the superimposed mammary gland.

(*d*) The **clavicular** branch passes upward beneath the clavicle, supplies the subclavius muscle, and anastomoses with the transverse scapular artery.

3. The **lateral thoracic** artery [a. thoracalis lateralis] may arise indirectly from the axillary, as a branch of the thoracoacromial or of the subscapular, or may be represented by two or more vessels. It descends along the lower border of the pectoralis minor, under cover of the pectoralis major, to the region of the second to the fourth or fifth intercostal spaces. It supplies both pectoral muscles

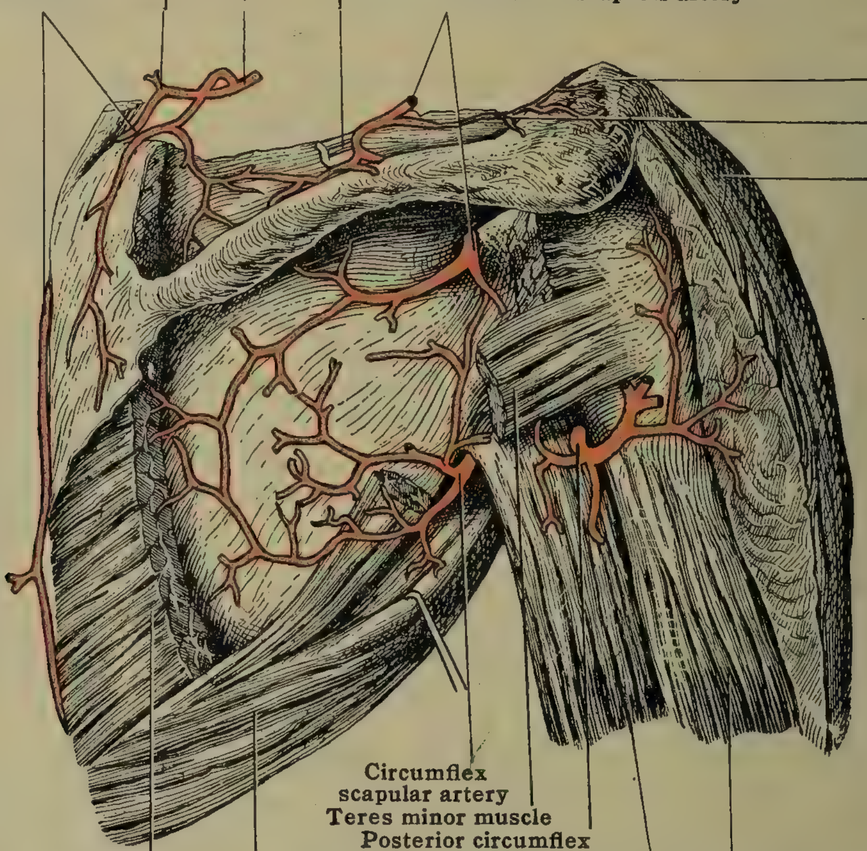


FIG. 545.—THE ARTERIES OF THE SHOULDER. (After Spalteholz.)

and the serratus anterior (magnus), sends branches around the lower border of the pectoralis major to the mammary gland, and terminates in the intercostal muscles by anastomosing with the aortic intercostals and the internal mammary. It also furnishes branches to the lymph-nodes of the axillary fossa. The branches to the mammary gland in the female are often of large size.

4. The **subscapular** artery [a. subscapularis] is the largest branch of the axillary. It arises opposite the lower border of the subscapularis, and runs in a downward and medial direction along the anterior border of that muscle under cover of the latissimus dorsi. It supplies the subscapularis, teres major, latissimus dorsi, and serratus anterior (magnus) muscles, and gives branches to the nodes in the axillary fossa. It is accompanied by two veins, which usually unite and then receive the circumflex (dorsal) scapular vein, and open as a single vein of large size either into the axillary or at the confluence of the medial brachial vena comitans with the basilic vein.

About 2.5 or 3.7 cm. (1 or 1½ in.) from its origin, the subscapular artery divides into two end branches, (1) the circumflex (dorsal) scapular, and (2) the dorsal thoracic.

(1) The **circumflex scapular** artery [a. circumflexa scapulæ], or dorsal scapular, arising from the subscapular, usually at the point above mentioned, passes backward through the triangular space bounded by the subscapularis above, the teres major below, and the long head of

the triceps laterally, and then between the teres minor and the axillary border of the scapula, which it commonly grooves. It thus reaches the infraspinous fossa, where, under cover of the infraspinatus, it anastomoses with the transverse scapular (suprascapular) artery and the descending branch of the transverse cervical (posterior scapular) (fig. 541). As it passes through the triangular space, it gives off a ventral branch which ramifies between the subscapularis and the bone, supplying branches to the subscapularis, to the scapula, and to the shoulder-joint. A second branch is often given off near the triangular space and passes downward between the teres major and teres minor, supplying both muscles (fig. 545).

(2) The **dorsal thoracic** artery [a. thoracodorsalis] continues in the course of the subscapular as far as the angle of the scapula, where it divides into branches which supply the neighboring muscles and anastomose with the circumflex scapular, the descending branch of the transverse cervical (posterior scapular), the lateral thoracic, and intercostal arteries.

5. The **anterior circumflex humeral** artery [a. circumflexa humeri anterior] (ventralis NK) usually quite a small vessel, comes off from the lateral side of the axillary artery, generally opposite the posterior circumflex. It passes beneath the coracobrachialis and short and long heads of the biceps, winding transversely round the front of the surgical neck of the humerus, across the intertubercular (bicipital) groove, and anastomoses with the posterior circumflex and thoraco-acromial arteries. It gives off the following small branches:

(*a*) The **bicipital** or ascending, which runs up the intertubercular groove to supply the long tendon of the biceps and the shoulder-joint; and (*b*) a **pectoral** or descending branch, which runs downward along the insertion of the pectoralis major, and supplies the tendon of that muscle.

6. The **posterior circumflex humeral** artery [a. circumflexa humeri posterior] (dorsalis NK) (fig. 545) arises from the posterior aspect of the axillary, just below the lower border of the subscapularis muscle. It passes through the quadrilateral space, bounded by the teres minor above, the latissimus dorsi and teres major below, the humerus laterally, and the long head of the triceps medially, and, winding round the back of the humerus beneath the deltoid, breaks up under cover of that muscle into a leash of branches, which for the most part enter its substance. The axillary (circumflex) nerve and two venæ comitantes run with it. It anastomoses with the anterior circumflex, the arteries on the acromion, and the profunda artery.

In addition to the leash of vessels to the deltoid, it gives off the following small branches:—(*a*) **nutrient**, to the greater tuberosity of the humerus; (*b*) **articular**, to the back of the shoulder-joint; (*c*) **acromial**, to the plexus on the acromion; and (*d*) **muscular**, to the teres minor and long and short heads of the triceps. One or more of these branches to the triceps descend either between the lateral and long head or in the substance of that muscle, to anastomose with an ascending branch from the profunda artery. It is by means of this anastomosis that the collateral circulation is chiefly carried on when the axillary or the brachial artery is tied between the origins of the posterior circumflex and profunda arteries.

THE BRACHIAL ARTERY

The **brachial** artery [a. brachialis] (fig. 546), the continuation of the axillary, extends from the lower border of the teres major to a little below the center of the crease at the bend of the elbow, where it divides, opposite the neck of the radius into the radial and ulnar arteries. The artery is at first medial to the humerus; but as it passes down the arm it gradually gets in front of the bone, and at the bend of the elbow it lies midway between the two epicondyles. Hence, in controlling hemorrhage, the artery should be compressed laterally against the bone in its proximal third, laterally and backward in its middle third, and directly backward in its distal third. Throughout the greater part of its course the artery is superficial, being overlapped slightly on its lateral side by the coracobrachialis and biceps muscles; but at the bend of the elbow it sinks deeply beneath the lacertus fibrosus of the biceps into the triangular interval (antecubital fossa) between the brachioradialis and pronator teres, and bifurcates at the proximal border of the latter muscle (fig. 547). A line drawn from the groove on the medial side of the coracobrachialis and biceps muscles to a point midway between the epicondyles of the humerus will indicate the course of the brachial artery. The artery is accompanied by two veins which frequently communicate across it. In addition to the branches named below, the artery gives off numerous unnamed muscular branches, usually from the lateral side; one in particular, which supplies the biceps muscle, is frequently of large size.

Relations.—In front, the artery is covered by the integument and superficial and deep fasciæ, and at the bend of the elbow by the lacertus fibrosus of the biceps, and in muscular subjects by the overlapping margins of the brachioradialis and pronator teres. In the middle

third of the arm it is crossed obliquely from the lateral to the medial side by the median nerve, and at the bend of the elbow by the median cubital vein, the bicipital fascia intervening.

Behind, it lies successively on the long head of the triceps, from which it is separated by the radial (musculospiral) nerve and profunda brachii artery, on the medial head of the triceps, on the insertion of the coracobrachialis, and thence to its bifurcation on the brachialis muscle.

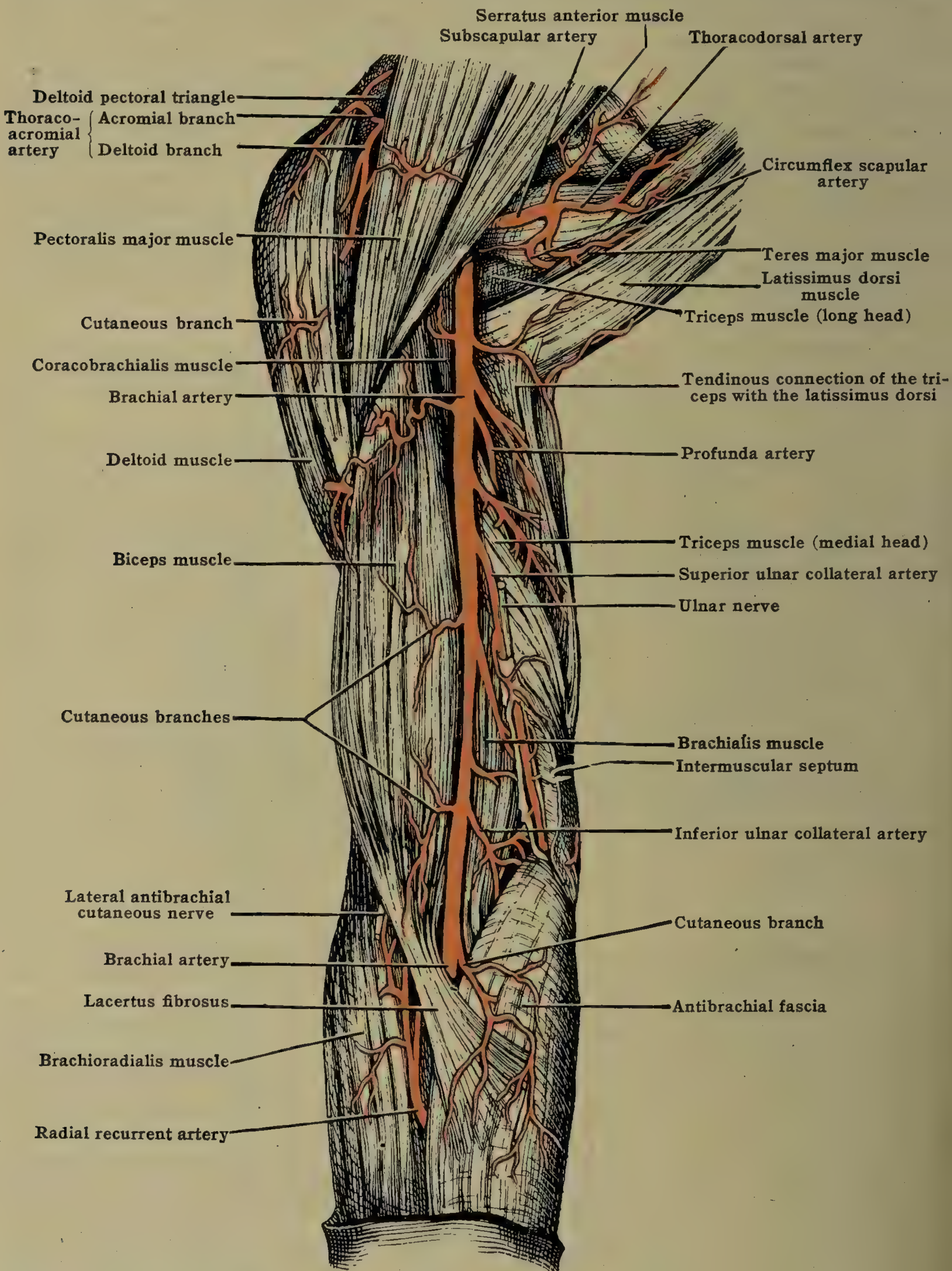


FIG. 546.—THE BRACHIAL ARTERY. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

Laterally the brachial artery is overlapped by the coracobrachialis above, and the muscular belly of the biceps below. The median nerve is in close contact with the lateral side of the artery in the upper third of its course, but in the middle third crosses the artery obliquely to gain the medial side. The tendon of the biceps lies laterally to the artery in its lower portion.

Medial to the artery in the upper part of its course are the medial antibrachial (internal) cutaneous and the ulnar nerves; the latter nerve, however, leaves the artery about the origin of the ulnar collateral (inferior profunda) branch, to pass, with that vessel, to the medial epicondyle. Lower down, the medial antibrachial cutaneous nerve also leaves the artery, by piercing the deep fascia. The median nerve is in close contact with the medial side of the

artery in its lower third and at the bend of the elbow. The basilic vein is superficial to it, and a little to its medial side in the greater part of its course, but separated from it by the deep fascia. The brachial artery is accompanied by two or more venæ comitantes.

In **ligature of the artery** here the line extends from the midaxillary region above, prolonged to the center of the front of the elbow. The only structures seen should be the medial edge of the biceps, the basilic vein, and the median nerve. Fig. 548 shows **collateral circulation** after ligature of the brachial, according as the vessel is tied above or below the profunda brachii, or below the superior ulnar collateral.

Branches of the Brachial Artery

The **branches of the brachial artery** are: (1) The profunda brachii; (2) the nutrient artery to the humerus; (3) the superior ulnar collateral (inferior profunda); (4) the inferior ulnar collateral (anastomotica magna); and (5) the terminal branches—the radial and ulnar arteries. The various anastomoses of the brachial artery are shown in fig. 548.

Fig. 547.—The Brachial Artery at the Elbow, Left Side, Front View. (From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

(1) The Profunda Artery

The **profunda brachii** (superior profunda) is the largest branch of the brachial. It arises from the medial and posterior aspect of the artery, a little below the inferior border of the tendon of the teres major. It at first lies to the medial side of the brachial, but soon passes behind that vessel, and, sinking between the medial and long heads of the triceps with the radial (musculospiral) nerve. Having given origin to the medial collateral artery, the remainder of the vessel, the radial collateral artery, follows the radial nerve, lying between the bone and the lateral head of the triceps. On reaching the lateral supracondyloid ridge of the humerus it perforates the lateral intermuscular septum, and, continuing forward between the brachioradialis and brachialis to the front of the lateral epicondyle, ends by anastomosing with the radial recurrent artery. Before perforating the septum it sends a branch distally to anastomose with the dorsal interosseous recurrent and with the inferior ulnar collateral (figs. 550, 552).

It gives off the following branches:

(a) The **deltoid** branch [r. deltoideus] which may, however, arise from the brachial itself or from the superior ulnar collateral. It runs across the anterior surface of the humerus, under cover of the coracobrachialis and biceps, and supplies the brachialis and deltoid.

(b) The **medial collateral** artery [a. collateralis media] runs in the substance of the medial head of the triceps as far as the elbow, where it often terminates in the articular rete.

(c) The **radial collateral** artery [a. collateralis radialis] is described above.

(d) A **nutrient humeral** artery [a. nutritia humeri], usually accessory to a larger one from the brachial itself, enters a canal above and to the medial side of the sulcus for the radial nerve.

(2) The Nutrient Humeral Artery

The **nutrient humeral** artery [a. nutritia humeri] arises near the origin of the superior ulnar collateral or, occasionally, from that artery. It traverses the brachialis muscle and enters a foramen usually just beyond the middle of the bone, immediately anterior to the proximal end of the medial epicondylic ridge.

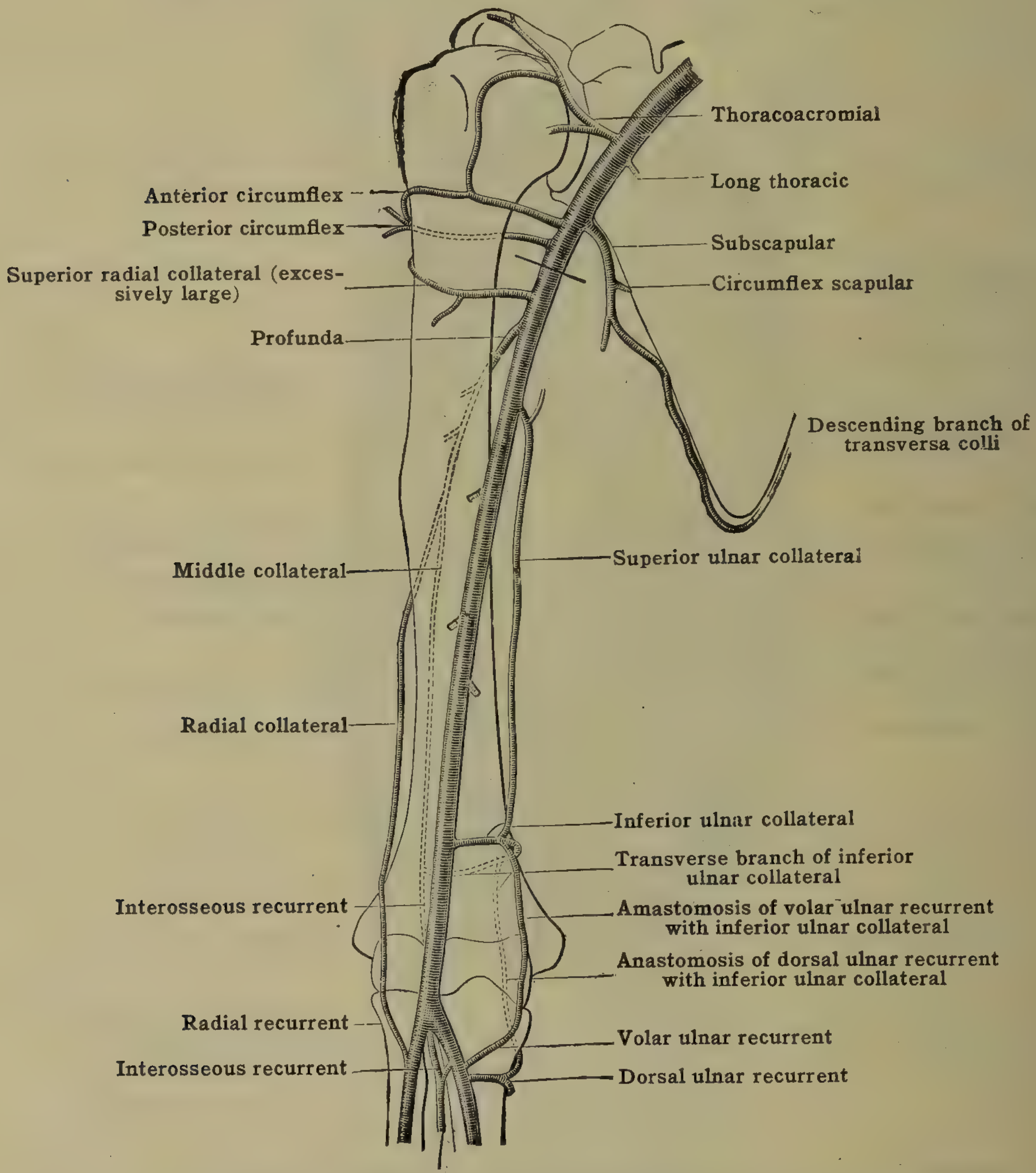


Fig. 548.—Diagram of the Anastomoses of the Brachial Artery. (MacCormac and Anderson.)

(3) The Superior Ulnar Collateral Artery.

The **superior ulnar collateral** artery [a. collateralis ulnaris superior] (proximalis NK) arises from the medial side of the brachial, usually about the level of the insertion of the coracobrachialis, sometimes from a trunk common to it and to the profunda brachii. It passes with the ulnar nerve medially and downward through the medial intermuscular septum, and then along the medial head of the triceps to the back of the medial epicondyle, where, under cover of the deep fascia and the origin of the flexor carpi ulnaris from the olecranon and medial epicondyle, it anastomoses with the inferior ulnar collateral and with the dorsal

ulnar recurrent. It frequently supplies the nutrient artery to the humerus. It gives branches to the triceps, to the elbow-joint, and a branch which passes in front of the medial epicondyle to anastomose with the volar ulnar recurrent and the inferior ulnar collateral.

(4) The Inferior Ulnar Collateral Artery

The **inferior ulnar collateral** artery [a. collateralis ulnaris inferior] (distalis NK) or anastomotica magna arises from the medial side of the brachial, about 5 cm. (2 in.) above its bifurcation into the radial and ulnar arteries, and, running medially and downward across the brachialis, divides into two branches, a posterior and an anterior. The **posterior** pierces the medial intermuscular septum, winds round the medial supracondylar ridge of the humerus, and pierces the triceps, between which and the bone it anastomoses with the dorsal ulnar recurrent. By means of a lateral branch, it anastomoses also with a branch of the profunda brachii, and to a lesser extent with the interosseous recurrent, forming an arterial arch or rete around the upper border of the olecranon fossa. The **anterior** branch passes medially and downward between the brachialis and pronator teres, and anastomoses in front of the medial epicondyle, but beneath the pronator teres, with the volar ulnar recurrent (fig. 550).

THE ULNAR ARTERY

The **ulnar** artery [a. ulnaris] (figs. 549 and 552), the larger of the two terminal branches of the brachial, begins opposite the neck of the radius in the middle line of the forearm. Thence through the proximal half of the forearm it runs beneath the pronator teres and superficial flexor muscles, and, having reached the ulnar side of the forearm about midway between the elbow and the wrist, it passes directly downward, being merely overlapped by the flexor carpi ulnaris. Crossing the transverse carpal (anterior annular) ligament immediately to the radial side of the pisiform bone, it enters the palm, where it divides into two branches, which enter respectively into the formation of the superficial and deep volar arches. The artery is accompanied by two veins, which anastomose with each other by frequent cross-branches, and usually terminate in the brachial venæ comitantes. The ulnar nerve is at first some distance from the artery, but approaches the vessel at the junction of its proximal and middle thirds, and then lies close to its medial or ulnar side. The course of the artery in the distal two-thirds of the forearm is indicated by a line drawn from the front of the medial epicondyle to the radial side of the pisiform bone; and in the proximal third of the forearm by a line drawn in a gentle curve with its convexity to the medial side from 2.5 cm. (1 in.) below the center of the bend of the elbow to a point in the former line at the junction of its proximal and middle thirds. The artery throughout its course is best reached through the interval between the flexor carpi ulnaris and the flexor digitorum sublimis.

The relations of the artery will be given in detail in the forearm, and in the palm of the hand. The **relations in the forearm** are:

In front.—In the proximal half of the forearm the ulnar artery is deeply placed beneath the pronator teres, the flexor carpi radialis, the palmaris longus, and the flexor digitorum sublimis. In the distal half it is comparatively superficial, being merely overlapped above by the tendon of the flexor carpi ulnaris, while the last inch or so of the vessel is only covered as a rule by the skin and superficial and deep fasciæ. As the artery lies beneath the pronator teres, it is crossed from the medial to the lateral side by the median nerve, the deep head of origin of the muscle intervening, when present. The distal part of the artery is crossed by the palmar cutaneous branch of the ulnar nerve. In **ligature of the artery** in the middle of the forearm, the white line and sulcus between the flexor carpi ulnaris and the sublimis must be identified. A small muscular branch will often lead down to the artery.

Behind.—For about 2.5 cm. (1 in.) of its course the artery lies upon the brachialis; but thence, as far as the transverse carpal (anterior annular) ligament, upon the flexor digitorum profundus, which separates it above from the interosseous membrane and bone, and at the wrist from the pronator quadratus. The artery is bound down to the flexor digitorum profundus by bands of fascia. To the **lateral side** in the distal two-thirds of its course is the flexor digitorum sublimis. To the **medial side** in the distal two-thirds is the flexor carpi ulnaris, the guide to the vessel. The ulnar nerve, as it enters the forearm from behind the medial epicondyle, is at first some distance from the artery, being separated from it in its proximal third by the flexor digitorum sublimis; but in its distal two-thirds is in close contact with the vessel on its ulnar side.

The **branches of the ulnar artery in the forearm** are: (1) the ulnar recurrent arteries; (2) the common interosseous; (3) muscular; (4) dorsal ulnar carpal; (5) volar ulnar carpal.

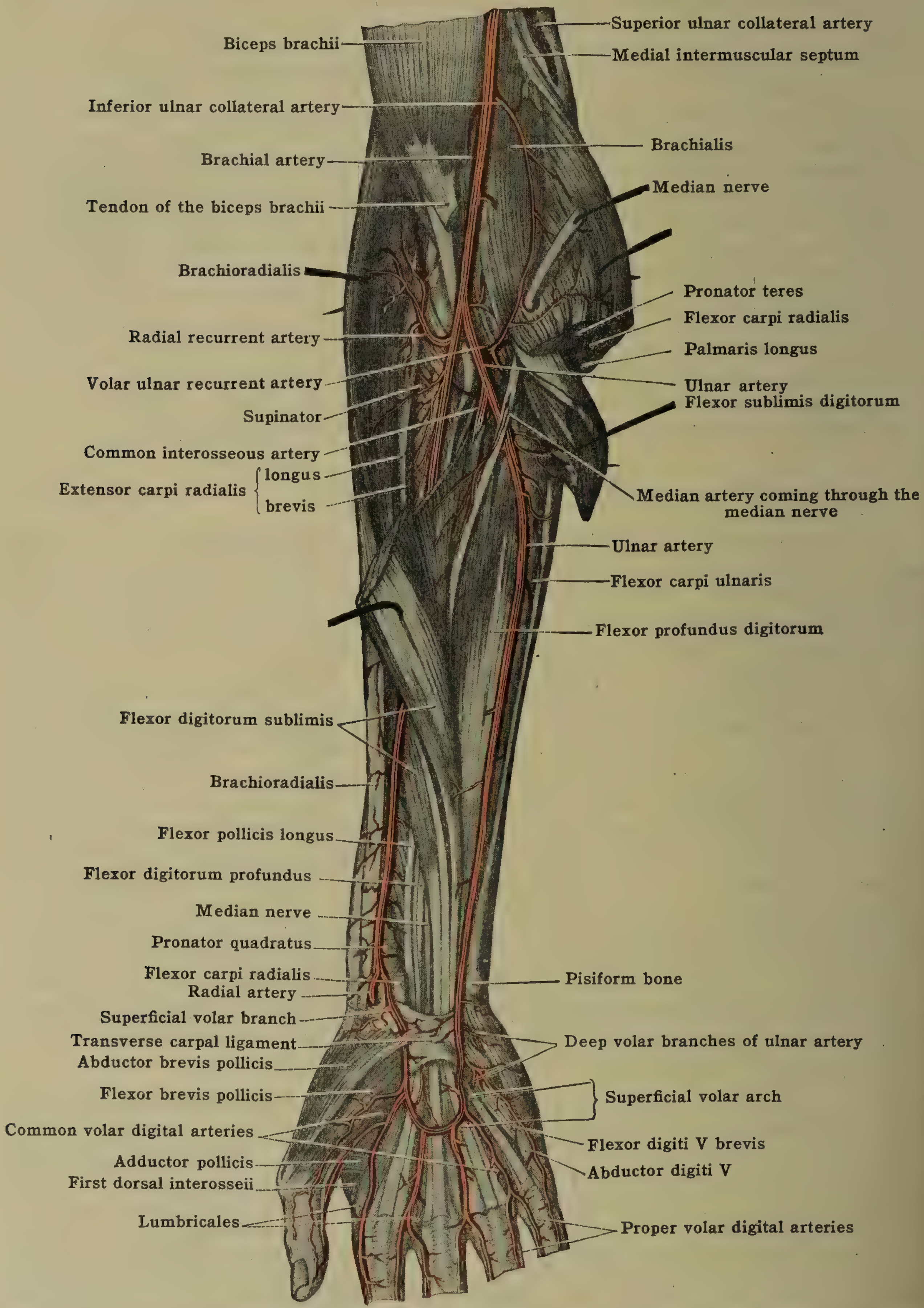


FIG. 549.—THE VOLAR ARTERIES OF THE FOREARM AND HAND. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

1. The **ulnar recurrent** arteries [aa. recurrentes ulnares] are two, the volar, and dorsal. The *volar* is a small branch which arises from the medial side of the ulnar artery, separately or in common with the dorsal ulnar recurrent. Running between the lateral edge of the pronator teres and the brachialis, it anastomoses in front of the medial epicondyle with the inferior and superior ulnar collaterals. It supplies branches to the muscles between which it runs, and to the skin. The *dorsal*, larger than the volar, comes off from the medial side of the ulnar artery, either a little beyond the latter branch, or in common with it, and, passing between the flexores digitorum sublimis and profundus, reaches the back of the medial epicondyle, where it lies with the ulnar nerve between the two heads of origin of the flexor carpi ulnaris. It supplies the

contiguous muscles, the elbow-joint and the ulnar nerve, and anastomoses with the inferior and superior ulnar collaterals, and with the interosseous recurrent, forming the so-called *rete olecrani.*

2. The **common interosseous** artery [a. interossea communis] is a short thick trunk 1.2 cm. (½ in.) or so in length, which comes off from the lateral and dorsal aspect of the ulnar artery about 2.5 cm. (1 in.) from its origin, and just before that artery is crossed by the median nerve. It passes backward and downward between the flexor pollicis longus and the flexor digitorum profundus, toward the triangular interval bounded by the upper border of the interosseous membrane, the oblique ligament, and the lateral border of the ulna, where it divides into the volar and dorsal interosseous arteries.

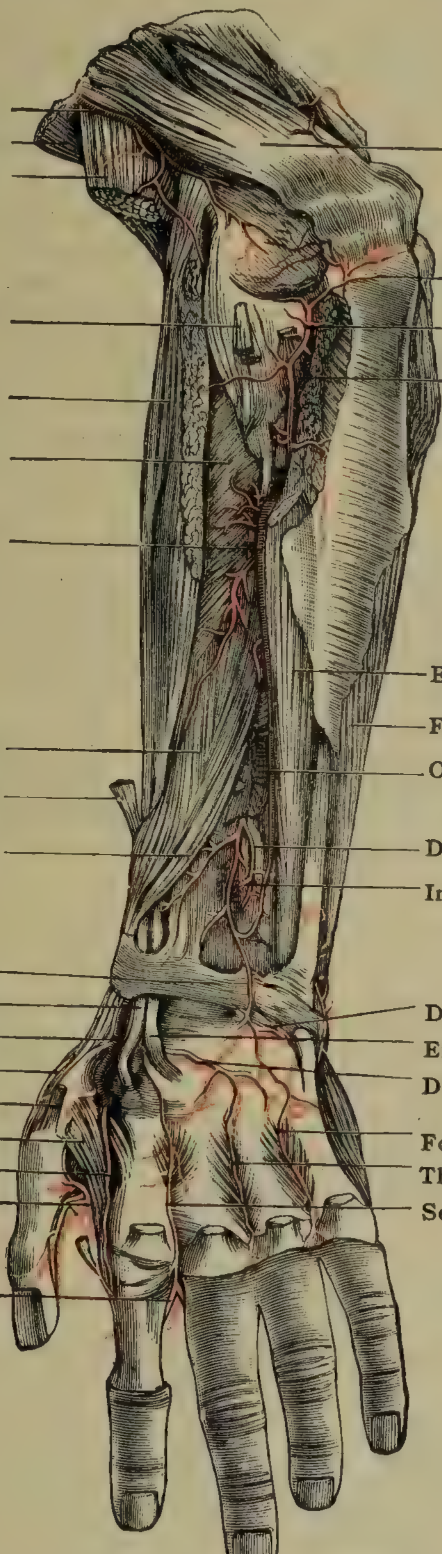


FIG. 550.—THE BACK OF THE LEFT FOREARM, WITH THE DORSAL INTEROSSEOUS ARTERY AND BRANCHES OF THE RADIAL AT THE BACK OF THE WRIST.
(From a dissection in the Hunterian Museum.)

(*a*) The **volar interosseous** artery [a. interossea volaris] passes distally in front of the interosseous membrane. It lies under cover of the overlapping edges of the flexor digitorum profundus and flexor pollicis longus, to both of which muscles it supplies branches. At the proximal border of the pronator quadratus it divides into two branches, the anterior and the posterior terminal (fig. 551).

The volar interosseous artery is accompanied by two veins and by the deep branch of the median nerve which lies to its radial side. The artery is bound down to the interosseous membrane by aponeurotic fibers.

The **branches of the volar interosseous artery** are: (i) The **median** artery [a. mediana] is a long slender vessel which arises from the proximal part of the artery. It passes forward between the flexor digitorum profundus and the flexor pollicis longus to the median nerve, with

which it descends beneath the transverse carpal (anterior annular) ligament into the palm, and when of large size sometimes enters into the formation of the superficial volar arch. This artery may arise from the common interosseous. (ii) The **nutrient arteries** of the radius and ulna. (iii) The **volar terminal** division of the volar interosseous artery passes behind the pronator quadratus and in front of the interosseous membrane, and anastomoses with the volar carpal branches of the radial and ulnar arteries, and with the recurrent branches from the deep volar arch in the so-called **volar carpal rete.** (iv) The **dorsal terminal,** the larger division, pierces the interosseous membrane, and continues under cover of the extensor muscles to the back of the wrist, where it ends by anastomosing with the dorsal carpal branches of the radial and ulnar arteries, in the so-called **dorsal carpal rete.** This branch anastomoses with the dorsal interosseous artery.

(*b*) The **dorsal interosseous** artery [a. interossea dorsalis] turns backward through the triangular interval bounded by the interosseous membrane, the oblique ligament, and the ulna. Emerging at the back of the forearm between the abductor pollicis longus and the supinator, it passes between the superficial and the deep extensors, crossing the abductor pollicis longus, the extensor pollicis brevis, the extensor pollicis longus, and the extensor indicis proprius (fig. 550). It anastomoses near the wrist joint with the dorsal branch of the volar interosseous, which here has perforated the interosseous membrane. It is separated from the deep radial nerve at first by the radius and the supinator, and on the back of the forearm by the extensores pollicis longus and indicis proprius.

The **interosseous recurrent** artery [a. interossea recurrens] arises from the dorsal interosseous as the latter emerges from beneath the supinator, or it may arise separately from the common interosseous. It runs between the anconeus and supinator, usually under cover of the former, to the interval between the lateral epicondyle and the olecranon, where it anastomoses with the profunda brachii, inferior ulnar collateral, radial recurrent, and dorsal ulnar recurrent arteries, and gives branches to the rete olecrani.

3. The **muscular** branches [rr. musculares] are numerous. They supply the deep and superficial flexors of the fingers, the flexor carpi radialis and ulnaris, and the pronator teres.

4. The **dorsal ulnar carpal** [r. carpeus dorsalis] arises from the ulnar artery near the proximal border of the transverse carpal (anterior annular) ligament and, winding medially round the end of the ulna or the ulnar collateral ligament of the wrist, beneath the flexor carpi ulnaris, ramifies on the back of the carpus beneath the extensor tendons. It forms by its anastomosis with the dorsal radial carpal and with the dorsal terminal branch of the volar interosseous artery, a **dorsal carpal arch** or **rete.** The branches given off from the rete are described with the dorsal carpal branch of the radial artery.

5. The **volar ulnar carpal** [r. carpeus volaris] is a small branch off from the ulnar artery opposite the carpus. It passes beneath the flexor digitorum profundus to anastomose with the volar radial carpal, with terminal twigs of the volar branch of the volar interosseous, and with recurrent branches from the deep volar arch, forming an arch across the front of the carpus—the **volar carpal arch** or **rete.**

The Ulnar Artery at the Wrist

The **ulnar artery at the wrist** may be said to extend from the proximal to the distal border of the transverse carpal (anterior annular) ligament upon which it rests. It here lies immediately to the radial side of the pisiform bone, and to the ulnar side of the hook of the hamate (unciform), the two bones forming for the vessel a protecting channel, which is further converted into a short canal by the overlying volar carpal ligament. The ulnar nerve is immediately to the ulnar side of the artery.

The Ulnar Artery in the Palm (Superficial Volar Arch)

The ulnar artery, on entering the palm, divides into two branches, the superficial and deep.

The **superficial branch** (fig. 550), the direct continuation of the ulnar artery usually forms the **superficial volar arch** [arcus volaris superficialis]. After descending a short distance toward the cleft between the fourth and fifth fingers, it turns toward the thumb, forming a curve with its convexity toward the fingers and, at the junction of the proximal with the middle third of the palm, inosculates with the superficial volar branch of the radial artery to complete the arch. The arch is completed in some cases, wholly or in part by the volar radial artery of the index. A line drawn transversely across the palm on a level with the metacarpophalangeal joint of the thumb will roughly indicate the situation of the arch.

Relations.—In front, in addition to the skin and superficial fascia, the vessel is crossed successively, by the palmaris brevis, the palmar branch of the ulnar nerve, the palmar aponeurosis and the palmar branch of the median nerve. **Behind,** it rests successively upon the short muscles of the little finger, the digital branches of the ulnar nerve, the flexor tendons, and the digital branches of the median nerve.

The **branches of the superficial volar arch.** In addition to small muscular and cutaneous branches the superficial volar supplies:

The **common digital arteries** [aa. digitales volares communes]. These, usually three in number, arise from the convexity of the superficial arch and, running downward through the palm, join the three corresponding volar metacarpal arteries to form short trunks which give the volar **digital arteries proper** [aa. digitales volares propriæ] to the radial side of the little finger and to both sides of the ring and middle fingers, and the ulnar side of the index finger. The radial side of the index finger is supplied by the a. volaris radialis indicis.

The proper digital artery for the ulnar side of the little finger passes distally over the hypothenar muscles and thence along the medial margin of the little finger. The remaining arteries pass distally in the three ulnar intermetacarpal spaces to within about 6 mm. (¼ in.) of the clefts between the fingers.

As the common digital arteries pass through the palm, they lie between the flexor tendons, on the digital nerves and lumbrical muscles, and beneath the palmar aponeurosis. Just before

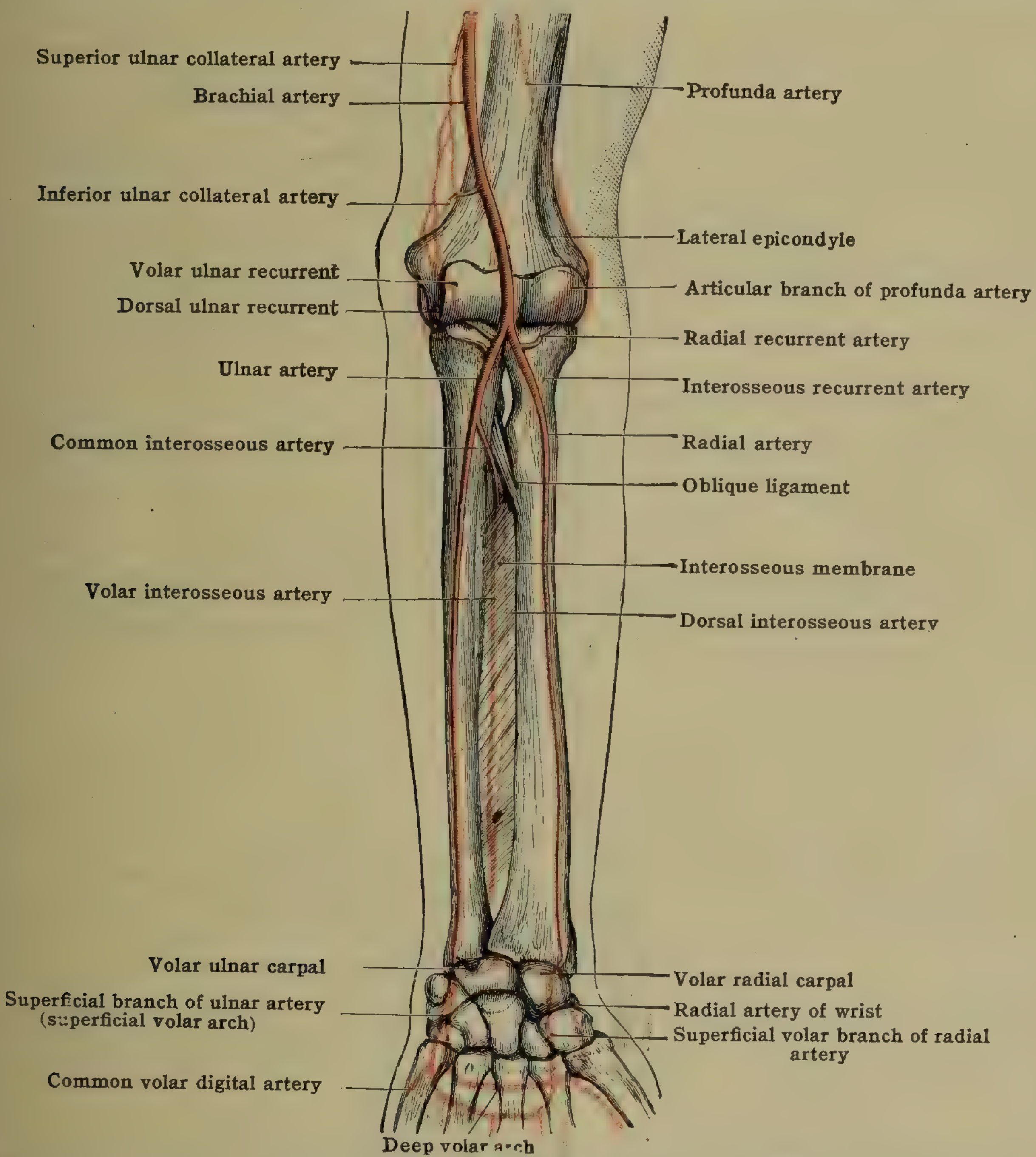


Fig. 551.—Diagram of the Relation of the Arteries of the Left Forearm to the Bones. (Walsham.)

uniting with the volar metacarpal branches from the deep volar arch, they pass under the transverse fasciculi and receive the volar perforating branches from the dorsal metacarpal vessels (fig. 553). On the sides of the fingers the proper digital arteries lie between the palmar and dorsal digital nerves. They anastomose by small branches, forming an arch across the front of the bones on the proximal side of each interphalangeal joint. They supply the flexor tendons and the integument, and terminate in a plexiform manner beneath the pulp of the finger and around the matrix of the nail. A dorsal digital branch is given off to the back of the fingers about the level of the middle of the first phalanx, and a second but smaller dorsal digital branch about the level of the middle of the second phalanx.

The **deep branch** of the ulnar artery [ramus volaris profundus], also called the communicating artery, sinks deeply into the palm between the abductor and flexor quinti digiti brevis, and joins the radial to complete the deep volar arch. (See Radial Artery.)

THE RADIAL ARTERY

The **radial** artery—the smaller of the two arteries into which the brachial divides—appears as the direct continuation of the brachial. It runs, at first curving laterally, along the radial side of the forearm as far as the styloid process, then, curving over the radial collateral ligament and the lateral and back part of the wrist, enters the palm between the bases of the first and second metacarpal bones, and ends by anastomosing with the deep branch of the ulnar to form the deep volar arch. Hence the artery is divisible into three parts: that in the forearm, that at the wrist, and that in the palm of the hand. The course of the artery is indicated by a line drawn from a point 2.5 cm. (1 in.) below the center of the elbow to a point situated just medial to the styloid process of the radius.

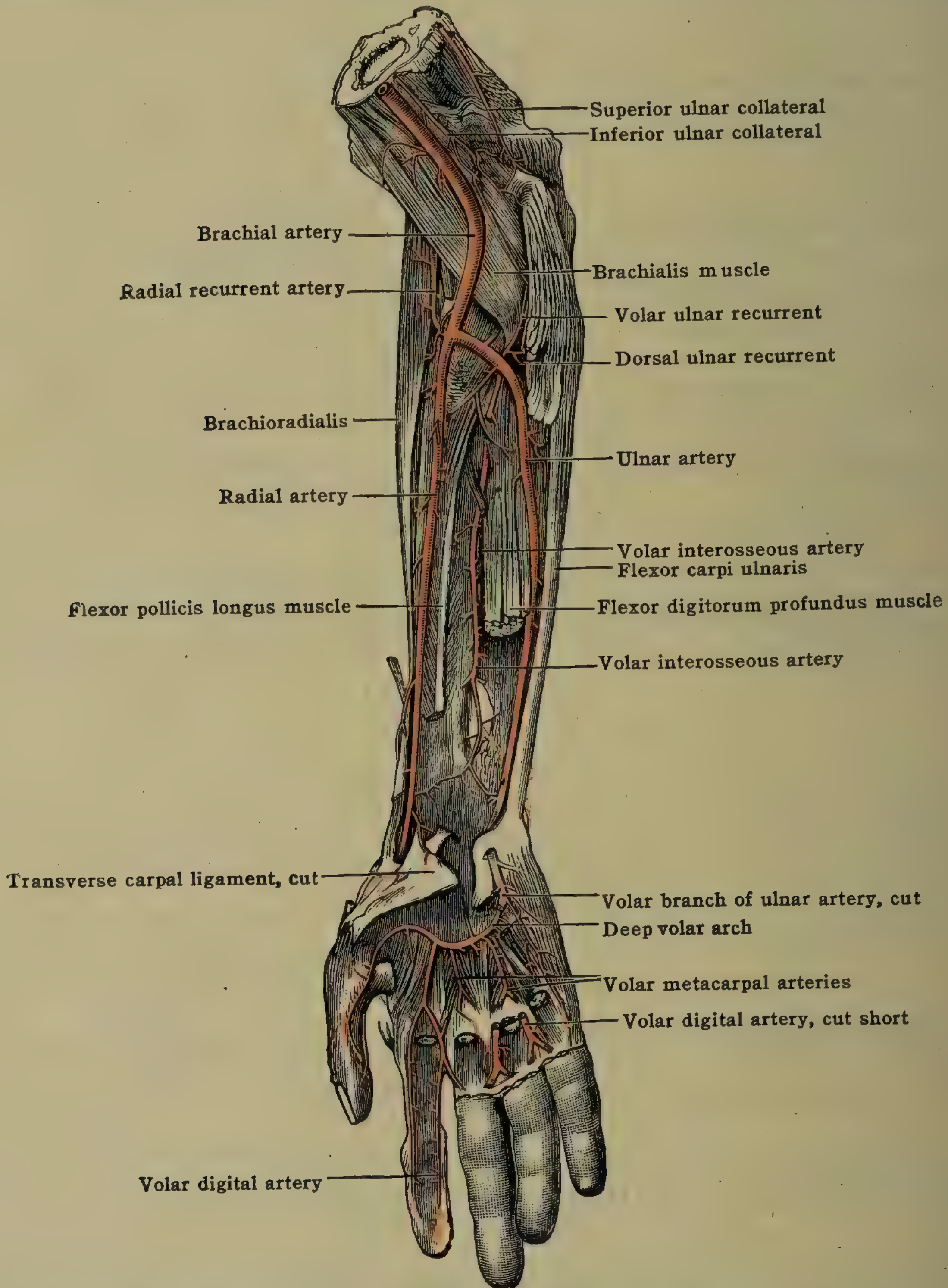


FIG. 552.—THE ARTERIES OF THE RIGHT FOREARM AND THE DEEP VOLAR ARCH.

1. THE RADIAL ARTERY IN THE FOREARM

In its course through the forearm (fig. 552) the radial artery is found in the most lateral of the intermuscular spaces, the radial sulcus, and for exposure, it is necessary to divide only the skin, superficial and deep fascia and, in the upper third of the forearm, to separate the brachioradialis from the pronator teres. There are two venæ comitantes.

Relations.—In front, the artery is at first overlapped by the brachioradialis, but for the rest of its course it is merely covered by the skin, superficial and deep fasciæ, by some cutaneous veins, and by cutaneous branches of the musculocutaneous nerve.

Behind, it lies successively on the tendon of the biceps, the supinator, from which it is separated by a layer of fat, on the insertion of the pronator teres, the radial origin of the flexor digitorum sublimis, the flexor pollicis longus, the pronator quadratus, and the volar surface of the distal end of the radius. It is in this last situation, where the artery lies upon the bone, that the pulse is usually felt.

On its **lateral side** it has, throughout the whole of its course, the brachioradialis muscle and tendon and, in its middle third, the superficial radial nerve. In its distal third the superficial radial nerve is to its lateral side, but separated from it by the brachioradialis and fascia.

On its **medial side**, in the proximal third is the pronator teres, and in the distal third the tendon of the flexor carpi radialis. It is accompanied by venæ comitantes.

The **branches of the radial artery in the forearm** are: (1) the radial recurrent; (2) the muscular; (3) the superficial volar and (4) the volar radial carpal.

(1) The **radial recurrent** [a. recurrens radialis] usually arises from the lateral side of the radial just beyond its origin from the brachial. It at first runs laterally on the supinator and then divides into three chief branches (figs. 549, 551). One of these continues laterally between the superficial (radial) and deep radial (posterior interosseous) nerves into the brachioradialis and extensor carpi radialis longus and brevis, and anastomoses with the interosseous recurrent. A second ascends between the brachialis and brachioradialis, with the radial (musculospiral) nerve, and anastomoses with the profunda brachii. A third descends with the superficial radial nerve under cover of the brachioradialis, supplying that muscle. The radial recurrent also gives off branches to the elbow-joint.

(2) The **muscular branches** [rr. musculares] come off irregularly to supply the contiguous muscles on the lateral side of the forearm.

(3) The **superficial volar** branch [r. volaris superficialis] leaves the radial artery as the latter vessel is about to turn over the radial collateral ligament to the back of the wrist. It courses forward over the short muscles of the ball of the thumb, and anastomoses with the superficial branch of the ulnar artery to complete the superficial volar arch. It supplies small branches to the muscles of the ball of the thumb, and frequently terminates in these muscles without joining the arch. Occasionally it passes beneath the abductor pollicis brevis.

(4) The **volar radial carpal** branch [r. carpeus volaris] arises from the medial side of the radial artery about the level of the distal border of the pronator quadratus. It crosses the front of the radius beneath the flexor muscles, and anastomoses with the volar carpal branch of the ulnar, forming the volar carpal rete. This plexus is joined proximally by terminal twigs from the volar interosseous artery, and distally by recurrent branches from the deep volar arch. It supplies branches to the distal end of the radius, and to the wrist and carpal joints.

II. The Radial Artery at the Wrist

The radial artery at the wrist winds over the radial side of the carpus, under the extensor tendons of the thumb, from a point a little beyond and medial to the styloid process of the radius to the proximal end of the first interosseous space. It sinks between the two heads of the first dorsal interosseous muscle into the palm, to form, by anastomosing with the deep branch of the ulnar artery, the deep volar arch. A line drawn from a point 1.2 cm. (½ in.) to the medial side of the styloid process to the base of the first interosseous space will roughly indicate the course of the artery (fig. 550).

Relations.—The artery is covered successively by the abductor pollicis longus and extensor pollicis brevis, by branches of the superficial radial nerve and veins, and, just before it sinks between the two heads of the interosseous muscle, by the tendon of the extensor pollicis longus. The branches of the superficial radial nerve to the thumb and index finger cross it. It is at first deeply placed beneath the long abductor and short extensor muscles of the thumb; but subsequently it lies quite superficial, and can be felt pulsating in a little triangular depression bounded on either side by the extensores pollicis longus and brevis, and above by the lower end of the radius. The artery lies successively on the radial collateral ligament of the wrist, on the navicular (scaphoid), the greater multangular (trapezium), the base of the first metacarpal bone, and on the dorsal ligaments uniting these bones. It has usually with it two companion veins, and a few branches of the musculocutaneous nerve.

The **branches of the radial artery at the wrist** are: (1) The dorsal radial carpal; (2) the first dorsal metacarpal.

(1) The **dorsal radial carpal** branch [r. carpeus dorsalis] arises from the radial as the latter vessel passes under the abductor pollicis longus, and runs medially beneath the extensor carpi radialis longus and brevis, and the extensor pollicis longus, across the dorsal surface of the carpus, to anastomose with the dorsal ulnar carpal and with the terminal twigs of the posterior branch of the volar interosseous artery. This anastomosis is called the **dorsal carpal rete** [rete carpi dorsale]. From this rete are given off the second, third, and fourth **dorsal metacarpal arteries** to the second, third, and fourth intermetacarpal spaces respectively. These vessels run distally on the dorsal interosseous muscles as far as the flexure of the fingers, and there divide into two **dorsal digital** branches [aa. digitales dorsales], which run along the sides of the dorsal aspect of the contiguous fingers. Between the bases of the metacarpal bones, the

dorsal metacarpal arteries anastomose with the **perforating branches of the deep volar arch.** Distally they are connected by **perforating** branches with the junction of the volar metacarpal and common digital arteries of the corresponding spaces. The proper dorsal digital arteries are usually small, the fingers being supplied largely by the volar proper digitals (fig. 553).

(2) The **first dorsal metacarpal** (fig. 550) is given off by the radial shortly before it passes between the two heads of the first dorsal interosseous muscle. It divides into two branches which supply the dorsal surface of the thumb and the radial side of the dorsal surface of the index-finger.

III. The Radial Artery in the Palm (Deep Volar Arch)

The radial artery enters the palm between the first and second metacarpal bones at the base of the first interosseous space, by passing between the two

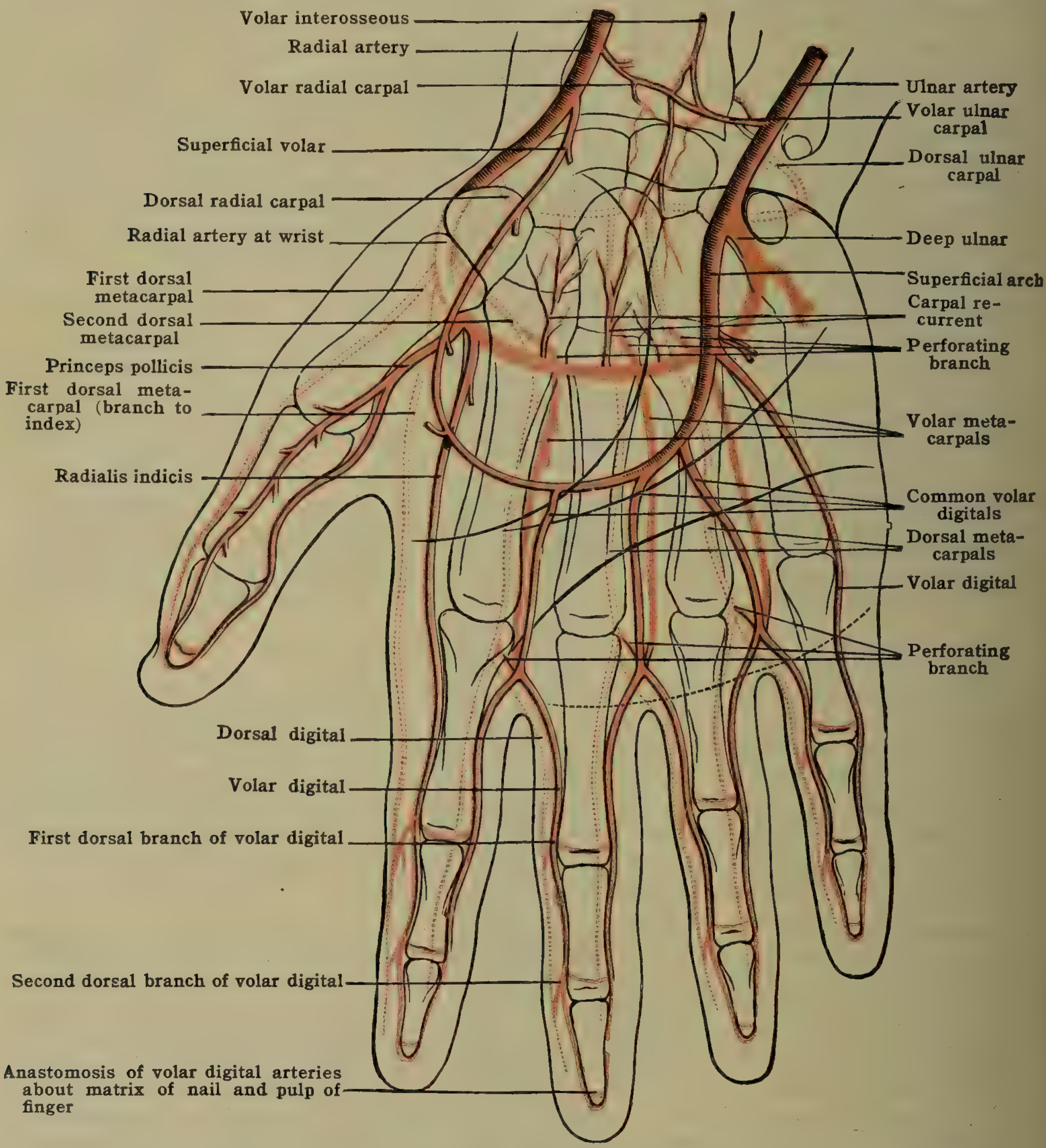


Fig. 553.—Anastomoses and Distribution of the Arteries of the Hand. (Walsham.)

heads of the first dorsal interosseous muscle. It then runs medially between the transverse and oblique heads of the adductor pollicis muscle and continuing its course, with a slight convexity forward, across the base of the metacarpal bones and interosseous muscles, joins the deep branch of the ulnar, forming the **deep volar arch** [arcus volaris profundus]. The arch may be said to extend from the first interosseous space to the base of the metacarpal bone of the little finger, and is a finger's breadth nearer the wrist than the superficial arch. It is covered by the superficial and deep flexor tendons, by the superficial head of the flexor pollicis brevis, and by part of the flexor quinti digiti brevis. It is accompanied by the deep branch of the ulnar nerve, and two small venæ comitantes (figs. 552, 553).

The **branches of the deep volar arch** are: (1) The princeps pollicis; (2) the volaris indicis radialis; (5) the volar metacarpals (three in number); (4) the recurrent carpal; (3) the dorsal perforating.

(1) The **arteria princeps pollicis** arises from the radial artery after it has entered the palm between the two heads of the first dorsal interosseous muscle. It passes downward between the adductor pollicis transversus and the first dorsal interosseous muscle, parallel with the metacarpal bone, and between the two portions of the flexor pollicis brevis under cover of the flexor pollicis longus. Opposite the metacarpophalangeal joint it usually divides into two branches, one of which is distributed to each side of the volar aspect of the thumb. These vessels anastomose with each other at the end of the thumb, like the other digital arteries.

(2) The **arteria volaris indicis radialis** comes off from the radial artery a little beyond the princeps pollicis, or as a common trunk with it, and passes forward between the first dorsal interosseous and adductor pollicis transversus, parallel with the radial side of the second metacarpal bone. After emerging from beneath the adductor pollicis transversus it continues along the radial side of the volar aspect of the index-finger, anastomosing with the digital artery on the opposite side of the finger in a way similar to that of the other digital arteries. It frequently communicates, at the lower border of the adductor pollicis, with the superficial volar arch, which it may complete, in the absence of the superficial volar artery. It gives off a dorsal branch, which anastomoses with the branch from the first dorsal metacarpal to the index-finger.

(3) The **volar metacarpal** arteries [aa. metacarpeæ volares], three in number, come from the convexity of the deep arch, and, running in the second, third, and fourth interosseous spaces on the interosseous muscles, terminate near the cleft of the fingers by anastomosing with the digital arteries from the superficial arch. These vessels supply the interosseous muscles and the bones, and the second, third, and fourth lumbricales.

(4) The **recurrent branches** come from the concavity of the arch, and consist of two or three small vessels which run toward the wrist, and anastomose with the volar branch of the volar interosseous, and the volar radial and ulnar carpal arteries.

(5) The **perforating** branches [rr. perforantes], which are usually three in number, pass from the arch directly through the second, third, and fourth interosseous spaces between the two heads of the corresponding dorsal interosseous muscle, and join the second, third, and fourth dorsal metacarpal arteries respectively.

THE THORACIC AORTA

The **thoracic aorta** [aorta thoracalis] (fig. 554) is the thoracic portion of the aorta descendens. It extends from the termination of the aortic arch at the lower border of the body of the fourth thoracic vertebra to the lower border of the body of the twelfth thoracic vertebra, where it passes between the medial crura of the diaphragm, and is thence continued under the name of the abdominal aorta. It is at first situated a little to the left of the vertebral column, but as it descends, approaches the front of the column, at the same time following its backward curve, and at the diaphragm is almost in the middle line. It lies in the posterior mediastinum, having the esophagus at first a little to the right of it, then in front, and finally (near the lower end of the esophagus) a little to the left side.

Relations.—In front the descending aorta is crossed from above downward by the root of the left lung, by the esophagus, which separates it from the pericardium and heart, and by the diaphragm. **Behind,** it lies upon the lower seven thoracic vertebræ, and is crossed obliquely opposite the seventh or eighth thoracic vertebra by the vena hemiazygos (azygos minor) and opposite the fifth or sixth vertebra by the accessory hemiazygos vein, or by one or more of the intercostal veins. On the **right side** it has, above, the esophagus and vertebral column; lower down the right pleura and lung. The vena azygos and thoracic duct also lie to the right, but on a somewhat posterior plane. On the **left side** it has the left lung and pleura above, and the esophagus below. The vena hemiazygos and the accessory hemiazygos vein are also to the left, but on a posterior plane.

Branches of the Thoracic Aorta

The **branches of the thoracic aorta** may be divided into (*A*) the visceral and (*B*) the parietal. The **visceral** are: (1) The pericardiac; (2) the bronchial; and (3) the esophageal. The **parietal** are: (1) The intercostal; (2) the superior phrenic; and (3) the arteria aberrans.

A. Visceral Branches

(1) The **pericardiac** branches [rr. pericardiaci]—two or three small branches, irregular in their origin, course, and distribution—pass to the posterior surface of the pericardium to supply that structure, and anastomose with the other pericardiac branches. They give small twigs to the posterior mediastinal glands.

(2) The **bronchial** arteries [aa. bronchiales] supply the bronchi and the lung substance. They vary considerably in their origin, course, and distribution; they are usually three in number—one on the right side, and two on the left.

(*a*) The **right bronchial** generally arises either from the first right aortic intercostal, or as a common trunk with the left upper bronchial from the front of the aorta just below the level of the bifurcation of the trachea. It passes laterally on the back of the right bronchus, and is distributed to the bronchi and lung substance. (*b*) The **left upper bronchial** arises from the front of the aorta just below the bifurcation of the trachea, or as a common trunk with the right bronchial. (*c*) The **left lower bronchial** arises from the front of the aorta just below the level

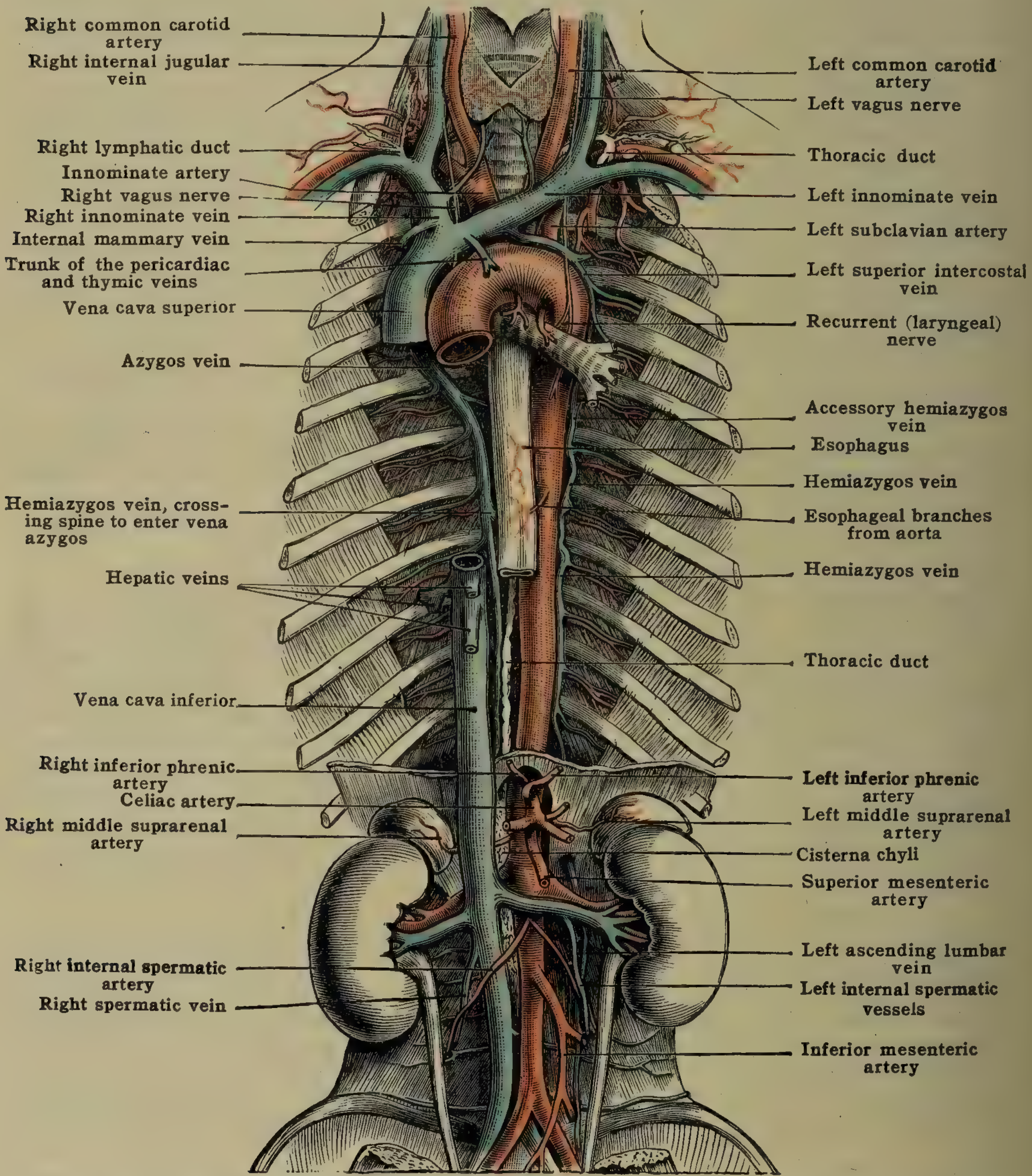


Fig. 554.—The Arch of the Aorta, the Thoracic Aorta, and the Abdominal Aorta, with the Vena Cava Superior and Inferior and the Innominate and Azygos Veins.

of the left bronchus. Like the corresponding artery on the right side, the left bronchial arteries run laterally on the left bronchus and, after dividing and subdividing on the back of the bronchi, supply the bronchi themselves and the lung substance. Small twigs are given from the bronchial arteries to the bronchial glands and to the esophagus.

(3) The **esophageal** arteries [aa. œsophageæ], four or sometimes five in number, arise at intervals from the front of the descending thoracic aorta, the first coming off just below the left lower bronchial. They usually increase in size from above downward, the upper arising toward the right side of the aorta, the lower more toward the left side. They pass forward to the esophagus, supplying that tube and anastomosing with each other and with the descending esophageal

branches of the inferior thyroid above, and with the ascending esophageal branches of the phrenic and gastric arteries below, thus forming a chain of anastomoses along the whole length of the tube.

B. Parietal Branches

(1) The **intercostal** arteries [aa. intercostales], usually ten in number on each side, supply the lower intercostal spaces, the two upper spaces (occasionally the first only) being supplied from the costocervical trunk of the subclavian artery. The lowest artery accompanies the twelfth thoracic nerve below the last rib and is therefore called the **subcostal artery.** Its distribution is similar to that of the lumbar arteries (p. 664) except that it commonly crosses the anterior surface, rather than the posterior, of the quadratus lumborum.

The intercostals arise in pairs from the back part of the aorta, and turning, the one to the right and the other to the left, wind backward over the front and sides of the vertebral bodies to reach the intercostal spaces. In fetal life these arteries run almost transversely, or even with a slight downward inclination, to the

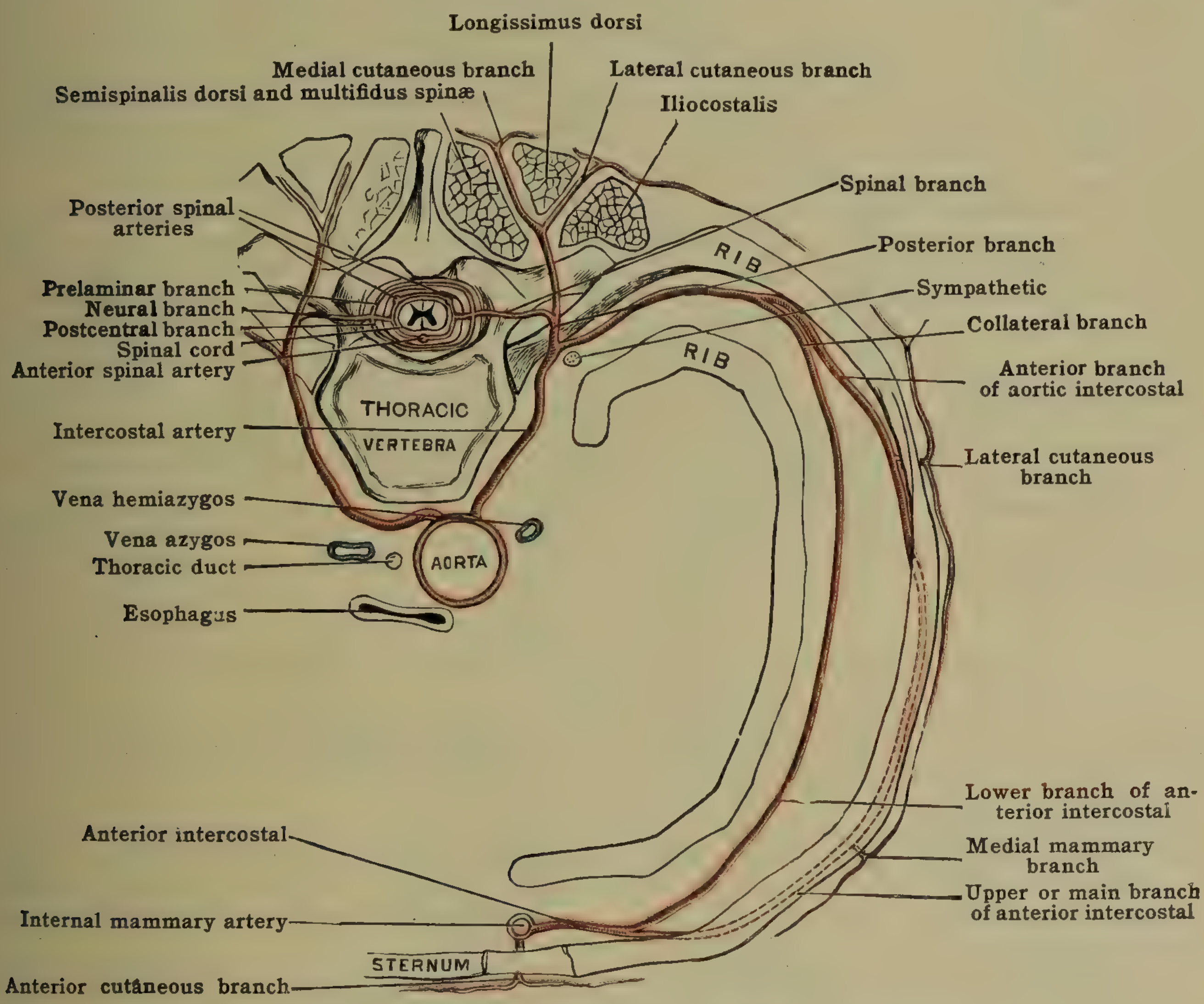


Fig. 555.—Scheme of Intercostal Artery. (Walsham.)

intercostal spaces; but after the first year, in consequence of the disproportionate growth of the aorta and vertebral column, the upper intercostals have to ascend to reach their respective spaces.

The arteries in their course around the vertebræ differ on the two sides of the body. On the **right side** they—and especially the upper, in consequence of the aorta lying a little to the left side of the spine in the upper part of its course—are longer than the left. They wind over the front and right side of the vertebræ, being crossed by the thoracic duct and vena azygos (major), and covered by the right pleura and lung. The upper are also crossed by the esophagus. They give small branches to the bodies of the vertebræ and anterior longitudinal ligament. On the **left side,** as the intercostals wind around the sides of the bodies of the vertebræ, the lower ones are crossed by the vena hemiazygos (azygos minor), the two upper by the left superior intercostal vein, and the two next by the accessory hemiazygos, when this is present. They are all covered by the left pleura and lung (figs. 554, 555).

The **branches of the intercostal arteries** are: (a) anterior, (b) posterior.

(*a*) The **anterior** branches [rr. anteriores] at first cross the intercostal space obliquely, in consequence of the downward direction of the ribs, toward the angle of the rib above, and thence

are continued forward in the costal groove. They anastomose with the superior branches of the anterior intercostal branches of the internal mammary in the upper spaces, and of the musculophrenic in the lower spaces. They lie at first on the external intercostal muscles, being covered in front by the pleura and lung, the posterior intercostal membranes and the subcostal muscles. Opposite the heads of the ribs they are crossed by the sympathetic nerve. At the angle of the ribs they pass under cover of the internal intercostal muscles, and thence to their termination lie between the two intercostal muscles. They are accompanied by a nerve and a vein, the vein lying above and the nerve below; except in the upper spaces, where the artery, having to ascend to reach the space, at first lies below the nerve which runs more horizontally. The uppermost branch anastomoses with the superior intercostal artery, and at times supplies almost entirely the second intercostal space. The arteries to the tenth and eleventh spaces on reaching the end of the costal cartilages pass between the abdominal muscles, and anastomose with the inferior epigastric and lateral epigastric arteries from the external iliac, and with the lumbar arteries from the abdominal aorta. The artery beneath the twelfth rib anastomoses with the lumbar arteries and with branches of the deep circumflex iliac.

Each anterior branch gives off the following: (i) The **collateral** branch which comes off near the angle of the rib and runs forward, between the external and internal intercostals, along the upper border of the lower rib enclosing the space. It is smaller than the main anterior branch and anastomoses with the lower anterior intercostal in each space. (ii) **Muscular** branches [rr. musculares] supply the intercostal, pectoral and abdominal muscles. (iii) The **lateral cutaneous** branches [rr. cutanei laterales] run with the corresponding branches of the intercostal nerves through the external intercostal and serratus anterior muscles. They then divide into *anterior* and *posterior* branches which turn forward and backward, respectively, to supply the integument. The anterior branches from the third, fourth and fifth spaces supply *lateral mammary* branches [rr. mammarii laterales] to the lateral region of the breast. (iv) **Anterior cutaneous** branches [rr. cutanei anteriores] pierce the anterior intercostal membrane and the pectoralis major near the sternum. They are distributed to the skin and give *medial mammary* branches [rr. mammarii mediales] to the medial region of the breast.

(*b*) **The posterior** branches [rr. posteriores].—These large branches arise from the intercostals opposite the quadrilateral space bounded by the transverse process of the vertebra above, the neck of the rib below, the body of the vertebra medially, and the anterior costo-transverse ligament laterally. Passing backward toward this space with the dorsal branch of the corresponding intercostal nerve, they divide opposite the intervertebral foramen into a muscular and a spinal branch. (i) The **muscular** branch [r. muscularis] passes backward through the quadrilateral space, and soon subdivides into a medial and a lateral branch. The former passes between the longissimus dorsi and iliocostalis, and, after supplying these muscles, gives off a **medial cutaneous** branch [r. cutaneus medialis]. The latter branch pierces the multifidus spinæ, and, emerging between the longissimus dorsi and semispinalis dorsi near the spinous processes, gives off a **lateral cutaneous** branch [r. cutaneus lateralis].

(ii) The **spinal** branch [r. spinalis] enters the intervertebral foramen with the spinal nerve of the corresponding segment. The disposition of the spinal branches of the intercostal arteries is similar to that of the corresponding branches which enter the canalis vertebralis in other regions.

ARTERIES OF THE VERTEBRAL CANAL

Pairs of spinal arteries are derived from the vertebral, ascending cervical and costocervical arteries from the dorsal rami of the intercostal (fig. 555) and lumbar arteries, and from the iliolumbar and lateral sacral arteries. Each artery divides into three branches, postcentral, prelaminar and neural.

Each *postcentral* branch divides on the lateral part of the posterior longitudinal ligament into an ascending and a descending branch by which means a bilateral series of anastomosing arches is formed throughout the length of the canal. From the concavities of the opposite arches transverse connecting stems are formed which are again connected by a median longitudinal channel.

The *prelaminar* branches also divide and form an anastomosis in front of the laminæ and ligamenta flava. This is similar in character to the postcentral, but much less regular.

The *neural* branches enter the dura mater and are usually small and end by supplying the nerve roots. A variable number of these (5–10 on a side) are larger than the others and reinforce the longitudinal anterior and posterior spinal arteries given off from the vertebrals within the cranium. (For arteries of the spinal cord, see Section VIII.)

(2) The **superior phrenic** arteries [aa. phrenicæ superiores], are small twigs coming off from the thoracic aorta immediately above the diaphragm. They are distributed to the vertebral portion of the diaphragm on its upper surface.

(3) The **arteria aberrans** is a small twig which, arising from the thoracic aorta near the right bronchial artery, passes upward and to the right behind the esophagus and trachea, and is occasionally found to anastomose on the esophagus with an arteria aberrans from the right subclavian, costocervical or superior intercostal artery (see p. 633). It is regarded as the remains of the right aortic dorsal stem (fig. 543).

(4) The **mediastinal** branches [rr. mediastinales], numerous, but small, are distributed to the pleura, and the vessels, nerves and lymph-nodes of the posterior mediastinum.

THE ABDOMINAL AORTA

The **abdominal aorta** [aorta abdominalis] (fig. 556), the abdominal portion of the descending aorta, begins at the aortic opening in the diaphragm opposite the lower border of the twelfth thoracic vertebra, and ends usually opposite the body of the fourth lumbar vertebra by dividing into the right and left common iliac arteries. It is at first centrally placed between the medial crura of the diaphragm, but as it descends it deviates a little to the left side.

The place at which the aorta bifurcates may be somewhat roughly indicated on the surface of the abdomen by a point about 2.5 cm. (1 in.) below and a little to the left of the umbilicus. The level of its bifurcation may be more accurately determined by drawing a straight line between the highest points of the iliac crests.

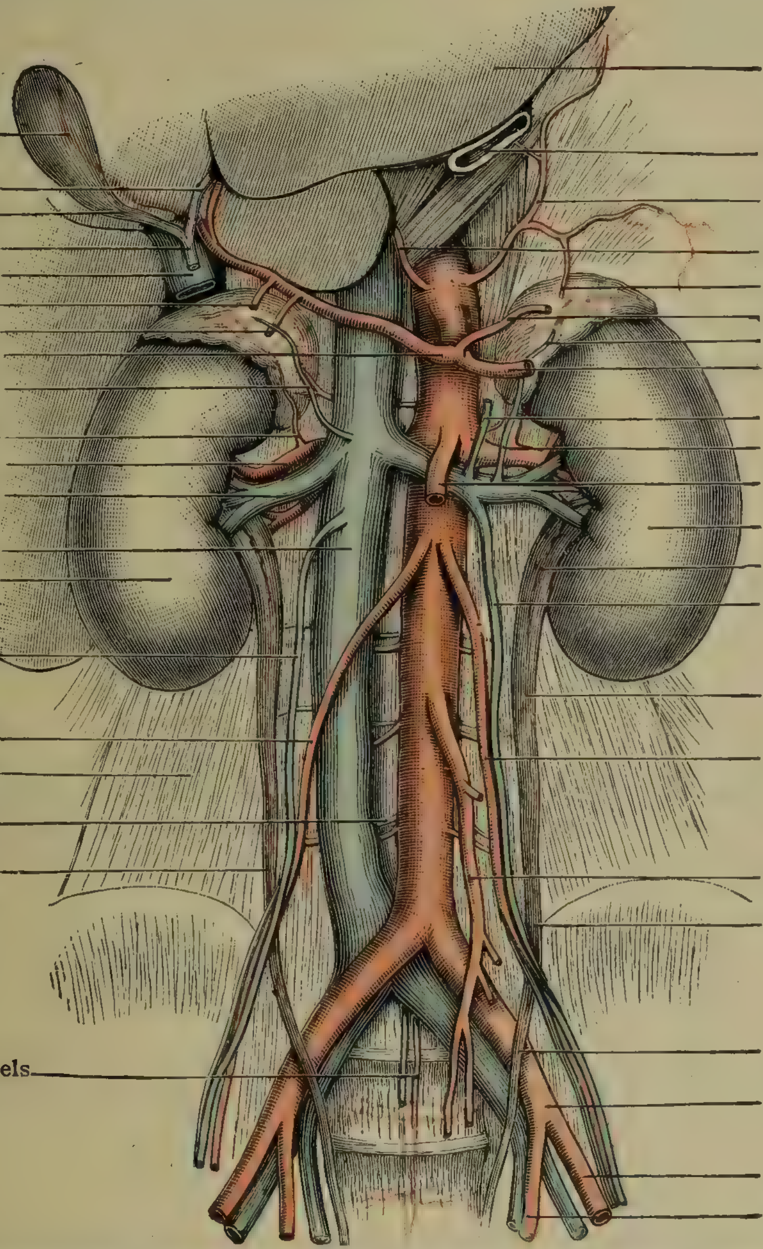


FIG. 556.—THE ABDOMINAL AORTA AND ITS BRANCHES, WITH THE VENA CAVA INFERIOR AND ITS TRIBUTARIES.

Relations.—**In front,** the aorta is successively crossed from above downward by the left lobe of the liver, the celiac (solar) plexus, the lesser omentum, the termination of the esophagus in the stomach, the ascending layer of the transverse mesocolon, the splenic vein or commencement of the portal vein, the pancreas, the left renal vein, the third portion of the duodenum, the mesentery, the aortic plexus of the sympathetic nerve, the internal spermatic or ovarian arteries, the inferior mesenteric artery, the median lumbar lymphatic nodes and lymphatic vessels, and the small intestines. Of these structures the celiac (solar) plexus, the aortic plexus, the splenic vein or the commencement of the portal vein, the pancreas, the left renal vein, the duodenum, the lymphatics, the spermatic or ovarian arteries, and the peritoneal reflexions are in direct contact with the aorta.

Behind, the aorta lies upon the bodies of the lumbar vertebræ and intervening intervertebral cartilages, the anterior longitudinal ligament, the origin of the left medial crus of the diaphragm, and the left lumbar veins.

On the **right side** from above downward are the right medial and intermediate crura of the diaphragm, the great splanchnic nerve, the caudate lobe of the liver, the cisterna chyli and beginning of the thoracic duct (the two latter structures are on a posterior plane), the right celiac (semilunar) ganglion, and the inferior vena cava. Inferiorly, the vena cava is in contact

with the aorta, and on a somewhat posterior plane. Superiorly, the vena cava is separated from the aorta by the right medial and intermediate crura of the diaphragm, and the caval opening of the diaphragm is on a plane anterior to the aortic.

On the **left side** are the left medial and intermediate crura of the diaphragm, the left splanchnic nerve, and the left celiac (semilunar) ganglion. The pancreas is also in contact with the aorta on the left side, and the small intestines are separated from it only by peritoneum.

Branches of the Abdominal Aorta

The **branches of the abdominal aorta** usually arise in the following order from above downward (figs. 556, 557):

(1) Right and left inferior phrenic; (2) celiac; (3) right and left middle suprarenal; (4) right and left first lumbar; (5) superior mesenteric; (6) right and left renal; (7) right and left internal spermatic; (8) right and left second lumbar; (9) inferior mesenteric; (10) right and left third lumbar; (11) right and left fourth lumbar; (12) right and left common iliac; (13) middle sacral.

These branches may be divided into the (A) parietal, (B) the visceral, and (C) the terminal.

The **parietal branches** are distributed to the abdominal walls. They are the right and left phrenic, and the four right and left lumbar arteries.

The **visceral branches** supply the viscera. Three of these are unpaired and arise from the front of the aorta, namely, the celiac, the superior mesenteric, and the inferior mesenteric; and three are given off in pairs, namely, the two middle suprarenal, the two renal, and the two spermatic arteries.

The **terminal branches** are the middle sacral and the right and left common iliac arteries.

A. The Parietal Branches of the Abdominal Aorta

1. THE INFERIOR PHRENIC ARTERIES

The **inferior phrenic** artery [a. phrenica inferior] usually arises from the aorta as it passes between the medial crura of the diaphragm. At times it comes off from the celiac artery; or when it arises as two separate vessels, either the right or left vessel may come from this artery, or from other of the upper branches of the abdominal aorta.

The **right phrenic** artery (fig. 556) passes over the right crus of the diaphragm behind the vena cava and then upward and to the right between the central and right leaflets of the central tendon of the muscle, where it divides into an **anterior** and a **posterior** branch. The former courses anteriorly and medially and anastomoses with the anterior branch of the left phrenic, with the musculophrenic branches of the internal mammary, and with the pericardiophrenic arteries; the latter passes posteriorly and laterally toward the ribs, and anastomoses with the intercostal arteries. Besides the two terminal branches and branches for the supply of the diaphragm itself the right phrenic gives off the **right superior suprarenal** [r. suprarenalis superior] (rami suprarenales NK) to the right suprarenal gland, as well as branches to the vena cava, to the liver, and to the pericardium.

The **left phrenic** crosses the left crus of the diaphragm behind the esophagus, and, like the right artery, divides into an anterior and posterior branch and gives off a left suprarenal branch. The distribution and anastomoses are similar on the two sides.

2. THE LUMBAR ARTERIES

The **lumbar** arteries [aa. lumbales] (fig. 556), usually eight in number, four on each side, come in pairs from the posterior aspect of the abdominal aorta, opposite the bodies of the four upper lumbar vertebræ. A fifth pair of lumbar arteries, generally of small size, frequently arises from the middle sacral artery opposite the fifth lumbar vertebra. The lumbar arteries, which are rather longer on the right than on the left side, in consequence of the aorta lying a little to the left of the median line, wind more or less transversely around the bodies of the vertebræ to the spaces between the transverse processes, where each gives a dorsal branch, and then, coursing forward between the abdominal muscles, terminates, by anastomosing with the other arteries of the abdominal wall.

Relations.—As they wind around the bodies of the vertebræ they pass beneath the sympathetic trunk, and the upper two beneath the medial and intermediate crura of the diaphragm. The right arteries also pass beneath the vena cava inferior, and the two upper on that side beneath the cisterna chyli. The arteries on both sides then dip beneath the tendinous arch thrown across the sides of the bodies of the vertebræ by the psoas, and continue beneath this muscle until they arrive at the interval between the transverse processes of the vertebræ and the medial edge of the quadratus lumborum. While under cover of the psoas they are accompanied by rami communicantes of the sympathetic and by the lumbar veins. A little anterior

to the transverse processes they are crossed by branches of the lumbar plexus of nerves, and here usually cross in front of the ascending lumbar vein. They now pass behind the quadratus lumborum, with the exception sometimes of the fourth, which may pass in front of the muscle. At the lateral edge of the quadratus they run between the transversus and the internal oblique, and then, after perforating the internal oblique, between the internal and external oblique. Finally, much diminished in size, they enter the rectus, and give off one or more anterior cutaneous branches, which accompany the branches of thoracic and the iliohypogastric nerves to the skin. They anastomose with the lower intercostal, iliolumbar, deep circumflex iliac, and inferior epigastric arteries.

The **branches of the lumbar arteries** are:

(*a*) **Vertebral** branches which supply the bodies of the vertebræ and their ligaments.

(*b*) **Muscular** branches to the psoas, quadratus lumborum, and to the oblique muscles of the abdomen.

(*c*) The **dorsal** branch [r. dorsalis]. This is of large size, and passes backward in company with the dorsal branch of the corresponding lumbar nerve between the transverse processes above and below, the intertransversalis medially and the quadratus lumborum laterally, to the muscles of the back. On reaching the interval between the longissimus dorsi and multifidus spinæ, it divides into a lateral and a medial branch. The former ends in the multifidus, the latter and larger supplies the sacrospinalis, and gives branches which accompany the termi-

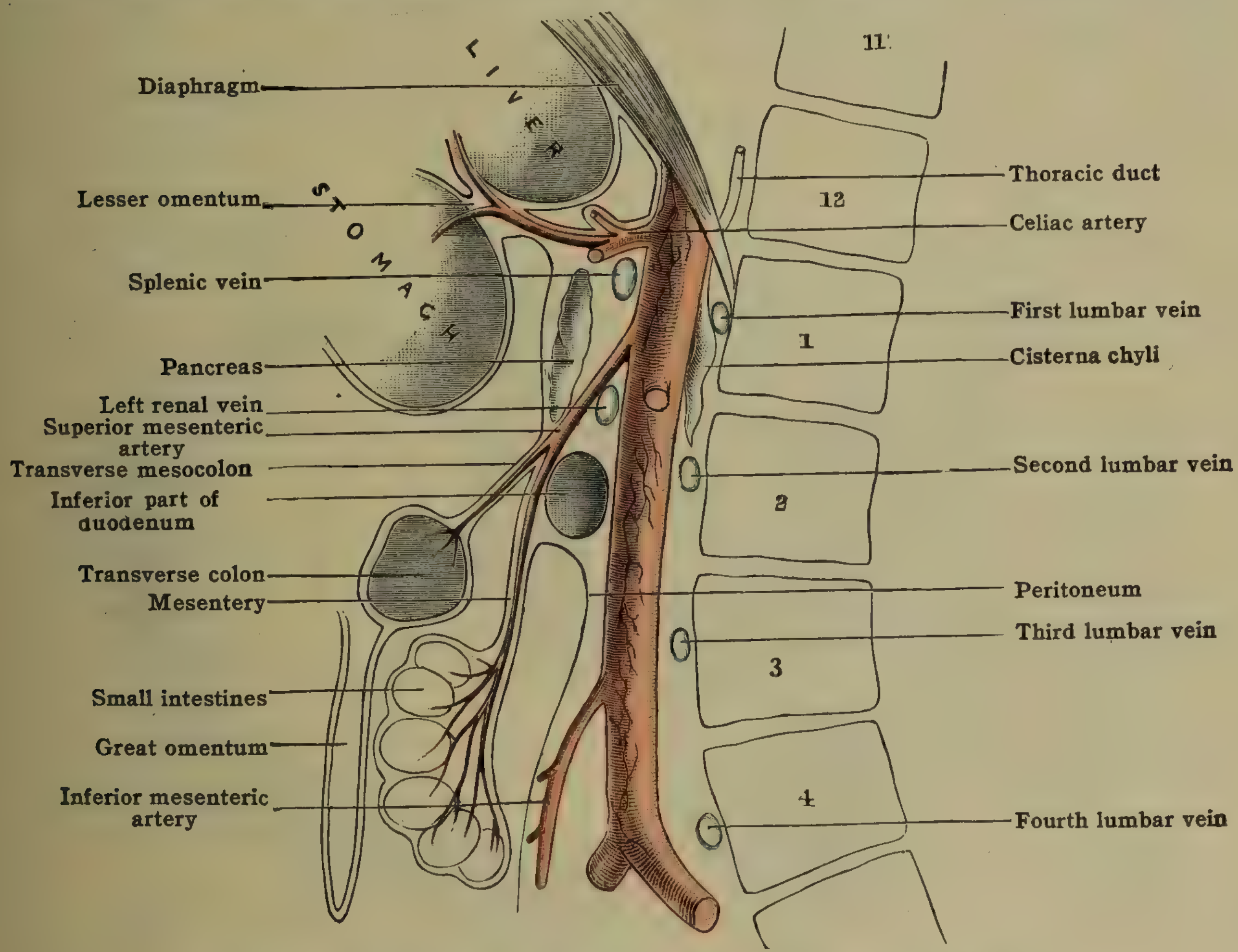


FIG. 557.—SCHEME OF THE ABDOMINAL AORTA. (Walsham.)

nation of the dorsal nerves to the skin. Just before the artery passes between the transverse processes it gives off a **spinal** branch [r. spinalis], which accompanies the lumbar nerve through the intervertebral foramen into the vertebral canal (see p. 662).

(*d*) **Renal** branches of small size pass forward in front of the quadratus lumborum to the capsule of the kidney. They anastomose with the renal artery. A communication is thus established between the renal arteries and the arteries supplying the lumbar region.

B. THE VISCERAL BRANCHES OF THE ABDOMINAL AORTA

THE CELIAC ARTERY

The **celiac** artery [a. cœliaca] or **celiac axis,** is a short thick trunk arising from the front of the aorta between the medial crura of the diaphragm a little below the aortic opening. It passes horizontally forward above the upper margin of the pancreas for about half an inch, and then breaks up into three branches for the supply of the stomach, duodenum, spleen, pancreas, liver, and gall-bladder (fig. 558).

Relations.—**In front** is the lesser omentum; **behind,** the aorta; **above,** the left lobe of the liver; **below,** the pancreas; to the **right,** the right celiac (semilunar) ganglion and caudate lobe of the liver; to the **left,** the left celiac (semilunar) ganglion and the cardiac end of the stomach. It is closely surrounded by the dense celiac (solar) plexus of sympathetic nerves.

The **branches of the celiac artery** are: (1) the left gastric, (2) the hepatic, and (3) the splenic arteries.

1. The Left Gastric Artery

The **left gastric** [a. gastric sinistra] (fig. 558), the smallest of the three branches of the celiac artery, courses at first upward and to the left toward the cardiac end of the stomach, where it turns sharply round, and then, following the lesser curvature of the stomach, descends from left to right toward the pylorus. It anastomoses with the right gastric branch of the hepatic artery, which has proceeded from the opposite direction, the two branches thus forming a continuous arterial arch corresponding to the lesser curvature of the stomach.

The artery at first lies behind the posterior layer of the omental bursa of peritoneum and then curves forward around the left side of the superior recess. In so doing, it raises a crescentic ridge of peritoneum, the left gastro-pancreatic fold. Reaching the area uncovered by peritoneum near the cardiac end of the stomach it passes, between the layers of the lesser omentum, in which it then runs to its terminal anastomosis with the right gastric artery. It is surrounded by a plexus of sympathetic nerves. It supplies both surfaces of the stomach around the lesser curvature and gives off small **esophageal** branches [rr. œsophagei] which anastomose with the esophageal branches from the thoracic aorta (fig. 558).

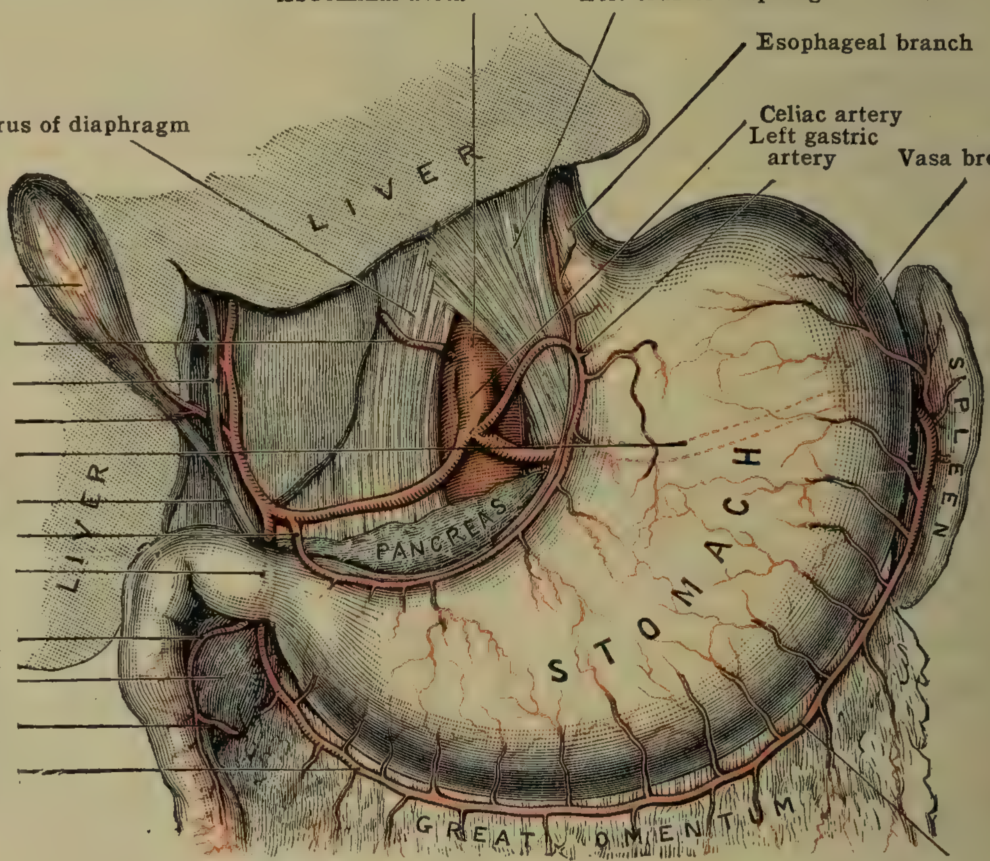


Fig. 558.—The Celiac Artery and its Branches.

2. The Hepatic Artery

The **hepatic artery** [a. hepatica] (a. hepatica communis NK) is the largest branch of the celiac artery in the fetus, but intermediate in the adult between the left gastric and the splenic. It arises on the right side of the celiac artery, and, winding upward and to the right to the porta (portal fissure) of the liver, there breaks up into two chief branches for the supply of the right and left lobes of that organ. It at first courses forward and to the right along the upper border of the head of the pancreas, behind the posterior layer of the peritoneal omental bursa, to the upper margin of the duodenum, where it passes forward in the right gastro-pancreatic fold, which limits the superior recess of the bursa on the right. It then runs between the two layers of the lesser omentum, and ascends along with the hepatic duct which lies to its right, and with the portal vein which lies behind it (figs. 556, 558).

The **branches of the hepatic artery** are: (1) the right gastric; (2) the gastroduodenal; (3) the hepatic proper.

(1) The **right gastric** artery [a. gastrica dextra] arises from the hepatic as the latter vessel enters the lesser omentum, and, descending to the pylorus, there

turns to the left, and, ascending from right to left, anastomoses along the lesser curvature of the stomach, as already mentioned, with the left gastric artery, which descends from the opposite direction.

(2) The **gastroduodenal** artery [a. gastroduodenalis] arises from the hepatic a little beyond the right gastric. It descends behind the first part of the duodenum to the lower border of the pylorus, where it divides into the **right gastroepiploic** and the **superior pancreaticoduodenal.** It varies from 1.2 to 2.5 cm. (½ to 1 in.) in length.

(*a*) The **right gastroepiploic** artery [a. gastroepiploica dextra] passes from right to left along the greater curvature of the stomach between the layers of the great omentum, and anastomoses with the left gastroepiploic branch of the splenic. From this anastomotic arch are given off: (i) **Ascending** or **gastric** branches, which supply the anterior and posterior surfaces of the stomach, and anastomose with the descending gastric branches of the arteries along the lesser curvature. (ii) **Epiploic** [rr. epiploici] or **omental branches**—long slender vessels which descend between the two anterior layers of the great omentum, and then, looping upward, anastomose with similar slender branches given off from the middle and left colic, and passing down in like manner between the posterior layers of the great omentum.

(*b*) The **superior pancreaticoduodenal** [a. pancreaticoduodenalis superior]—the smaller division of the gastroduodenal—arises from that vessel as it passes behind the first portion of the duodenum, and courses downward behind the peritoneum, in the anterior groove between the descending portion of the duodenum and the pancreas, to anastomose with the inferior pancreaticoduodenal, a branch of the superior mesenteric. Both the inferior and the superior pancreaticoduodenal give off **duodenal** [rr. duodenales] and **pancreatic** branches [rr. pancreatici] to supply these organs.

(3) The **hepatic artery proper** [a. hepatica propria] is the continuation of the hepatic after the gastroduodenal has arisen. It ascends between the layers of the lesser omentum, preserving the relations of the main artery to the portal vein and common bile (and hepatic) duct, and divides, near the porta hepatis, into **right** and **left** branches.

(*a*) The **right branch** [r. dexter], given off at the porta (portal fissure) of the liver, runs to the right either behind the hepatic and cystic ducts, or between these structures. At the right end of the porta it divides into branches, which again subdivide as they enter the liver substance for the supply of the right lobe. As it crosses the cystic duct it gives off the cystic artery.

The **cystic** artery [a. cystica] (a. vesicæ felleæ NK) courses forward and downward through the angle formed by the union of the hepatic and cystic ducts, and just before it reaches the gall-bladder divides into a superficial and deep branch. The former breaks up into a number of small vessels, which ramify over the free surface of the gall-bladder beneath the peritoneal covering, and furnish branches to the muscular and mucous coats. The deep branch ramifies between the gall-bladder and the liver-substance, supplying each, and anastomosing with the superficial branch.

(*b*) The **left** branch [r. sinister], the smaller division of the hepatic artery, runs toward the left end of the porta hepatis, and, after giving off a distinct branch to the caudate (Spigelian) lobe, enters the left lobe of the liver.

3. The Splenic Artery

The **splenic** artery [a. lienalis] (fig. 558)—the largest branch of the celiac artery—arises from the left side of the termination of that vessel below the left gastric, and passes along the upper border of the pancreas in a tortuous manner to the spleen. It at first lies behind the posterior wall of the bursa omentalis, but on nearing the spleen enters the phrenolienal (lienorenal) ligament, and there breaks up into numerous branches, which enter the hilus and supply the organ. It crosses in front of the left crus of the diaphragm and the upper end of the left kidney and is placed above the splenic vein.

The **branches of the splenic artery** are: (*a*) The pancreatic; (*b*) the left gastroepiploic; (*c*) the vasa brevia; and (*d*) the terminal.

(*a*) The **pancreatic** branches (rr. pancreatici) arise from the splenic at varying intervals as that vessel courses along the upper margin of the pancreas and enter to supply the organ. One larger branch usually arises from the splenic about the junction of its middle with its left third. Entering the pancreas obliquely, it runs from left to right, commonly above, and a little behind, the pancreatic duct, which it supplies together with the substance of the organ.

(*b*) The **left gastroepiploic** [a. gastroepiploica sinistra] arises from the splenic near the greater curvature and below the fundus of the stomach and, passing between the anterior layers of the great omentum, descends along the greater curvature of the stomach from left to right, and anastomoses with the right gastroepiploic. Like that vessel, it gives off **ascending** or **gastric** branches to the anterior and posterior surfaces of the stomach respectively, and long slender **descending epiploic** or **omental** branches to the great omentum which anastomose with like branches from the right and left colic arteries.

(*c*) The **vasa brevia** [aa. gastricæ breves] come off from the splenic just before it divides into its terminal branches, or from some of the terminal branches themselves. Passing from

between the folds of the phrenolienal ligament into those of the gastrolienal, they reach the fundus of the stomach, where, ramifying over its anterior and posterior surfaces, they anastomose with the left gastric and left gastroepiploic arteries.

(*d*) The **splenic** or **terminal** branches, five to eight or more in number, are given off from the splenic as it lies in the phrenolienal ligament, and, entering the spleen at the hilum, are distributed as noted in the description of that organ.

THE SUPERIOR MESENTERIC ARTERY

The **superior mesenteric artery** [a. mesenterica superior] arises from the front of the aorta a little below the celiac, which it nearly equals in size; sometimes the two vessels arise by a common trunk. Lying at first behind the pan-

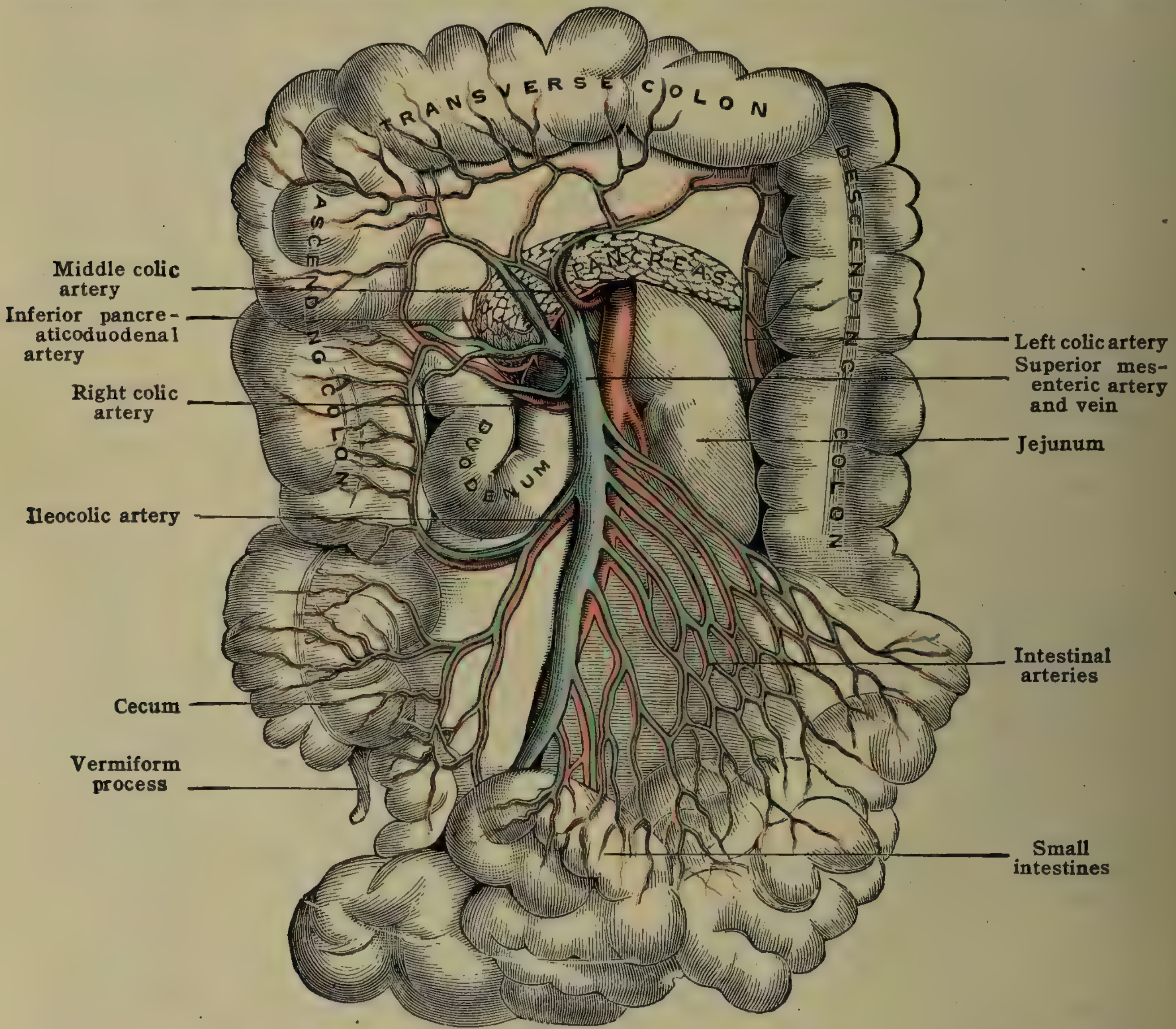


FIG. 559.—THE SUPERIOR MESENTERIC ARTERY AND VEIN.
(The colon is turned up, and the small intestines are drawn over to the left side.)

creas and splenic vein, it soon passes forward between the lower border of the pancreas and the upper border of the inferior portion of the duodenum. It here gives its middle colic branch and, crossing the inferior part of the duodenum, it enters the mesentery, in which it runs in the form of a curve with its convexity to the left, to the cecum, where it anastomoses with its ileocolic branch. Its vein lies to its right side above, having previously crossed obliquely in front of the artery from the left. It is surrounded by the mesenteric plexus of nerves. The uncinate process of the head of the pancreas dips in behind the vessel.

The **branches of the superior mesenteric** are: (1) the inferior pancreaticoduodenal; (2) the intestinal arteries; (3) the ileocolic; (4) the right colic; and (5) the middle colic (fig. 559).

(1) The **inferior pancreaticoduodenal** [a. pancreaticoduodenalis inferior] artery arises either from the superior mesenteric as that vessel emerges from the contiguous margins of the pancreas and inferior part of the duodenum or from its first intestinal branch. Crossing behind the superior mesenteric vein, it courses upward and to the right between the head of the pancreas and the duodenum, and beneath the ascending layer of the transverse mesocolon, to anastomose with the superior pancreaticoduodenal artery.

(2) The **intestinal** arteries [aa. intestinales] arise from the convex side of the superior mesenteric both before and after it enters the mesentery. Varying from twelve to sixteen in number,

Fig. 560.—The Blood-vessels of the Ileocecal Region. (From Kelley.)
(Arteries red, veins blue.) The peritoneal covering is removed so as to show the vessels more clearly. Above and to the right are seen the cut ends of the ileocolic artery and vein. This artery gives off a branch to the ascending colon and a posterior and anterior cecal artery, the latter descending through the ileocolic fold. A short anastomosis connects the ileocolic with the mesenteric. The artery of the vermiform process (appendix) is seen to arise from the posterior cecal artery, 2 cm. above the ileum. It passes behind the ileum in the free border of the mesoappendix and gives off five branches (long appendices have 8–12, short appendices, 2–3), which traverse the mesoappendix at fairly regular intervals in the direction of the hilus of the appendix, where they divide into anterior and posterior branches. The branches in the mesoappendix are sometimes seen to anastomose, forming loops of varying size. The terminal branch curves around the tip. The cecoappendicular junction is supplied by a separate branch arising likewise from the posterior ileocecal trunk. This branch may or may not anastomose with the proximal appendicular twig and while in some cases it supplies only the cecum, in others, as in the present case, it sends a few delicate branches into the appendix. At the place where this cecoappendicular artery crosses the ileocecal fold it is seen to give off a delicate recurrent twig to this structure. Throughout their entire course the arteries are accompanied by veins.

they radiate in the mesentery, where each divides into two branches, which inosculate with similar branches given off from the branch above and below. From the primary loops thus formed, secondary loops are derived in like manner, and from these tertiary, and at times quaternary, or even quinary loops. From the ultimate loops terminal **jejunal and ileac** branches [aa. jejunales et ileæ] pass on to the muscular coat of the gut. These terminal vessels bifurcate, the two branches encircling the intestine, and thus forming with those above and below a series of vascular rings surrounding the small intestine throughout its whole length. The first intestinal artery anastomoses with the pancreaticoduodenal artery, and the last (the continuation of the main artery) with the ileocolic. The branches of the superior mesenteric in their course to the intestine also supply the mesentery and the mesenteric glands.

(3) The **ileocolic** artery [a. ileocolica] arises just before the superior mesenteric enters the mesentery and descends behind the peritoneum toward the cecum. Here it divides into a colic branch which tracks upward beneath the peritoneum to anastomose with the descending branch of the right colic; and into an iliac branch which passes between the layers of the mesentery and anastomoses with the termination of the superior mesenteric artery. Near the site of division the ileocolic gives off anterior and posterior cecal branches. From the latter of these arises a cecoappendicular artery, to the cecum and root of the vermiform process, and a main **appendicular** artery [a. appendicularis] (fig. 560).

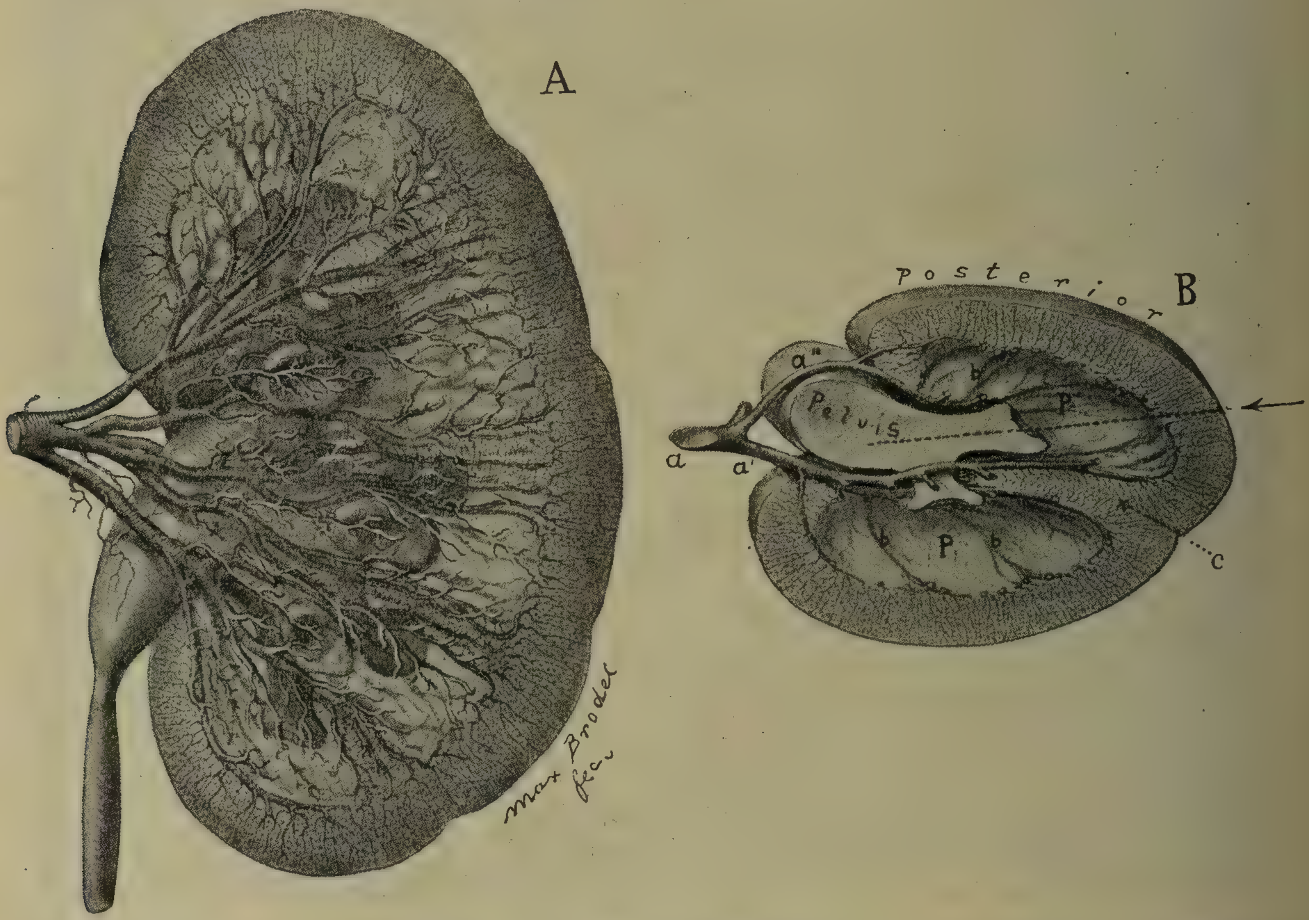


Fig. 561.—A. The Renal Artery and the Distribution of its Branches in Relation to the Pelvis. B. Transverse Section through the Middle of the Same Kidney. (After Brödel, Johns Hopkins Hospital Bulletin.)

a, renal artery; *a′* and *a″*, its anterior and posterior branches; *b*, branches to pyramids; *c*, line of division between anterior and posterior pyramids. The arrow and dotted line indicate the line of separation between the terminals of the anterior and posterior branches.

(4) The **right colic** [a. colica dextra]—sometimes given off as a common trunk either with the middle colic or with the ileocolic—passes to the right behind the peritoneum to the back of the ascending colon, where it divides into an ascending branch, which enters the mesocolon to anastomose with the descending branch of the middle colic, and a descending branch which anastomoses behind the peritoneum with the ascending or colic branch of the ileocolic.

(5) The **middle colic** [a. colica media], arising from the concavity of the superior mesenteric a little below the pancreas, enters the transverse mesocolon, and divides into two branches—one of which passes to the left and anastomoses with the ascending branch of the left colic; the other, winding downward and to the right, anastomoses with the ascending branch of the right colic.

THE RENAL ARTERIES

The **renal** arteries [aa. renales] come off one on each side of the abdominal aorta, a little below the superior mesenteric and first lumbar arteries, on a level with the first lumbar vertebra. They pass laterally across the intermediate crura of the diaphragm to the kidneys, the right being on a slightly lower plane and somewhat longer than the left, and passing behind the vena cava inferior. In front of each is the corresponding renal vein, and behind, at the hilus of the kidney,

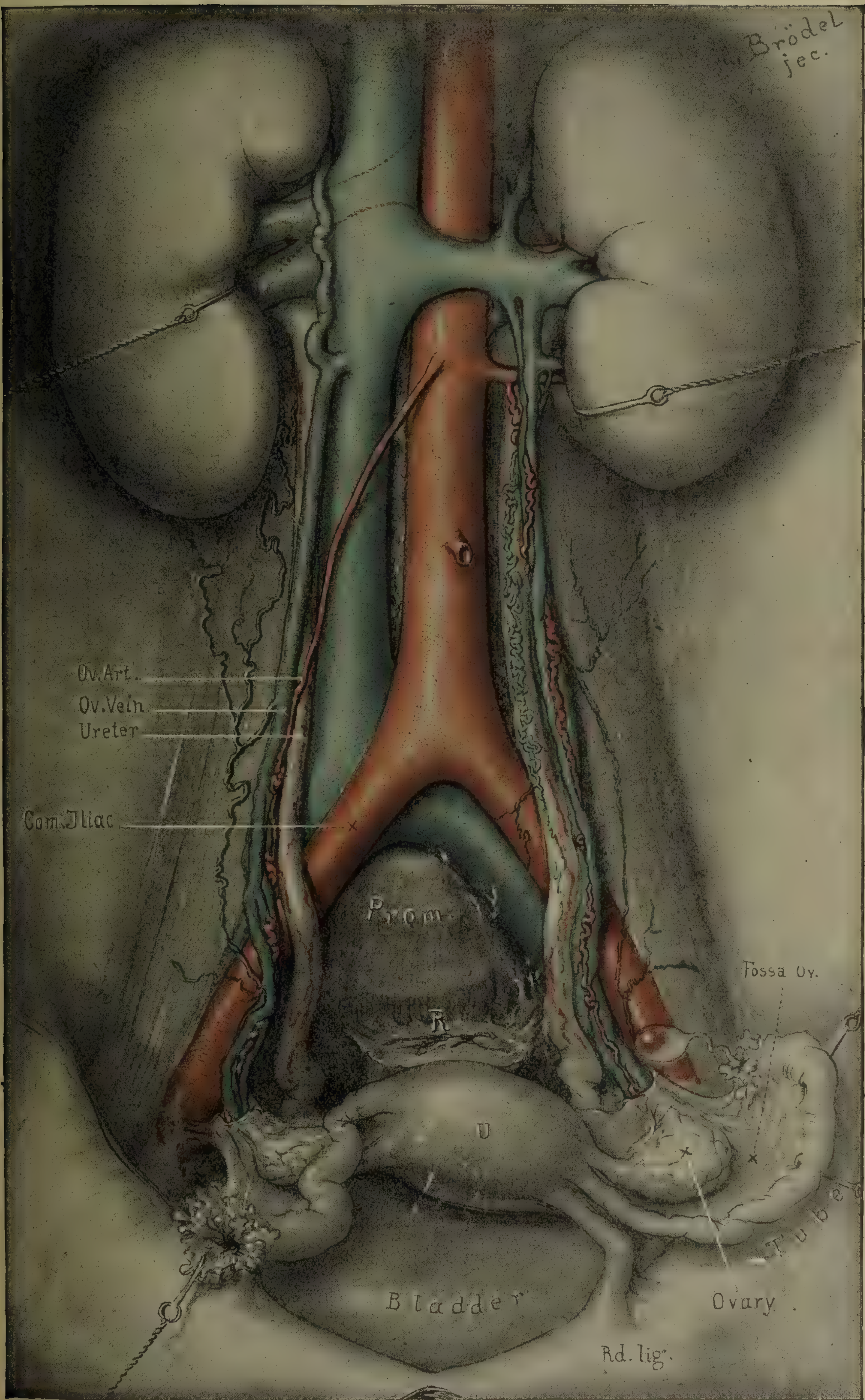


FIG. 562.—THE VASCULAR TRUNKS OF THE LOWER ABDOMEN. (From Kelley, by Brödel.)

is the commencement of the ureter. Each artery as it enters the hilus usually divides into three main stems, one of which passes toward the upper part of the pelvis, a second to its middle portion, and a third to its lower. Each of these primary stems then divides so that there result from seven to nine secondary branches, the majority of which pass anteriorly to the pelvis, while the remainder are posterior to it (fig. 561). No anastomoses take place between the branches of the anterior and posterior secondary stems and hence a longitudinal incision

Fig. 563.—The Ovarian Vessels. (After Clark.)

into the kidney along its curved border, half way between the anterior and posterior calices, will cut only terminal arteries. (For internal distribution see Section XII.)

The branches of the renal arteries are:

(1) The **inferior suprarenal** [a. suprarenalis inferior] (rami suprarenales NK) which ascends to the suprarenal body.

(2) The **capsular** or **perirenal** branches to the capsule of the kidney and perirenal fat.

(3) The **ureteral** branch to the upper end of the ureter.

THE MIDDLE SUPRARENAL ARTERIES

The **middle suprarenal** artery [a. suprarenalis media] (a. suprarenalis NK) comes off, one on each side from the aorta, just above the first lumbar artery, and passes laterally to the suprarenal body, across the crura of the diaphragm a little above the renal arteries. In the fetus they are as large as the renals, but in the adult they are much smaller. They anastomose with the superior and inferior suprarenal arteries from the inferior phrenic and renal arteries respectively. For the distribution of the suprarenal vessels within the suprarenal bodies, see Section XIII.

THE INTERNAL SPERMATIC ARTERIES

The **internal spermatic** arteries [a. spermatica interna] (figs. 556, 618), right and left, come off from the front of the abdominal aorta. They diverge from each other as they descend over the aorta and psoas muscle to the abdominal inguinal (internal abdominal) ring, where they are joined by the ductus deferens and, passing with it through the inguinal canal and out of the subcutaneous inguinal (external abdominal) ring, run downward into the scrotum in a tortuous course to the testes. They terminate in branches to the epididymis and testis. Within the abdomen they lie beneath the peritoneum, and cross in their descent over the ureters and distal ends of the external iliac arteries; the right being superficial to the vena cava, and behind the termination of the ileum; and the left beneath the sigmoid colon. In the inguinal canal and in the scrotum the spermatic veins lie in front of the artery, and the ductus deferens lies behind it.

In the fetus these vessels pass in a transversely lateral direction to the testis, which in early fetal life lies in the loin in front of the kidney; but as the testes descend to the scrotum, the vessels become elongated, and are drawn with the testis into the scrotum.

The **branches of the internal spermatic artery** are: (1) ureteral; (2) cremasteric; (3) epididymal; and (4) testicular.

(1) The **ureteral** are small branches given off to the ureter as the spermatic artery crosses it. They anastomose with the other ureteral branches derived from the renal, common iliac, and vesical arteries, and also supply the adjacent retroperitoneal tissue.

(2) The **cremasteric** are small branches given off to the cremaster muscle; they anastomose with the external spermatic branch of the inferior epigastric.

(3) The **epididymal** arteries are distributed to the epididymis, and anastomose with the deferential artery.

(4) The **testicular** arteries [aa. testiculares] are the terminal branches of the spermatic; they perforate the tunica albuginea posteriorly, and are distributed to the body of the organ as described in the section on the Testis.

THE OVARIAN ARTERIES

The **ovarian** arteries [aa. ovaricæ] (figs. 562, 563, 571) are the homologs of the internal spermatic arteries in the male, and correspond in their relations in the upper part of their course. They diverge somewhat less, however, and, on reaching the level of the common iliac artery, turn medialward over that vessel and descend tortuously into the pelvis on each side between the folds of the suspensory ligament of the ovaries. Continuing between the layers of the broad ligament of the uterus, the ovarian artery lies below the Fallopian tube and inosculates with the uterine artery forming an arch (fig. 571) from which the ovary and uterine tube are supplied (see Uterine artery, p. 683).

The **ureteral** branches are distributed, as in the male, to the ureter, which is crossed by the ovarian artery as it descends toward the pelvis (shown in fig. 562).

Like the spermatic, the ovarian arteries in the fetus come off at right angles to the aorta, and pass transversely lateralward to the ovaries, which are formed, as are the testes, in the right and left loin in front of the kidneys. They elongate as the ovaries descend into the pelvis. During pregnancy these arteries undergo great enlargement.

THE INFERIOR MESENTERIC ARTERY

The **inferior mesenteric** artery [a. mesenterica inferior], smaller than the superior, arises from the front of the abdominal aorta about 3,7 cm. (1½ in.) above the bifurcation of that vessel. It runs obliquely downward and to the left, behind the peritoneum, across the lower part of the abdominal aorta and then over the left psoas muscle and left common iliac artery. It descends into the pelvis between the layers of the sigmoid mesocolon, and terminates on the rectum as in the superior hemorrhoidal artery. It supplies the lower half of the large

intestine. Its vein lies at first close to the left side, but soon passes upward on the psoas, away from the artery, to end in the splenic vein (fig. 564).

The **branches of the inferior mesenteric** are: (1) the left colic; (2) the sigmoid; and (3) the superior hemorrhoidal.

(1) The **left colic** artery [a. colica sinistra] runs transversely to the left, beneath the peritoneum, and divides into two branches, one of which ascends and, entering the transverse mesocolon, passes to the right, to anastomose with the middle colic. The other descends, and, entering the sigmoid mesocolon anastomoses with the ascending branch of the sigmoid artery. The distribution of the branches of the left colic and of the sigmoid artery to the colon is similar to that of the colic branches of the superior mesenteric, and does not require a separate description.

(2) The **sigmoid arteries** [aa. sigmoideæ] run downward and to the left over the psoas muscle and, entering the sigmoid mesocolon, are distributed to the iliac and anastomose with the left colic and the lower with the superior hemorrhoidal. The distribution of the branches of the left colic and of the sigmoid arteries to the colon is similar to that of the colic branches of the superior mesenteric, and does not require a separate description. (See p. 670.)

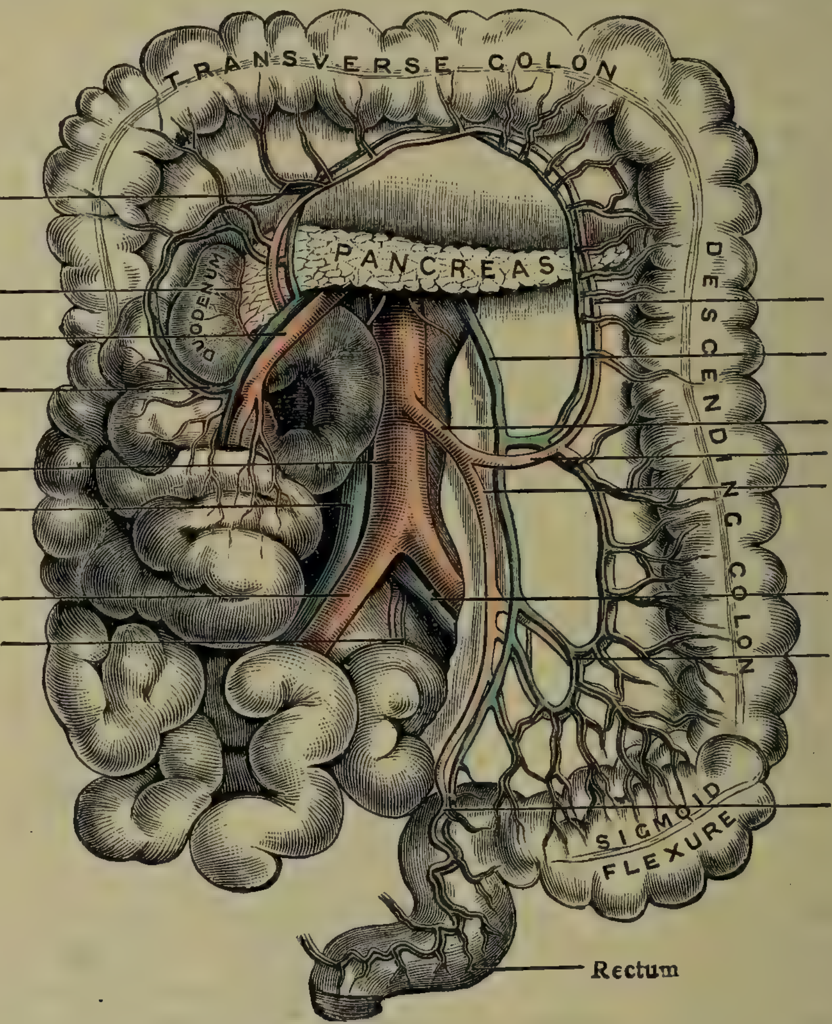


Fig. 564.—The Inferior Mesenteric Artery and Vein.
(The colon is turned up, and the small intestines are drawn to the right side.)

(3) The **superior hemorrhoidal** artery [a. hæmorrhoidalis superior] (a. rectalis cranialis NK) (fig. 564) is the continued trunk of the inferior mesenteric. It descends into the pelvis, behind the rectum, between the layers of the sigmoid mesocolon. It bifurcates about 18 cm. (7.2 in.) from its origin and the two branches redivide several times finally forming an arcade parallel with the gut, continuous with that formed by the sigmoid arteries. Offshoots, reaching the muscularis again divide, and the branches, piercing the muscular coat, descend between that coat and the mucous membrane, forming with each other, and with the middle hemorrhoidal arteries—derived from the hypogastric (internal iliac)—a series of small vessels, running longitudinally to the rectum, and parallel with each other as far as the level of the internal sphincter, where, by their anastomosis, they form a series of loops around the lower part of the rectum.

C. The Terminal Branches of the Abdominal Aorta

THE MIDDLE SACRAL ARTERY

The **middle sacral** artery [a. sacralis media] (aorta caudalis NK) extends from the bifurcation of the aorta to the tip of the coccyx. As it passes downward into the pelvis, it runs behind the left common iliac vein, the hypogastric plexus of the sympathetic nerve, and the peritoneum. It lies successively upon the intervertebral disk between the fourth and fifth lumbar vertebræ, the fifth

lumbar vertebra, the intervertebral disk between that vertebra and the sacrum, and lower down upon the anterior surface of the sacrum and coccyx. Along the course of the middle sacral artery are some scattered nodules forming the *glomus coccygeum* (see fig. 1166).

(1) The **lowest lumbar** artery [a. lumbalis ima] runs laterally beneath the common iliac artery and vein; and, after giving off a dorsal branch, ramifies over the lateral part of the sacrum, and ends in the iliacus muscle by anastomosing with the circumflex iliac artery. The **dorsal branch** passes to the back between the last lumbar vertebra and the sacrum and ramifies in the gluteus maximus, anastomosing with the lumbar arteries above, and the superior gluteal artery below.

(2) **Lateral sacral** branches, are usually four in number. They are serially homologous with the intercostal and lumbar arteries given off by the aorta. They run laterally, and anastomose with the lateral sacral branches of the hypogastric (internal iliac) artery. They give off small spinal branches, which pass through the sacral foramina, and supply the sacral canal and back of the sacrum.

(3) **Rectal** or **hemorrhoidal** branches pass forward beneath the peritoneum or in the sigmoid mesocolon to the rectum, which they help to supply, and anastomose with the other hemorrhoidal or rectal arteries.

THE COMMON ILIAC ARTERIES

The **common iliac** arteries [aa. iliacæ communes] arise opposite the left side of the middle of the body of the fourth lumbar vertebra, at the bifurcation of the abdominal aorta, and, diverging from each other in the male at about an angle of 60°, and in the female at an angle of 68°, terminate opposite the lumbosacral articulation by bifurcating into the external iliac, which is continued along the brim of the pelvis to the lower limb, and into the hypogastric (internal iliac), which descends into the pelvis minor (fig. 565). The relations differ slightly on the two sides, which may be considered separately.

The Right Common Iliac Artery

The **right common iliac** artery (fig. 565) measures about 5 cm. (2 in.) in length, and is rather longer than the left, in consequence of the aorta bifurcating a little to the left of the median line.

Relations.—**In front** it is covered by the peritoneum, and is crossed by the right ureter a little before its bifurcation, by the ovarian artery in the female, by the termination of the ileum by the terminal branches of the superior mesenteric artery, and by branches of the sympathetic nerve descending to the hypogastric plexus.

Behind, it lies on the right common iliac vein, the end of the left common iliac vein, and the commencement of the vena cava inferior which separate it from the fourth and fifth lumbar vertebræ and their intervening disks, the psoas muscle, and the sympathetic nerve trunk. Still deeper in the groove between the fifth vertebra and the psoas are the lumbosacral trunk the obturator nerve, and the iliolumbar artery.

To the **right side** are the beginning of the vena cava inferior, the end of the right common iliac vein, and the psoas muscle. The muscle, however, is separated from the upper part of the artery by the vena cava inferior.

To the **left side** are the right common iliac vein, the termination of the left common iliac vein, and the hypogastric plexus.

The Left Common Iliac Artery

The **left common iliac** artery, 4 cm. (1.6 in.) in length, is a little shorter and thicker than the right.

Relations.—**In front** it is covered by the peritoneum and is crossed by the ureter, the ovarian artery in the female, branches of the sympathetic nerve descending to the hypogastric plexus, the termination of the inferior mesenteric artery, the sigmoid colon, and the sigmoid mesocolon.

Behind are the lower border of the body of the fourth lumbar vertebra, the disk between the fourth and fifth lumbar vertebra, the body of the fifth lumbar vertebra, and the disk between it and the sacrum. Crossing deeply behind the artery between the fifth lumbar vertebra and the psoas, are the obturator nerve, the lumbosacral trunk, and the iliolumbar artery.

To the **left side** is the psoas muscle.

To the **right side** are the left common iliac vein, the hypogastric plexus, and the middle sacral artery.

Collateral Circulation

The **collateral circulation** after obstruction or ligature of the common iliac artery is carried on chiefly (fig. 574) by the anastomosis of the middle sacral with the lateral sacral; the internal mammary with the epigastric; the lumbar arteries of the aorta with the iliolumbar and deep circumflex iliac; the pubic branch of the epigastric with the pubic branch of the obturator; the posterior branches of the sacral arteries with the superior gluteal (gluteal); the superior hemorrhoidal from the inferior mesenteric, with the hemorrhoidal branches of the hypogastric (in-

ternal iliac) and pudic; the ovarian arteries from the aorta with the uterine branches of the hypogastric (internal iliac); and by the anastomosis across the middle line of the pubic branch of the obturator with the like vessel of the opposite side; the lateral sacral with the opposite lateral sacral; and the vesical, hemorrhoidal, uterine, and vaginal branches of the hypogastric with the corresponding branches of the opposite hypogastric (internal iliac).

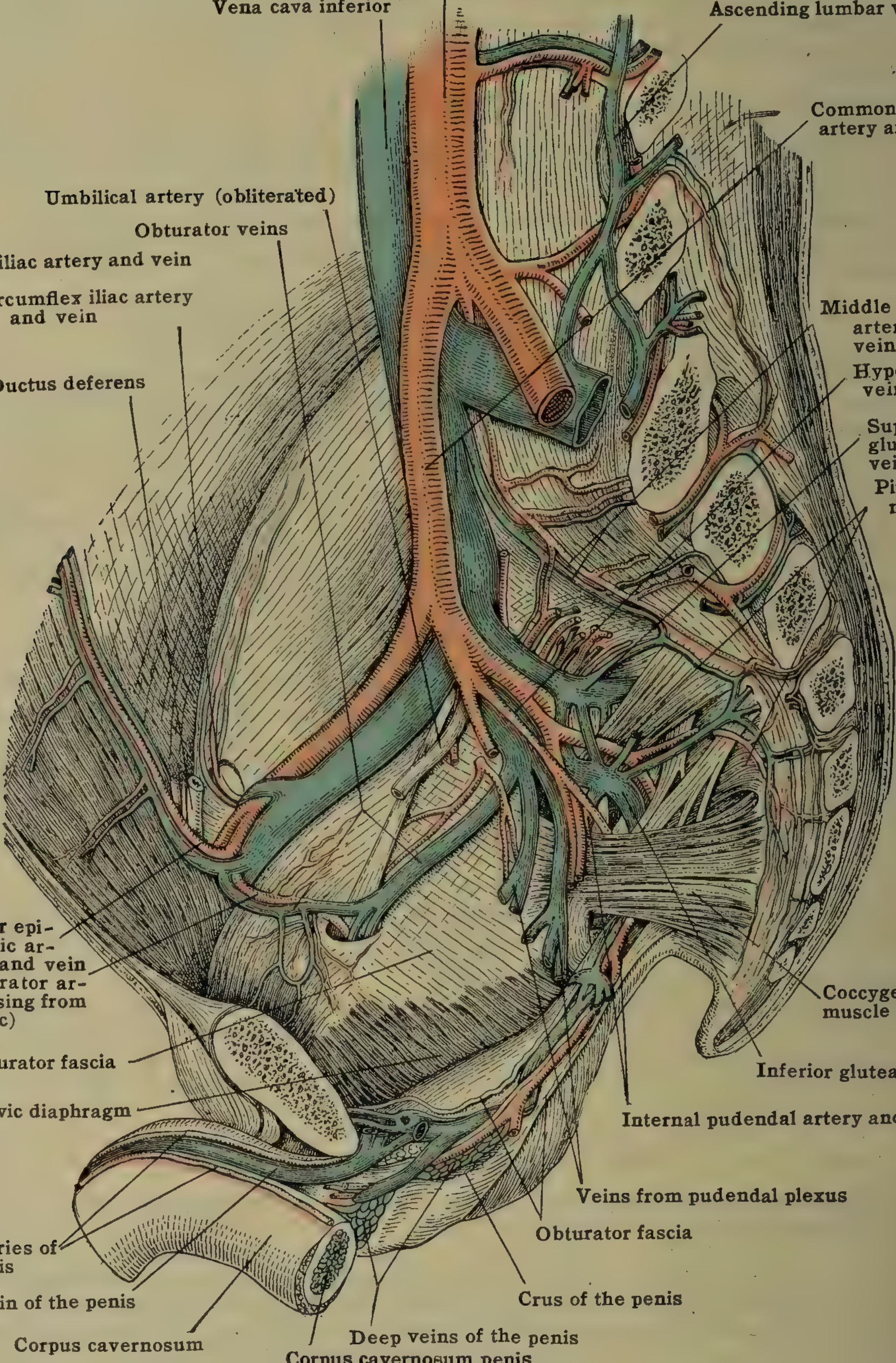


FIG. 565.—BLOOD-VESSELS OF THE MALE PELVIS. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

BRANCHES OF THE COMMON ILIAC ARTERY

The **branches of the common iliac artery** (fig. 565) are:—(1) The hypogastric (internal iliac); and (2) the external iliac.

A few small, unimportant branches are distributed to the peritoneum and subperitoneal fat. They anastomose with vessels given off from the lumbar, inferior phrenic, and renal arteries, forming a subperitoneal arterial anastomosis. The ureter as it crosses the artery receives small twigs which anastomose with the ureteral arteries given off from the internal spermatic above, and with those derived from the vesical arteries below.

THE HYPOGASTRIC ARTERY

The **internal iliac** or **hypogastric** artery [a. hypogastrica] (a. ilica interna NK) (figs. 565, 566), arises at the bifurcation of the common iliac opposite the lumbosacral articulation. It descends into the pelvis minor medially to the common iliac and external iliac veins, and arches forward to become continuous with the lateral umbilical ligament.

In the fetus the hypogastric artery is larger than the external iliac; for through it the fetal blood is returned to the placenta. The common iliac-hypogastric trunk replaces the proximal part of the original umbilical branch of the aorta, which disappears at an early stage of develop-

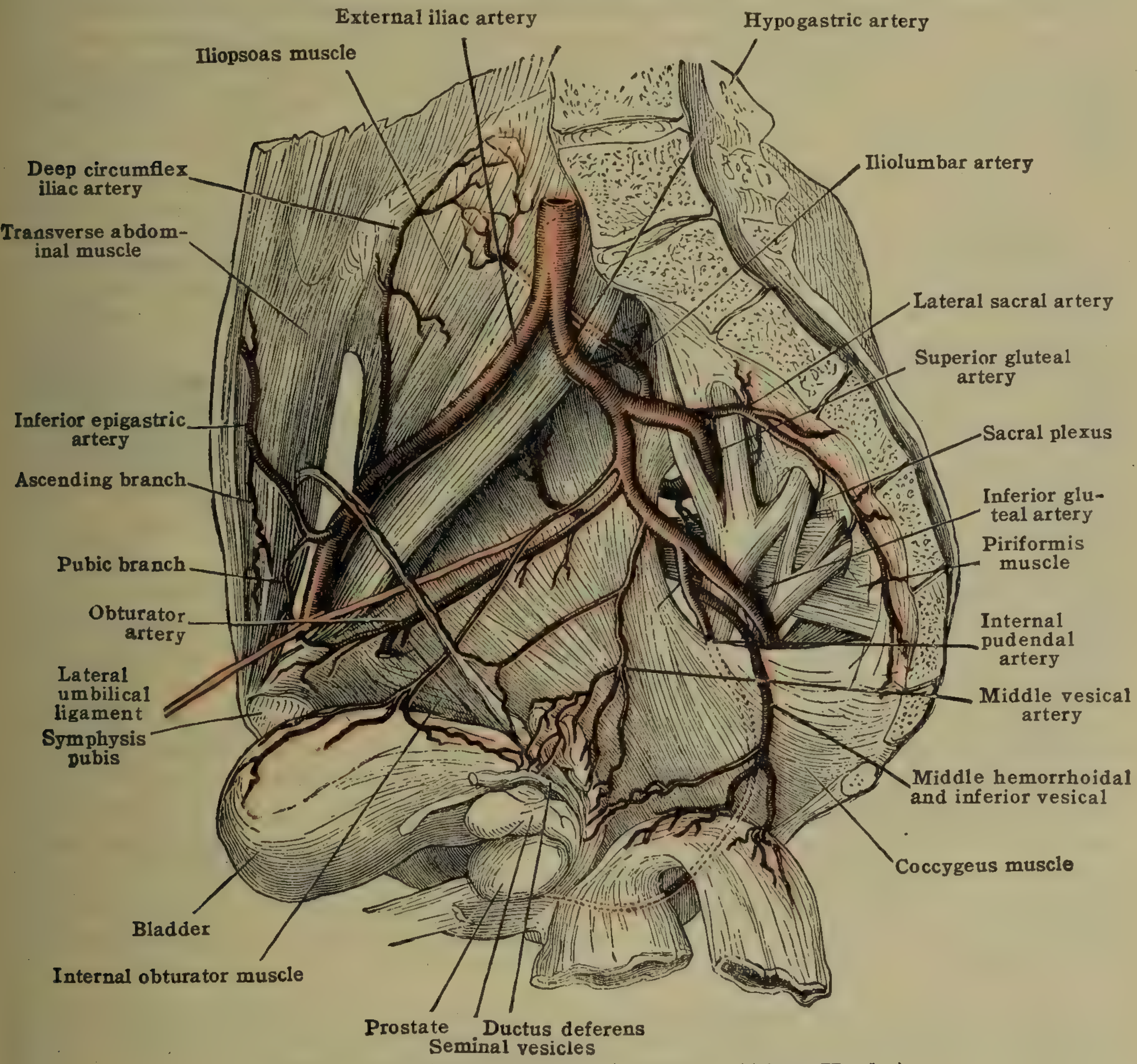


FIG. 566.—THE HYPOGASTRIC ARTERY. (After Henle.)

ment. The larger part of the remainder of the umbilical artery is reduced, shortly after birth, to an impervious cord, the lateral umbilical ligament.

Relations.—Laterally, the hypogastric artery rests on the common iliac vein and the termination of the external iliac vein, which separate it from the medial margin of the psoas muscle, and the obturator nerve. **Behind** it rests on the hypogastric vein. **In front,** it is covered by the peritoneum, and is crossed by the ureter.

The **branches of the hypogastric artery** may be divided into parietal and visceral sets. The **parietal** branches are: (1) the iliolumbar; (2) the lateral sacral; (3) the obturator; (4) the internal pudendal and (5) the gluteal arteries.

The **visceral** branches are: (1) the umbilical; (2) the inferior vesical; (3) the deferential; (4) the middle hemorrhoidal; and (5) the uterine.

The branching of the hypogastric artery is subject to great variation. While some branches take direct origin from the artery, many arise indirectly from it, being associated with others by means of a common trunk of origin. The studies of Adachi, Jastschinski, Lipschitz and others show that the large parietal branches, the superior gluteal, the inferior gluteal and the internal pudendal arise in that order, although the origin of any two or all of them may be united by a common trunk of origin. The so-called anterior division of the artery (formed to a large extent by a trunk common to the origin of the inferior gluteal and internal pudendal arteries) may therefore not exist at all; nor may the posterior division (formed by the superior

gluteal associated only with the iliolumbar and lateral sacral arteries). The obturator may arise separately from the hypogastric or in common with one or both of the gluteal arteries. The iliolumbar and lateral sacral arteries are most commonly associated with the superior gluteal. Of the visceral branches, the superior vesical is almost invariably the last direct branch of the hypogastric. The others vary greatly as to site of origin. The uterine seems most frequently to be a direct branch of the artery, from which the inferior vesical and deferential often arise by a common trunk. The middle hemorrhoidal is often associated in origin with the inferior gluteal.

Parietal Branches of the Hypogastric Artery

1. THE ILIOLUMBAR ARTERY

The **iliolumbar** artery [a. iliolumbalis] runs upward and laterally beneath the common iliac artery, first between the lumbosacral trunk and obturator nerve, and then between the psoas muscle and the vertebral column. On reaching the superior aperture of the pelvis minor it divides into two branches, an iliac and a lumbar (fig. 566).

The **iliac** branch [r. iliacus] passes laterally beneath the psoas and the femoral (anterior crural) nerve and, perforating the iliacus, ramifies in the iliac fossa between that muscle and the bone. It supplies a nutrient artery to the bone, and then breaks up into several branches which radiate from the parent trunk, upward toward the sacroiliac synchondrosis, laterally toward the crest of the ilium, downward toward the anterior superior spine, and medially toward the pelvis minor. The first anastomoses with the last lumbar; the second with the lateral circumflex and gluteal; the third with the deep circumflex iliac from the external iliac; the fourth with the iliac branch of the obturator. The **lumbar** branch [r. lumbalis] ascends beneath the psoas, and, supplying that muscle and the quadratus lumborum, anastomoses with the last lumbar artery. It sends a **spinal** branch (r. spinalis) into the vertebral canal through the intervertebral foramen between the last lumbar vertebra and the sacrum; this branch anastomoses with the other spinal arteries. The iliolumbar artery is serially homologous with the lumbar arteries. Hence the similarity in its course and distribution.

2. THE LATERAL SACRAL ARTERIES

The **lateral sacral** artery [a. sacralis lateralis] may be represented by two vessels. The **superior** artery (or branch, in cases in which two branches arise from a common stem), runs downward and medially to the first anterior sacral foramen, through which it passes. After supplying the spinal membranes and anastomosing with the other spinal arteries, it passes through the first posterior sacral foramen, and is distributed to the skin over the back of the sacrum, there anastomosing with branches of the superior and inferior gluteal arteries. The **inferior lateral sacral** descends on the side of the sacrum, on the lateral side of the sacral sympathetic trunk, and medially to the anterior sacral foramina, crossing in its course the slips of origin of the piriformis muscle and the first anterior sacral nerve. On reaching the coccyx it anastomoses in front of that bone with the middle sacral artery, and with the inferior lateral sacral of the opposite side (fig. 566).

In this course it gives off:—**Spinal** branches [rr. spinales], which enter the second, third and fourth anterior sacral foramina, and, after supplying the spinal membranes and anastomosing with each other, leave the spinal canal by the corresponding posterior sacral foramina, and are distributed to the muscle and skin over the back of the sacrum; and **rectal** branches which run forward to the rectum.

At times the lateral sacral arteries are very small, the spinal branches then coming chiefly from the middle sacral. The anastomosing branches between the lateral sacral and middle sacral are regarded as sacral segmental arteries serially homologous with the lumbar and intercostal arteries.

3. THE OBTURATOR ARTERY

The **obturator** artery [a. obturatoria] (fig. 566), sometimes arises from the inferior epigastric (fig. 565) or from the external iliac artery (see p. 686). It runs forward and downward a little below the brim of the pelvis, having the obturator nerve above and the obturator vein below. It here lies between the peritoneum and the endopelvic fascia, but later it passes through the obturator canal, the aperture in the upper part of the obturator membrane. In this course it is crossed by the ductus deferens. On emerging from the obturator canal the artery divides into two branches, anterior and posterior, which wind around the margin of the obturator foramen beneath the obturator externus muscle.

The **branches of the obturator artery** are: (1) the iliac or nutrient branch; (2) the pubic branch; (3) the anterior, and (4) the posterior terminal branches.

(1) The **iliac or nutrient** branch ascends to the iliac fossa, passing between the iliacus muscle and the bone. It supplies a nutrient vessel to the ilium, and anastomoses with the medial branch of the iliac division of the iliolumbar artery.

(2) The **pubic** branch [r. pubicus] comes off from the obturator as that vessel is leaving the pelvis by the obturator canal. It runs upward and medially behind the pubis, anastomosing with its fellow of the opposite side of the body, and with the pubic branch of the inferior epigastric artery. One of the anastomosing channels between the pubic branch of the obturator and pubic branch of the inferior epigastric arteries is sometimes of large size (fig. 566), a fact of surgical interest in that the enlarged vessel may then run around the medial side of the femoral ring (p. 686; fig. 1019).

(3) The **anterior** branch [r. anterior] (medialis NK) runs around the medial margin of the obturator foramen, and anastomoses with the posterior branch and with the medial circumflex artery. It supplies branches to the obturator and adductor muscles.

(4) The **posterior** branch [r. posterior] (lateralis NK) skirts the lateral margin of the obturator foramen, lying between the obturator externus and the obturator membrane. At the lower margin of the foramen it divides into two branches. One branch continues its course around the lower margin of the foramen, and anastomoses with the anterior branch of the obturator and with the medial circumflex. The other branch turns laterally below the acetabulum, and ends in the muscles arising from the tuberosity of the ischium. It anastomoses with the inferior gluteal artery. This branch gives off a small twig, the **acetabular** artery [a. acetabuli], which

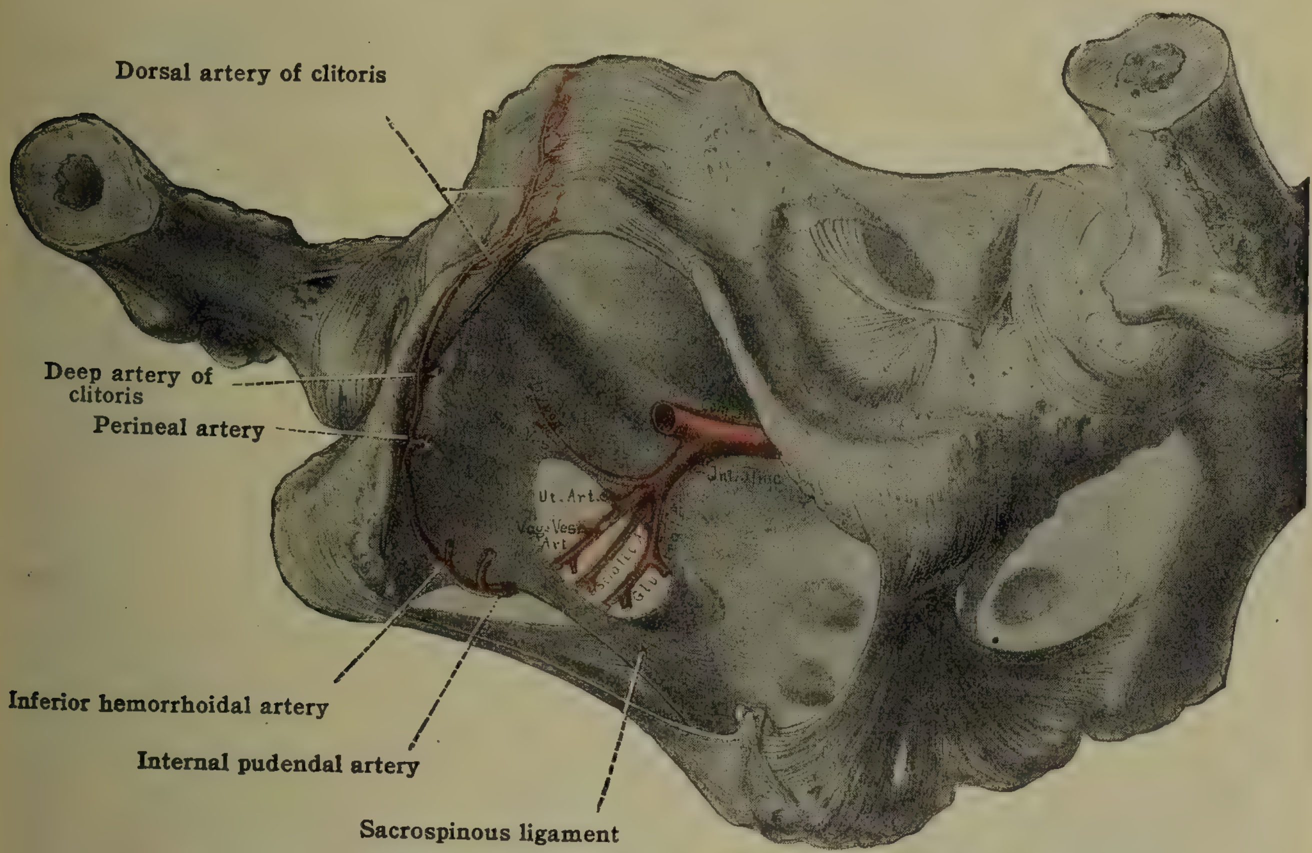


FIG. 567.—THE INTERNAL PUDENDAL ARTERY. (From Kelley, by Brödel.)

passes under the transverse ligament into the hip-joint, where it supplies the synovial membrane, the ligamentum teres, and the fat in the fossa at the bottom of the acetabulum.

4. THE INTERNAL PUDENDAL ARTERY

The **internal pudendal** (pudic) artery [a. pudenda interna] (figs. 567, 568, 569) arises opposite the piriformis muscle and accompanies the inferior gluteal downward to the lower border of the great sciatic foramen. It leaves the pelvis between the piriformis and coccygeus and winds over the ischial spine to enter the ischiorectal fossa through the small sciatic foramen. Running forward in the ischiorectal fossa, in a canal in the obturator fascia, it ends by dividing into the **perineal artery** and the **artery of the penis** (or clitoris).

Relations.—*Within the pelvis*, the artery lies anteriorly to the piriformis muscle and the sacral plexus of nerves, and laterally to the inferior gluteal artery. It passes between the piriformis and coccygeus, with the gluteal artery and pudendal nerve on the medial side, and the nerve to the obturator internus upon the lateral. The sciatic and posterior femoral cutaneous (lesser sciatic) nerves lie still more laterally. *On the ischial spine* the artery retains its relations to the pudendal nerve (which often divides in this situation into its two terminal branches) and the nerve to the obturator internus. It is accompanied by venæ comitantes and covered by the gluteus maximus muscle. *In the ischiorectal fossa* the artery is placed on the lateral wall about 3.5 cm. (1½ in.) above the tuberosity of the ischium. It is accompanied in a canal in the obturator fascia (*Alcock's canal*) by the dorsal nerve of the penis and the perineal nerve, which are respectively above and below the artery.

The **branches of the internal pudendal artery** are:—(1) Small branches to the gluteal region; (2) the inferior hemorrhoidal arteries; and the terminal branches, (3) perineal; and (4) artery of the penis or clitoris.

(1) The **branches of the gluteal region** are:—(*a*) twigs to the gluteus maximus; (*b*) branches accompanying the nerve to the obturator internus; (*c*) a sacral branch which pierces the sacrotuberous ligament and anastomoses with the inferior gluteal artery.

(2) The **inferior hemorrhoidal** artery [a. hæmorrhoidalis inferior] (a. analis NK) (figs. 567, 568) arises at the posterior part of the ischiorectal fossa and, perforating the obturator fascia, at once breaks up into several branches. These, running medially toward the anus, traverse the ischiorectal fat and supply the fascia, skin and the levator ani and external sphincter muscles. The inferior hemorrhoidal branches anastomose with those from the middle and superior hemorrhoidal, and from the gluteal and perineal arteries.

Fig. 568.—The Perineal and Hemorrhoidal Branches of the Internal Pudendal Arteries. (From Kelley, by Brödel.)

(3) The **perineal** artery [a. perinei] (figs. 567, 568), one of the terminal arteries of the internal pudendal, arises at the anterior part of the ischiorectal fossa. It pierces the base of the urogenital diaphragm (triangular ligament), and enters the space deep to Colles's fascia. Here it runs forward between the ischiocavernosus and bulbocavernosus muscles to the scrotum or labium majus and divides into numerous terminal branches. Immediately after piercing the diaphragm, the perineal artery gives off a constant **transverse perineal** branch which runs toward the median line along the superficial transverse perineal muscle. The terminal branches of the perineal are the **posterior scrotal or labial** arteries [aa. scrotales, or labiales posteriores] which ramify on the scrotum or labia majora (according to sex) and anastomose with external pudendal arteries.

(4) The **artery of the penis, or clitoris** [a. penis; a. clitoridis] (figs. 567, 569) pierces the posterior border of the urogenital diaphragm and runs forward between the layers of the diaphragm with the dorsal nerve of the penis along the inferior ramus of the pubis. It traverses the fibers of the deep transverse perineal muscle and of the sphincter of the membranous urethra and ends by dividing into deep and dorsal arteries of the penis, or clitoris, according to sex.

The **branches of the artery of the penis** (or **clitoris**) are:—(*a*) The artery to the bulb; (*b*) the urethral artery; (*c*) the deep artery, and (*d*) dorsal artery of the penis or clitoris.

(*a*) The **artery of the bulb** [a. bulbi urethræ; a. vestibuli vaginæ] takes a medial direction through the fibers of the m. transversus perinei profundus. It then pierces the inferior fascia of the urogenital diaphragm to reach the bulb, the erectile tissue of which it supplies, in either sex. This vessel also supplies branches to the bulbourethral gland (Cowper's) in the male, or the greater vestibular (Bartholin's) gland in the female.

(*b*) The **urethral** artery [a. urethralis] is a small branch which passes into the corpus cavernosum urethræ (corpus spongiosum) and anastomoses with branches from the artery of the bulb.

(*c*) The **deep artery of the penis or clitoris** [a. profunda penis; a. profunda clitoridis], larger in the male sex, pierces the inferior layer of the urogenital diaphragm near the inferior ramus of the pubis. It enters the crus of the penis (fig. 569) or clitoris, and is distributed in the corpus cavernosum penis.

(*d*) The **dorsal artery of the penis or clitoris** [a. dorsalis penis; a. dorsalis clitoridis] (figs. 567–569), perforates the inferior fascia of the urogenital diaphragm near its apex. The dorsal nerve lies on the lateral side of the artery and joins the dorsal vein (which lies between the

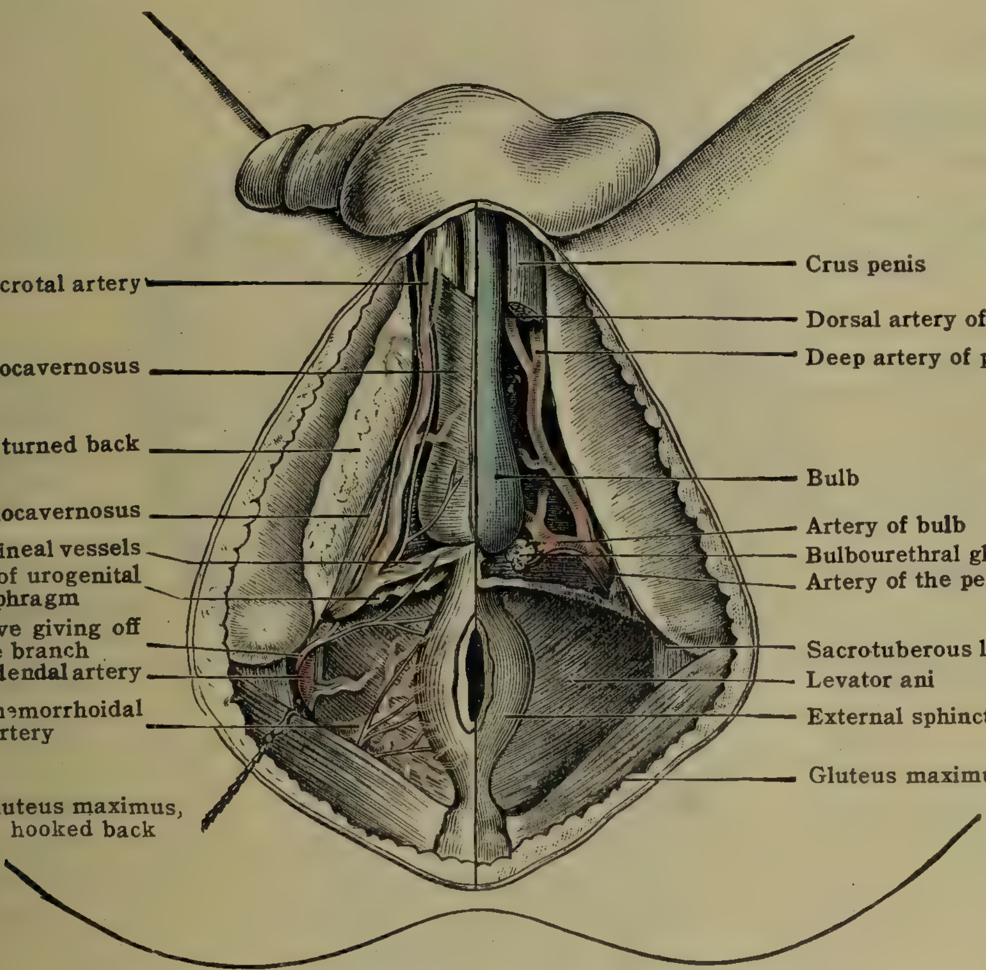


FIG. 569.—THE ARTERIES OF THE MALE PERINEUM.

arteries of either side) on the dorsum of the penis or clitoris. The artery is much larger in the male than the female; in either sex it supplies the glans, corona, and prepuce and anastomoses with the external pudendal artery.

5. THE GLUTEAL ARTERIES

There are two gluteal arteries, the **superior** and **inferior** (fig. 570). The **superior gluteal** artery [a. glutea superior], comes off as a short trunk from the lateral and back part of the hypogastric associated in origin with the iliolumbar and lateral sacral and sometimes with the interior gluteal or with the inferior gluteal and the internal pudendal. Passing backward between the first sacral nerve and the lumbosacral trunk through an osseo-tendinous arch formed by the margin of the bone and the upper edge of the endopelvic fascia, it leaves the pelvis through the great sciatic foramen above the piriformis muscle in company with its vein and the superior gluteal nerve. At its exit posteriorly from the great sciatic foramen it lies under cover of the gluteus maximus and beneath the superior gluteal vein, and in front of the superior gluteal nerve. It here breaks up into two chief parts, the superficial and deep. Its emergence from the pelvis is indicated on the surface by a point situated at the junction of the posterior with the middle third of a line drawn from the anterior superior to the posterior inferior spine of the ilium.

The **branches of the superior gluteal artery** are:—

(*a*) **Within the pelvis,** branches are distributed to the obturator internus, the piriformis, the levator ani, the coccygeus, and the pelvic bones.

(*b*) **External to the pelvis,** the artery divides into a superficial and deep part, the latter again subdividing into a superior and an inferior branch.

The superficial part of the superior gluteal artery breaks up at once into a number of large vessels for the supply of the upper portion of the gluteus maximus, some of them piercing the muscle and supplying the skin over it, and anastomosing with the posterior branches of the lateral sacral arteries; one of larger size, emerging from the muscle near the iliac crest, anasto-

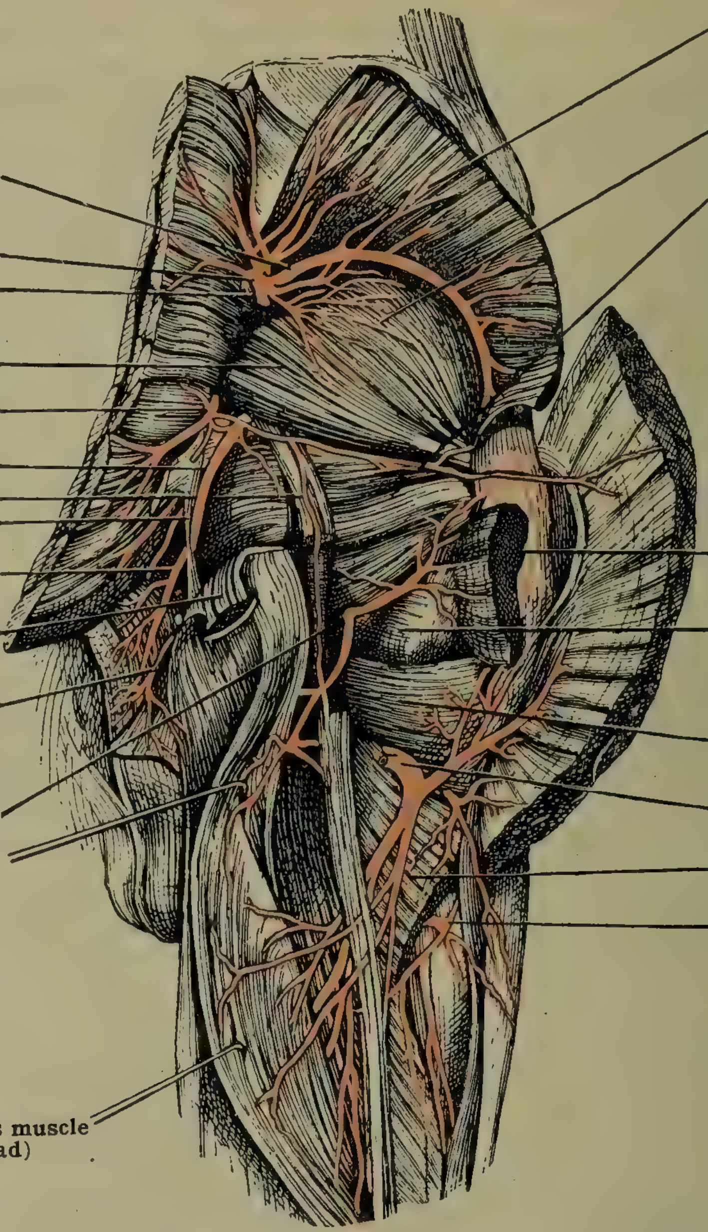


Fig. 570.—The Gluteal Arteries. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

moses with the deep circumflex iliac artery. The lower branches to the muscle anastomose with branches of the inferior gluteal (sciatic).

(ii) The deep part of the artery subdivides into two branches. The **superior branch** [r. superior] skirts along the line of origin of the gluteus minimus (fig. 570), between the gluteus medius and the bone, and, emerging in front from beneath these muscles under cover of the tensor fasciæ latæ, anastomoses with the ascending branch of the lateral circumflex and the deep circumflex iliac arteries. The **inferior branch** [r. inferior] passes forward between the gluteus medius and minimus, accompanied by the branch to the tensor fasciæ latæ of the inferior division of the superior gluteal nerve, toward the greater trochanter, where it anastomoses with the ascending branch of the lateral circumflex. It supplies branches to the contiguous muscles and to the hip-joint. The inferior branch before its division gives off the external nutrient artery of the ilium.

The **inferior gluteal** artery [a. glutea inferior], leaves the pelvis below the piriformis muscle, and immediately breaks up into a number of diverging branches. The largest enter the gluteus maximus muscle, where they anastomose with the superior gluteal branches. Others pass to the hip-joint, and the deep muscles around it; a third group passes downward to the hamstring muscles and anastomoses with the medial and lateral circumflex and first perforating; a fourth

slender branch, the **sciatic** artery [a. comitans n. ischiadici], accompanies the sciatic nerve (fig. 570).

Visceral Branches of the Hypogastric Artery

1. THE UMBILICAL ARTERY

The **umbilical** artery in the fetus is the continuation of the hypogastric. Passing forward along the side of the pelvis, it runs beneath the lateral reflection of peritoneum from the bladder, where, after giving off one or more vesical branches, it ceases to be pervious and passes on to the upper part of the bladder. Thence it ascends in the lateral umbilical fold, as a fibrous cord [ligamentum umbilicale laterale] (chorda umbilicalis lateralis NK), to the umbilicus, where it is joined by its fellow of the opposite side. As it lies upon the bladder it is crossed by the ductus deferens.

The **branches of the umbilical artery** are:—(1) Superior vesical arteries, the lowest of which is sometimes called (2) the middle vesical artery (fig. 566).

The **superior vesical arteries** [aa. vesicales superiores] ramify over the upper surface of the bladder, anastomosing with the artery of the opposite side and with the middle and inferior vesical below. They give off the following branches:—(*a*) The **urachal** branches which pass upward along the urachus. (*b*) The **ureteric** branches pass to the lower end of the ureter, and anastomose with the other ureteric arteries. (*c*) The **middle vesical** may come off from one of the superior vesicals or from the umbilical. It is distributed to the sides and base of the bladder, and anastomoses with the other vesical arteries.

2. THE INFERIOR VESICAL ARTERY

The **inferior vesical** artery [a. vesicalis inferior] arises commonly before the superior vesical in common with the deferential (fig. 566), and passes downward and medially to the fundus of the bladder, where it breaks up into branches which ramify over the lower part of the viscus.

It gives branches to the prostate, which supply that organ and anastomose with the arteries of the opposite side by passing through the prostatic plexus of veins, and with the inferior hemorrhoidal branches of the internal pudendal. At times one of these prostatic branches is of large size, and supplies certain of the parts normally supplied by the internal pudendal. It is then known as the **accessory pudendal** and most commonly terminates as the dorsal artery of the penis.

3. THE DEFERENTIAL ARTERY

The **deferential** artery [a. deferentialis] divides, on the ductus deferens, into an ascending and a descending branch. The ascending branch follows the ductus through the inguinal canal to the testis, where it anastomoses with the internal spermatic artery. The descending branch passes downward to the dilated portion of the ductus and to the vesiculæ seminales.

4. THE MIDDLE HEMORRHOIDAL ARTERY

The **middle hemorrhoidal** artery [a. haemorrhoidalis media] (a. rectalis caudalis NK) (fig. 566), variable in origin, most usually arises in common with the internal pudendal. It runs medially to the side of the middle portion of the rectum, dividing into branches which anastomose above with the superior hemorrhoidal derived from the inferior mesenteric, and below with the inferior hemorrhoidal derived from branches of the internal pudendal. Its corresponding vein terminates in the inferior mesenteric vein. In the female it also sends branches to the vagina.

5. THE UTERINE ARTERY

The **uterine** artery [a. uterina] (fig. 571), runs downward and medially through the pelvic connective tissue, crossing the ureter about 12 mm. ($\frac{1}{2}$ in.) from the cervix uteri. It then ascends in the parametrium between the layers of the broad ligament at the side of the uterus in a coiled and tortuous manner, and, after giving off a number of tortuous branches which ramify horizontally over the front and back of the uterus, inosculates with the ovarian artery to complete an arch from which the following branches arise:

(1) **Cervical.**—This branch arises from the uterine artery as it crosses the ureter to turn upward on to the uterus. It is directed medially, and divides into three or four branches which pass on to the cervix; one branch anastomosing with its fellow of the opposite side in front and

behind the neck, forming the so-called coronary artery of the cervix. (2) The **tubal branch** [r. tubarius] courses along the lower surface of the tuba uterina (Fallopian tube) as far as fimbriated extremity, and may also send a branch to the ligamentum teres. (3) The **ovarian** branch [r. ovarii] runs along the attached border of the ovary, sending branches to that structure. (4) The **ligamentous** branch is distributed to the round ligament, passing with that structure through the inguinal canal; it anastomoses with the superficial external pudendal artery. (5) The **vaginal** artery [a. vaginalis] is usually a branch of the uterine, and corresponds

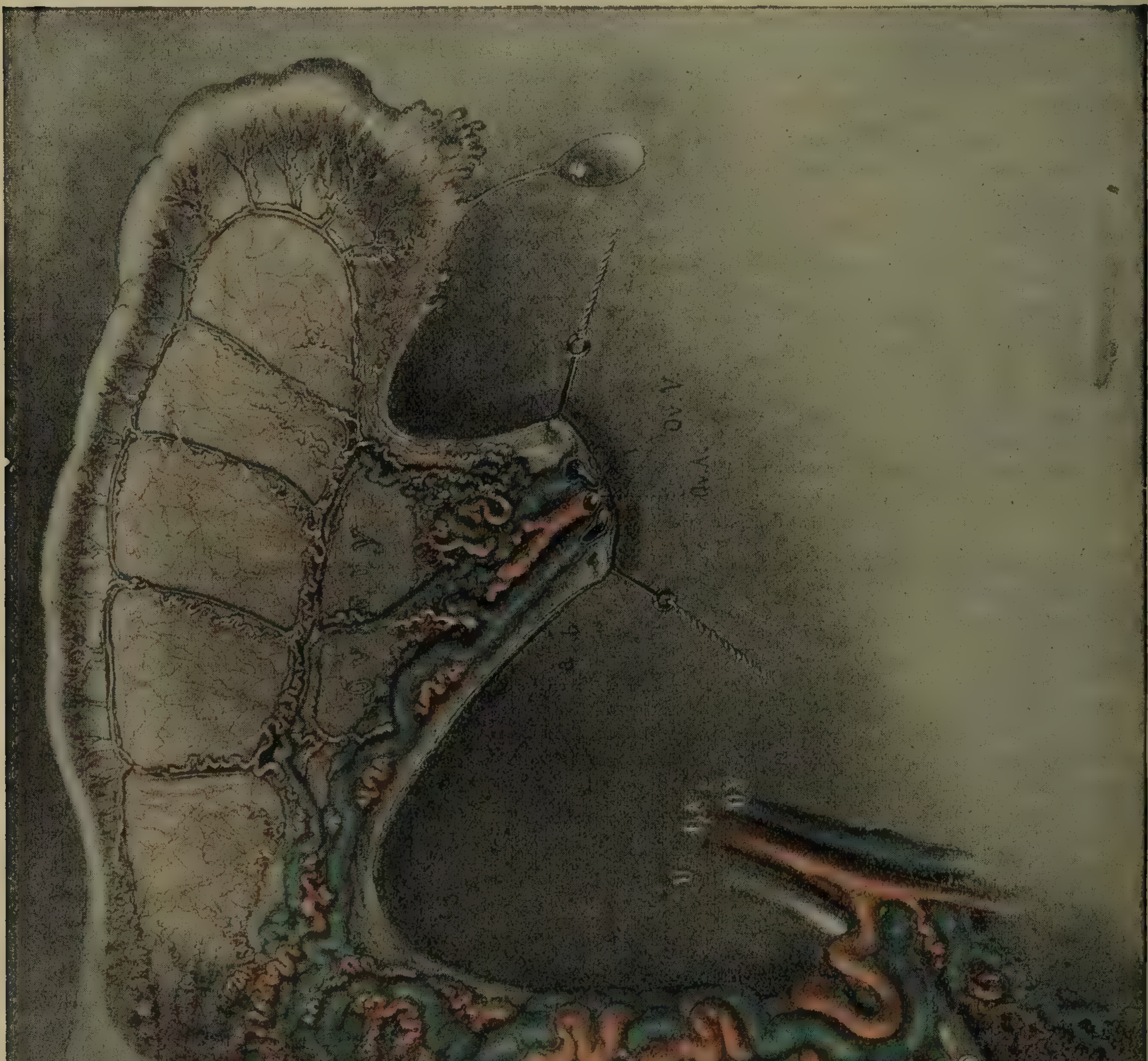


FIG. 571.—OVARIAN AND UTERINE AND VAGINAL ARTERIES. (From Kelly, by Brödel.)

to the inferior vesical artery of the male. It passes medially, behind the ureter, to the upper part of the vagina, and sends numerous branches to that structure and also some to the posterior part of the fundus of the bladder.

The branches to the vagina tend to anastomose with one another and with the cervical branch of the uterine, to form a more or less perfect vertical stem in the median line of the vagina, both back and front. This stem is sometimes termed the **azygos artery of the vagina.** Branches also pass to the vagina from the middle hemorrhoidal artery.

THE EXTERNAL ILIAC ARTERY

The **external iliac** artery [a. iliaca externa]—the larger in the adult of the two vessels into which the common iliac divides opposite the lumbosacral articulation

(fig. 565)—extends along the superior aperture of the pelvis minor, lying upon the medial border of the psoas muscle. At the lower margin of the inguinal ligament, midway between the anterior superior spine of the ilium and the symphysis pubis, it passes into the thigh, and takes the name of the femoral.

It measures 8.5 to 10 cm. (3½ to 4 in.) in length. The course of the vessel is indicated by a line drawn from 2.5 cm. (1 in.) below and a little to the left of the umbilicus to a point midway between the symphysis pubis and the anterior superior spine of the ilium. If this line is divided into thirds, the lower two-thirds of it will indicate the situation of the external iliac, and the upper third that of the common iliac. The external iliac vein, the continuation upward of the femoral vein from the thigh, lies to the medial side of the artery but on a slightly deeper plane, and, just before its termination, extends a little behind the artery on the right side.

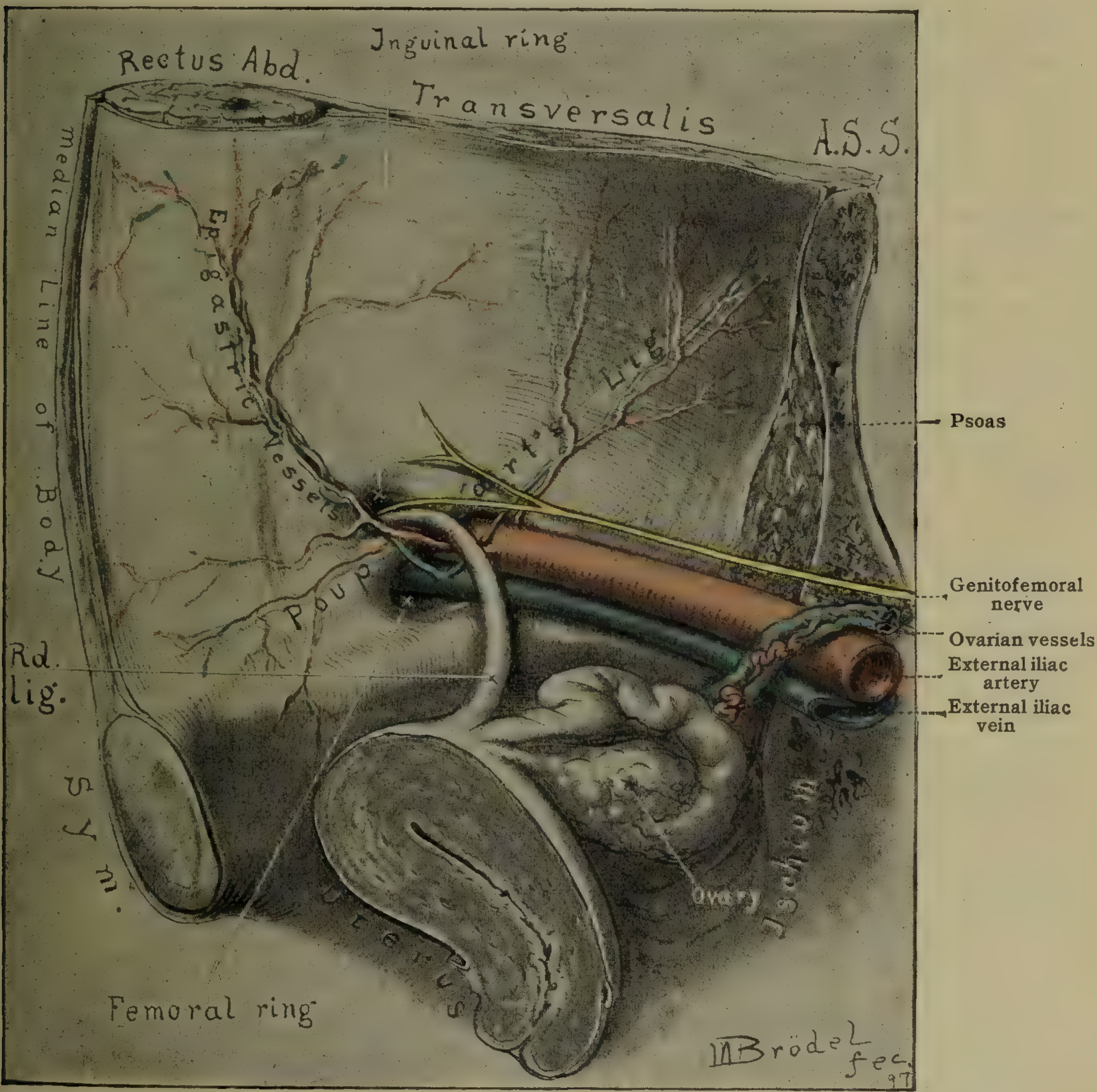


FIG. 572.—THE INFERIOR (DEEP) EPIGASTRIC ARTERY. (From Kelley, by Brödel.)

Relations.—In front, the artery together with the vein is covered by the parietal peritoneum descending from the abdomen into the pelvis, and by a layer of condensed subperitoneal tissue (Abernethy's fascia). It is crossed by the termination of the ileum on the right side, and by the sigmoid colon on the left. The external spermatic (genital) branch of the genitofemoral (genitocrural) nerve runs obliquely over its lower third, and just before its termination it is crossed transversely by the deep circumflex iliac vein. The internal spermatic or ovarian vessels lie for a short distance on the lower part of the artery, and the ductus deferens in the male curves over it to descend to the pelvis. It is sometimes crossed at its origin by the ureter. The external iliac lymphatic nodes lie along the course of the artery. The commencement of its inferior epigastric branch is also in front.

Behind.—The artery at first lies partly upon its own vein; lower down upon the medial border of the psoas; just before it passes through the lacuna vasorum, beneath the inguinal ligament, it lies upon the tendon of the psoas. The iliac fascia is also behind it.

To its **medial side** are the external iliac vein, the peritoneum, and the ductus deferens in the male, or the ovarian vessels in the female.

To its **lateral side** are the psoas muscle and the iliac fascia.

The **collateral circulation** is carried on (fig. 574) when the external iliac is tied, by the anastomosis of the iliolumbar and lumbar arteries with the circumflex iliac; the internal mammary with the inferior epigastric; the obturator with the medial circumflex; the inferior gluteal with the medial circumflex and superior perforating; the gluteal with the lateral circumflex; the arteria comitans nervi ischiadici from the inferior gluteal, with the perforating branches of the profunda; the external pudenal with the internal pudendal; the pubic branch of the obturator with the pubic branch of the inferior epigastric.

The **branches of the external iliac artery** are:—(1) The inferior epigastric; (2) the deep circumflex iliac; and (3) several small and insignificant twigs to the neighboring psoas muscle and lymphatic glands.

(1) The Inferior Epigastric Artery

The **inferior** or **deep epigastric** artery [a. epigastrica inferior] (fig. 572) usually arises just above the inguinal (Poupart's) ligament. Immediately after its origin, it passes on the medial side of the ductus deferens in the male, or of the round ligament in the female, and to the abdominal inguinal (internal abdominal) ring. Thence it ascends with a slightly medial direction passing above and to the lateral side of the subcutaneous inguinal (external abdominal) ring, lying between the fascia transversalis and the peritoneum. Having pierced the fascia transversalis, it passes in front of the linea semicircularis (Douglas' fold) and turns upward between the rectus and its sheath. Finally, it enters the substance of the rectus muscle, and anastomoses with the superior epigastric artery from the internal mammary.

The situation of the artery should be borne in mind in the operation for strangulated inguinal hernia. The artery is accompanied by two veins which end in a single trunk before opening into the external iliac vein.

The **branches of the inferior epigastric** are small and include:—(*a*) The **external spermatic** [a. spermatica externa], which runs with the ductus through the inguinal canal, supplies the cremaster muscle, and anastomoses with the internal spermatic, external pudendal, and perineal arteries. In the female a corresponding artery [**a. lig. teretis uteri**] (a. chordæ uteroinguinalis NK) accompanies the round ligament of the uterus through the inguinal canal and anastomoses in a similar manner. (*b*) **The pubic** branch [r. pubicus], which passes below, or sometimes above, the femoral ring to the back of the pubis, where it anastomoses with the pubic branch of the obturator. This branch, though usually small, is occasionally considerably enlarged (fig. 536), when its exact course becomes of great interest to the surgeon. Thus it may descend on the medial side of the femoral vein, and therefore lateral to the side of the femoral ring, or it may course medially in front of the femoral ring and turn downward either behind the os pubis or immediately behind the free edge of the lacunar (Gimbernat's) ligament, in which situation it would be exposed to injury in the operation for the relief of a strangulated femoral hernia. In such cases the obturator may not be connected with the hypogastric artery at all, but may take origin entirely from the external iliac or from the inferior epigastric. This abnormal origin of the obturator is said to occur once in every three and a half subjects but the abnormal artery courses around the medial side of the ring—in which situation it is liable to injury in operation for femoral hernia—in exceptional cases only. According to Langton (Holden's 'Anatomy'), the chances are about seventy to one against this occurrence. But even when it takes the abnormal course it lies 3 mm. or so from the margin of the ring, and will probably escape injury in the division of the stricture if several short notches are made in place of a single and longer incision.

(2) The Deep Circumflex Iliac Artery

The **deep circumflex iliac** artery [a. circumflexa ilium profunda], (fig. 573) arises from the lateral side of the external iliac artery either opposite the epigastric or a little below the origin of that vessel. It courses laterally behind the inguinal (Poupart's) ligament, lying between the fascia transversalis and the peritoneum, or in a fibrous canal formed by the union of the fascia transversalis with the iliac fascia. Near the anterior superior spine of the ilium, it perforates the transversus, and then courses between that muscle and the internal oblique, along and a little above the crest of the ilium. It finally runs backward to anastomose with the iliolumbar artery. It is accompanied by two veins. These unite into one trunk, which then crosses the external iliac artery to join the external iliac vein.

The **branches of the deep circumflex iliac artery** are as follows:—(*a*) **Muscular** branchse which supply the psoas, iliacus, sartorius, tensor fasciæ latæ, and the oblique and transvercs muscles of the abdomen. One of these branches, larger than the rest, is the *a. epigastriae lateralis* (Führer) or '*la branche ascendante*' of French anatomists, who regard this as one of the terminal divisions of the artery ('la branche transversale' being the other). This branch

arises about 2.5 cm. (1 in.) medially to the anterior superior spine of the ilium. It ascends between the transversus muscle and the internal oblique and is important to the surgeon, as it indicates the intermuscular plane between the two muscles. (*b*) **Cutaneous** branches, which supply the skin over the course of the vessel, and anastomose with the superficial circumflex iliac, the superior gluteal, and the ascending branch of the lateral circumflex.

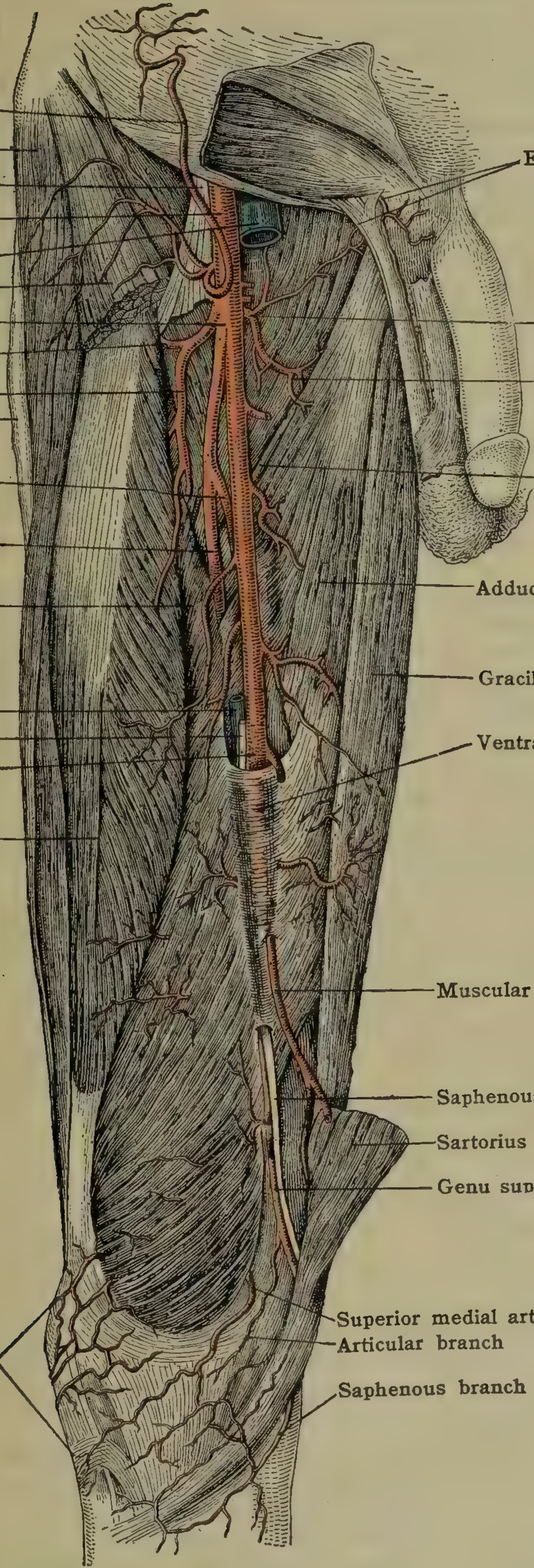


Fig. 573.—The Femoral Artery. (After Toldt, 'Atlas of Human Anatomy', The Macmillian Company.)

THE FEMORAL ARTERY

The **femoral** artery (fig. 573) is the continuation of the external iliac, and extends from the lower border of the inguinal (Poupart's) ligament, down the anterior and medial aspect of the thigh, to the tendinous opening in the adductor magnus, through which it passes into the popliteal space, and is then known as the popliteal. The femoral artery is at first quite superficial, being covered only by

the skin, and superficial and deep fascia; but after passing about 13 cm. (5 in.) downward through the space known as the femoral trigone (Scarpa's triangle), it sinks at the apex of that triangle beneath the sartorius muscle. Thence to its termination it continues beneath the sartorius, coursing deeply between the vastus medialis and the adductor muscles in the space known as the adductor (Hunter's) canal. It at first rests upon the brim of the pelvis minor and head of the femur from which it is separated by the capsule of the hip-joint and the tendon of the psoas. Owing to the obliquity of the neck of the femur and the direct course taken by the artery, the latter lies lower down on muscles only, at some distance from the bone. At its termination, in consequence of the shaft of the femur inclining toward the middle line of the body, the artery lies close to the medial side of the femur.

The *course of the vessel* when the thigh is slightly flexed and abducted is indicated by a line drawn from a point midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle. When the thigh is in the extended position and parallel with its fellow, the course of the artery will correspond to a line drawn from the spot above mentioned to the medial border of the patella. Its *anastomoses* are shown in fig. 574.

The relations of the femoral artery in the femoral trigone.—In front, the femoral artery (fig. 573) is covered by the skin, the superficial fascia, the iliac portion of the fascia lata, and the lumboinguinal (crural) branch of the genitofemoral nerve. The superficial circumflex iliac vein descends over the artery from the lateral to the medial side. Just proximally to the sartorius, the artery is crossed by the most medial of the anterior cutaneous branches of the femoral nerve. The fascia transversalis, which is continued into the thigh beneath the inguinal ligament, is also in anterior relation, but it soon becomes indistinguishable from the sheath of the vessel.

Behind, the artery rests in turn upon the tendon of the psoas muscle, which separates it from the brim of the pelvis and capsule of the hip-joint, the pectineus and the adductor longus. The artery is partially separated from the pectineus by the femoral vein and the profunda vein and artery, and from the adductor longus by the femoral vein which is almost directly behind the artery near the apex of the femoral trigone. The small nerve to the pectineus crosses behind the artery to reach its medial side.

A prolongation similar to that derived from the fascia transversalis in front, descends behind the vessel from the iliac fascia; but this, like the anterior prolongation or fascia, soon blends with the sheath of the vessels.

To the **medial side** is the femoral vein. This is separated from the artery, where the two vessels lie in the femoral sheath, by a thin fascial septum. More distally, the vein gradually reaches the posterior aspect of the artery.

To the **lateral side.**—Proximally, the common stem of the femoral (anterior crural) nerve is about 1 cm. (⅓ in.) lateral to the artery. When the femoral nerve gives off its branches, the saphenous nerve and the nerve to the vastus medialis accompany the artery on the lateral side.

The **adductor (Hunter's) canal** (fig. 573) is triangular in section, bounded by the vastus medialis laterally and in front, the adductors longus and magnus posteriorly, and by an aponeurosis thrown across from the adductors to the vastus medially and in front. Distally, the canal terminates at the tendinous opening in the adductor magnus; proximally, its limit is less well defined, as here the aponeurosis between the muscles becomes less tendinous, and gradually fades away into the perimuscular fascia. The transverse direction of the fibers of the aponeurotic covering at the distal two-thirds of the canal is characteristic. Lying superficially to the aponeurosis is the sartorius muscle.

The femoral artery, in the adductor (Hunter's) canal, has the **following relations:—Medially** in addition to the skin, superficial and deep fascia, are the sartorius muscle and the aponeurotic fibers of the canal. **Behind,** the artery is in contact with the adductor longus, and near the opening in the adductor magnus, usually with the latter muscle. The femoral vein lies behind the artery, but gets a little lateral to it at the distal part of the canal. It is here very firmly and closely attached to the artery, embracing it as it were on its posterior and lateral aspect. Hence it is very liable to be punctured on ligaturing the artery in this part of its course. To the **lateral side** are the vastus medialis, the nerve to the vastus medialis, and at the distal part of the canal, the femoral vein. The saphenous nerve crosses in front of the artery from the lateral to the medial side, lying in the wall of the canal. There are sometimes two veins, which then more or less surround the artery.

Clinical aspects.—Pressure may be applied to the femoral artery—(1) Immediately below the inguinal ligament, where it should be directed backward so as to compress the vessel against the brim of the pelvis and the capsule of the hip-joint; (2) at the apex of the femoral trigone, the pressure here being directed laterally and a little backward, so as to compress the vessel against the bone; (3) in the adductor canal the pressure should be directed laterally with the same object. Care must be taken, especially above, to avoid the vein, which lies very close to the artery, and also the femoral nerve, which enters the thigh about 1.2 cm. (½ in.) lateral to the artery, and at once breaks up into its branches, superficial and deep.

In ligature of the femoral in the femoral trigone the incision should be about 7.5 cm. (3 in.) long, in the line of the artery, and begins about 7.5 cm. (3 in.) below the inguinal ligament, and runs over the apex of the triangle. The femur is flexed slightly, abducted and rotated laterally. The fascia lata being divided, the sartorius, readily recognized by its direction, is drawn laterally. The closely subjacent sheath must be opened on its lateral side. Structures that may be seen are a vein joining the great saphenous, the anterior cutaneous and saphenous nerves, and the nerve to the vastus medialis. The **collateral circulation** (fig. 574) is mainly through the following channels:—(1) The lateral and medial circumflex above, with the genu suprema and

lower muscular branches of the femoral, and the articular of the popliteal. (2) The perforating branches of the profunda above, with the vessels below first given. (3) The a. comitans nervi ischiadici with the articular of the popliteal. Ligature of the femoral artery and vein results in gangrene in 36 to 39 per cent. of cases (Kagiyama).

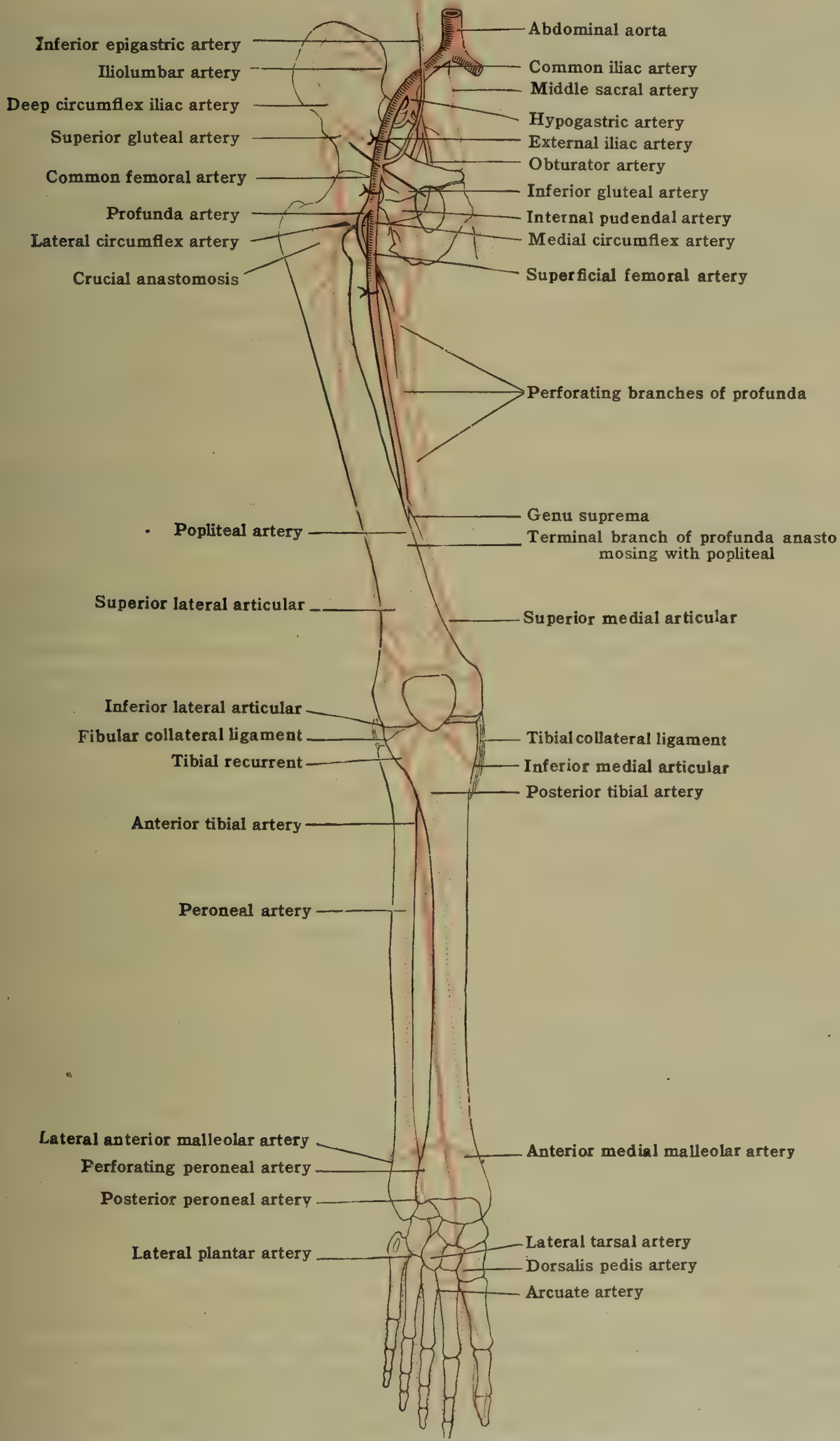


FIG. 574.—TO SHOW THE ANASTOMOSES OF THE ARTERIES OF THE LOWER EXTREMITY. (After Smith and Walsham.)

In **ligature of the femoral artery in Hunter's canal**, the line of the incision, in the middle third of the thigh, must exactly follow that of the vessel. It is frequently made too lateral, exposing the vastus medialis. Branches of the saphenous vein being removed, the fascia lata is slit up and the sartorius identified by its fibers descending medially. Those of the vastus

medialis are less oblique and are directed downward and laterally. The sartorius having been drawn to the medial side, usually, the aponeurotic roof of the canal is opened, and the femoral artery identified. The vein, here posterior and to the lateral side, is closely connected to the artery. The saphenous nerve and the nerve to the vastus medialis are superficial to the vessels and should be avoided.

The close contiguity of the femoral artery and vein accounts for the comparative frequency of arteriovenous aneurysms especially in the upper part, where the vessels are easily wounded. Their superficial position here further accounts for the facility with which malignant disease, e. g., epitheliomatous glands, may cause fatal hemorrhage.

Branches of the Femoral Artery

The **branches of the femoral artery** are:—(1) the superficial epigastric; (2) the superficial circumflex iliac; (3) the external pudendal; (4) the inguinal; a group of muscular branches, the chief of which are (5) the profunda artery and (6) the medial circumflex and (7) the lateral circumflex artery; and (8) the highest genicular or genu suprema.

(1) The **superficial epigastric** artery [a. epigastrica superficialis] (fig. 573) arises from the femoral about 1.2 cm. (½ in.) beyond the inguinal ligament. At its origin it is beneath the fascia lata, but almost at once passes through this fascia, or else through the fossa ovalis, and courses in an upward and slightly medial direction in front of the external oblique muscle almost as far as the umbilicus.

It ends in numerous small twigs, which anastomose with the cutaneous branches from the inferior epigastric and internal mammary. In its course it gives off small branches to the inguinal glands and to the skin and superficial fascia. Running with it is the superficial epigastric vein, which ends in the great saphenous just before the latter passes through the fossa ovalis (saphenous opening).

(2) The **superficial circumflex iliac** artery [a. circumflexa ilium superficialis], usually smaller than the superficial epigastric, arises either in common with that vessel, or as a separate branch from the femoral. It passes laterally over the iliacus, and, soon perforating the fascia lata a little to the lateral side of the fossa ovalis, runs more or less parallel with the inguinal ligament about as far as the crest of the ilium, where it ends in branches which anastomose with the deep circumflex iliac artery.

In its course it gives off branches to the iliacus and sartorious muscles to the inguinal glands, and to the fascia and skin. Its companion vein ends in the great saphenous vein just before the latter passes through the fossa ovalis (saphenous opening).

(3) The **external pudendal** arteries [aa. pudendæ externæ], arise from the medial side of the femoral or, occasionally, from the profunda. They run medially over the pectineus muscle and the adductor longus, both of which then supply, and send branches through the fascia lata near or through the fascia covering the fossa ovalis (saphenous opening).

Some of these cross the spermatic cord in the male, or round ligament in the female, to reach and supply the integument above the pubes. One branch descends along the penis and anastomoses at the corona with the dorsal artery, and with the corresponding artery of the opposite side. In the female, this branch terminates in the preputium clitoridis, anastomosing with the dorsal artery of the clitoris. Other branches the *anterior scrotal or labial arteries* [aa. scrotales; aa. labiales anteriores] perforate the fascia close to the ramus of the pubis and supply the skin of the *scrotum* or the *labium majus* in the female, anastomosing with the posterior scrotal or labial branches of the perineal artery.

(4) The **inguinal** branches [rr. inguinales], a series of five or six small twigs arise a short distance below the inguinal ligament. They supply the subinguinal lymph-nodes, and the skin and muscles in this region.

The *muscular* branches [rr. musculares] are numerous and vary inversely in size with the muscular branches of the external pudendal and the highest genicular, and with the large muscular arteries belonging to a group arising either separately or in common from the proximal fourth of the femoral. The large arteries belonging to this group are the profunda artery, the lateral circumflex femoral artery and the medial circumflex femoral. They have been found to take common origin from the femoral in about half the cases.

The usual text-book description is applicable to such an arrangement, but not the numerous cases in which one or more of these vessels arises separately from the femoral. Winslow avoided a too rigid method of describing the ways in which these arteries may arise, by saying that any two or all of them may take origin from the femoral by means of a common trunk of origin. As providing the plasticity demanded by the situation, this method is followed here.

(5) The **profunda** artery [a. profunda femoris] (figs. 573, 574) is the largest muscular artery of the thigh. It is usually given off from the back and lateral part of the common femoral, about 4 cm. (1½ in.) beyond the inguinal (Poupart's) ligament and supplies the posterodistal part of the thigh. At first it is a little lateral to the femoral, but as it runs distally and backward it gets behind that artery and closer to the bone. On reaching the proximal border of the adductor longus muscle, it leaves the femoral, and, passing beneath the muscle, pierces the abductor magnus. Finally, much reduced in size, it ends in the hamstring muscles, anastomosing with the third perforating and muscular and articular branches of the popliteal.

Relations.—**Behind,** the profunda artery lies successively upon the iliacus, the pectineus, the adductor brevis, and adductor magnus muscles. **In front,** at first it is superficial, being merely covered by the skin, superficial and deep fasciæ, and branches of the femoral (anterior crural) nerve; but as it sinks behind the femoral artery, it has in front of it both the femoral and the profunda veins and, more distally, the adductor longus muscle. **Laterally** is the femur at the angle of union of the adductors longus and brevis. **Medially** is the pectineus in the proximal part of its course.

Branches of the profunda.—The profunda gives four perforating arteries, the fourth being the termination of the artery.

The **perforating arteries of the profunda** are so called because they perforate, in a more or less regular proximodistal order certain of the adductor muscles. They form a series of loops by anastomosing with one another (fig. 570) on the posterior surface of the adductor magnus muscle, and with the gluteal and circumflex arteries and with the muscular and genicular branches of the popliteal. All the perforating arteries contribute to reinforce the artery of the sciatic nerve, a branch of the inferior gluteal (sciatic) artery. They are each accompanied by two veins which terminate in the profunda vein.

The **first perforating** artery [a. perforans prima] is given from the profunda as that vessel sinks beneath the adductor longus. It either pierces the adductor brevis, or runs between the pectineus and adductor brevis, and then passes through a small aponeurotic opening in the adductor magnus close to the medial lip of the linea aspera. In this course it supplies branches to the adductors, and, after perforating the adductor magnus, is distributed to the lower part of the gluteus maximus and the hamstring muscles, a recurrent branch commonly running beneath the gluteus maximus to anastomose with the lateral circumflex, medial circumflex, and inferior gluteal (sciatic) arteries, forming the **cruciate anastomosis** at the junction of the neck of the femur with the great trochanter (fig. 570). A second branch anastomoses with a recurrent branch of the second perforating.

The **second perforating** artery [a. perforans secunda] which is given off from the profunda as it lies behind the adductor longus, pierces the adductor brevis, and then passes through a second aponeurotic opening in the adductor magnus a little distally to that of the first perforating artery, and also close to the linea aspera. It supplies the hamstring muscles, sends a branch to anastomose with the first perforating, and another branch to anastomose in like manner with a recurrent branch of the third perforating.

The **third perforating** artery [a. perforans tertia] also arises from the profunda as it lies under the adductor longus, usually about the level of the distal border of the adductor brevis. It turns beneath this border, and then, like the first and second perforating, passes through an aponeurotic opening in the adductor magnus close to the linea aspera. It also supplies the hamstring muscles, and divides into two branches, which anastomose above with the second perforating, and with the termination of the profunda.

Two **nutrient** arteries to the femur (aa. nutritiæ femoris superior et inferior] arise from the perforating arteries. The superior generally arises from the first perforating, the inferior usually from the third, but there is some variation in this regard.

(6) The **lateral circumflex** artery [a. circumflexa femoris lateralis] may arise directly from the femoral or in common with one or both of its fellows. It passes in a transversely lateral direction over the iliacus and under the sartorius and rectus. It then divides into two or more chief branches—the ascending and descending.

The **ascending** branch [r. ascendens] breaks almost at once into numerous branches, some of which ascend under the sartorius to anastomose with the superior gluteal under cover of the tensor fasciæ latæ. One large branch—the r. transversus of English text-books—runs laterally between the vastus lateralis and the iliotibial tract and anastomoses under the gluteus maximus with the medial circumflex, inferior gluteal and the first perforating artery (cruciform anastomosis).

The **descending** branch [r. descendens] runs with the nerve to the vastus lateralis muscle beneath the rectus and on the vasti intermedius and lateralis. It sends branches to the knee joint which anastomose with the supreme genicular and with the genicular branches of the popliteal artery. The descending branch of the lateral circumflex is developed separately from the trunk and ascending branch of the artery. Although they are usually combined in the adult, as described above, they may arise from different parts of the femoral, either alone or in common with the one or more of the other elements of the group.

(7) The **medial circumflex** artery [a. circumflexa femoris medialis] may arise from the femoral directly, or in combination with the lateral circumflex or the profunda. It passes medially over the iliacus and psoas and then turns backwards, as the **deep** branch [r. profundus], between the latter muscle and the pectineus. Continuing above the adductor brevis and the obturator externus, it enters the gluteal region between the quadratus femoris and the adductor magnus, covered by the gluteus maximus.

Before leaving the femoral trigone it gives a **superficial** branch [r. superficialis] to the pectineus, adductor longus, adductor brevis and the proximal part of the gracilis, which varies inversely in size with the external pudendal arteries and may replace them. The deep branch gives an **acetabular** branch [r. acetabuli] to the acetabulum and an ascending branch along the tendon of the obturator externus, which anastomoses with the obturator artery and with the inferior gluteal in the trochanteric fossa. The remainder of the deep branch, formerly described

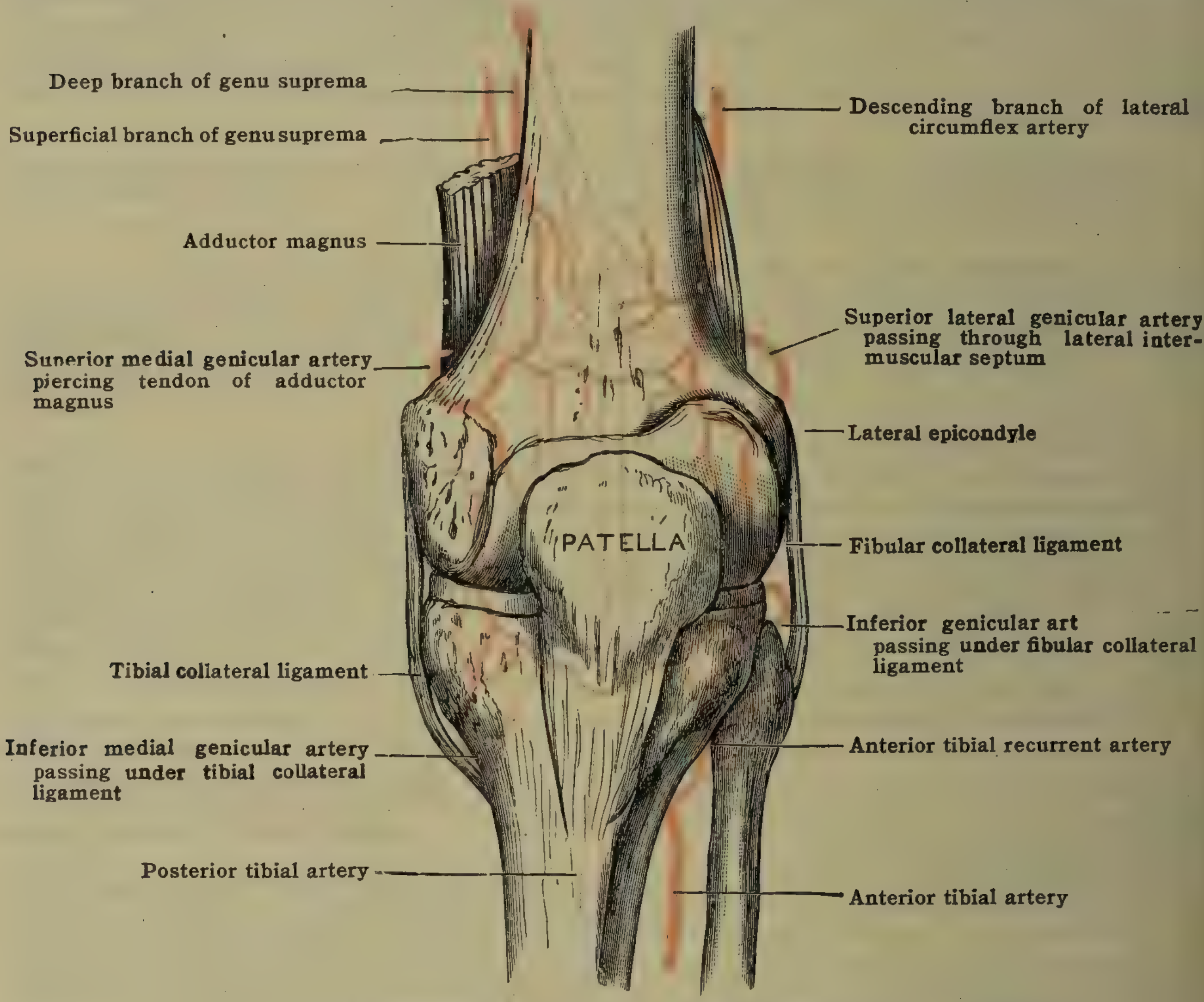


Fig. 575.—The Anastomosis about the Left Knee-Joint. (Walsham.) (Semi-diagrammatic.)

as the r. transversus, anastomoses under the gluteus maximus with the inferior gluteal, first perforating and lateral circumflex arteries (cruciform anastomosis).

(7) The **supreme genicular** artery [a. genu suprema] (or anastomotica magna) (figs. 573, 575) arises from the front and medial side of the femoral just before the latter perforates the adductor magnus muscle, and almost immediately divides into branches, (*a*) saphenous, (*b*) muscular, and (*c*) articular. These branches may sometimes come off separately from the femoral.

(*a*) The **saphenous** branch [a. saphena] pierces the aponeurotic covering of the adductor canal, passes between the sartorius and gracilis muscles along with the saphenous nerve, and, perforating the deep fascia, supplies the skin of the proximal and medial side of the leg and anastomoses with the inferior medial genicular branch of the popliteal and the other vessels forming the plexus or rete at the medial side of the knee. In its course it gives twigs to the distal part of the sartorius and gracilis muscles.

(*b*) The **muscular** branches [rr. musculares] run distally in front of the adductor magnus tendon, burrowing amongst the fibers of the vastus medialis as far as the medial condyle. They break up into numerous twigs which supply the distal ends of the vasti muscles and adductor magnus. One branch runs laterally across the distal end of the femur to end in the vastus lateralis.

(*c*) The **articular** branches [rr. articulares] come off from the saphenous and muscular branches and enter the arterial rete on the medial and lateral sides of the knee. They anas-

tomose with the medial and lateral superior genicular branches of the popliteal and the anterior tibial recurrent and supply branches to the joint.

THE POPLITEAL ARTERY

The **popliteal artery** [a. poplitea] (fig. 576) runs through the popliteal fossa. It is a continuation of the femoral, and extends from the aponeurotic opening

Fig. 576.—The Popliteal and Posterior Tibial Arteries, Left Side.

in the adductor magnus at the junction of the middle with the distal third of the thigh to the lower border of the popliteus muscle, where it terminates by dividing into the anterior and posterior tibial arteries. The proximal part of the artery is accompanied by the branch of the obturator nerve to the knee-joint. The vein is behind the artery throughout; it lies at first a little laterally, but as the vessels pass through the popliteal fossa the vein crosses obliquely over the artery,

and at the termination of the artery lies a little to its medial side. The tibial (internal popliteal) nerve is superficial to both artery and vein. At the proximal part of the fossa it is well to the lateral side of the vessels, but as it descends it crosses behind them and reaches their medial side. The artery in the whole of its course is deeply placed and covered by a considerable amount of fat and areolar tissue.

Relations (fig. 576).—**In front,** the artery lies successively on the popliteal surface of the femur (from which it is separated by a little fat and sometimes one or two small glands); on the popliteal ligament of the knee; on the hinder edge of the articular surface of the head of the tibia; and on the popliteus muscle. From the latter muscle it is separated by the expansion from the semimembranosus which covers the muscle and is attached to the popliteal line on the tibia.

Behind, the artery is covered, proximally by the semimembranosus; in the center of the popliteal fossa by the skin, superficial and deep fascia; and distally, by the gastrocnemius. The popliteal vein is behind it in the whole of its course. The tibial (internal popliteal) nerve crosses behind it obliquely, from the lateral to the medial side, about the center of the fossa. As the artery divides into the anterior and posterior tibial, it is crossed by the aponeurotic arch of the soleus which stretches between the tibial and fibular origins of that muscle.

To the **medial side** are the semimembranosus proximally, and the medial head of the gastrocnemius and the tibial (internal popliteal) nerve distally.

To the **lateral side** are the biceps and the tibial (internal popliteal) nerve proximally, and the lateral head of the gastrocnemius and the plantaris distally.

The **popliteal artery may be ligatured**—(A) **Behind,** in the upper part of the popliteal space, just after its emergence from under the semimembranosus. Here, for a short space of about 2.5 cm. (1 in.), the vessel is comparatively superficial after division of the fasciæ. The nerve is generally seen first, and, with the vein, must be drawn laterally. (B) **From the front,** at the medial side. The thigh being flexed, abducted, and rotated laterally, a free incision is made parallel and just behind the adductor magnus tendon, commencing at the junction of the middle and lower third of the thigh. The sartorius and the hamstrings are drawn backward, and the adductor magnus forward. Care must be taken of the genu suprema (fig. 577). The space between the hamstrings and the adductor magnus being carefully opened up, the artery will be found in fatty areolar tissue. The vein and tibial nerve are on the lateral side of the vessel. The collateral circulation (fig. 575) depends chiefly on the genu suprema.

Branches of the Popliteal Artery

The **branches of the popliteal** include the following:—(1) the sural; (2) the genicular; and (3) the terminal.

(1) The **sural** arteries [aa. surales] arise irregularly from the popliteal and supply the muscles of the calf, sending branches to the muscles bounding the proximal part of the popliteal fossa. From the sural arteries also arise the superficial sural or cutaneous branches which pass distally between the two heads of the gastrocnemius, and, perforating the deep fascia, supply the skin and fascia of the calf. A branch, usually of moderate size, accompanies the small saphenous vein.

(2) The **genicular** arteries, five in number, are divided into two superior (medial and lateral), two inferior (medial and lateral), and the middle or azygos (figs. 576, 577). The superior and inferior come off transversely in pairs from either side of the popliteal, the superior above, the inferior below the joint. Winding round the bones to the front of the knee, they form—by anastomosing with one another and with the genu suprema (anastomotica magna), the termination of the profunda, the descending branch of the lateral circumflex, and the tibial recurrent arteries—a superficial and deep arterial rete (fig. 577). The superficial anastomosis or rete lies between the skin and fascia round about the patella (**patella rete**), which it supplies, the larger branches entering it from above. The deep anastomosis or **articular rete** [rete articularis genu] lies on the surface of the bones around the articular surfaces of the femur and tibia, supplying branches to the contiguous bones and to the joints. The middle genicular is a single short trunk coming off from the deep surface of the popliteal artery. It at once passes through the popliteal ligament into the joint.

(*a*) The **superior lateral genicular** artery [a. genu superior lateralis], the larger of the two superior genicular branches, runs in a lateral direction above the lateral head of the gastrocnemius, and, passing beneath the biceps and through the lateral intermuscular septum and vastus lateralis, enters the substance of the vastus intermedius (crureus), and anastomoses, proximally with the descending branch of the lateral circumflex, distally with the inferior lateral genicular, and across the front of the femur with the superior medial genicular, the genu suprema (anastomotica magna), and termination of the profunda, forming with them, as already described, the deep articular rete. Branches are given off to the patella, to the upper and lateral part of the joint, to the bone, and to the contiguous muscles.

(*b*) The **superior medial genicular** artery [a. genu superior medialis] runs medially just above the medial head of the gastrocnemius, beneath the semimembranosus, and, after perforating the tendon of the adductor magnus, enters the substance of the vastus medialis. Here it anastomoses with the deep branch of the genu suprema (anastomotica magna) and termination of the profunda above, with the inferior medial genicular below, and with the superior lateral genicular across the front of the femur. It supplies small branches to the contiguous muscles, to the femur, to the patella, and to the joint.

(*c*) The **inferior medial genicular** artery [a. genu inferior medialis], the larger of the two inferior genicular arteries, passes in an obliquely medial direction across the popliteus, below the medial condyle (tuberosity) of the tibia and beneath the tibial collateral ligament to the front and medial side of the knee-joint. Here it anastomoses (fig. 575), proximally with the superior medial genicular and the superficial branch of the genu suprema (anastomotica magna), across the front of the tibia with the inferior lateral genicular and distally, anterior to the popliteus muscle, with the posterior tibial recurrent. It supplies branches to the lower and medial part of the joint.

(*d*) The **inferior lateral genicular** artery [a. genu inferior lateralis] passes laterally above the head of the fibula, along the tendon of the popliteus muscle, beneath the lateral head of the gastrocnemius, and then under the tendon of the biceps, and between the long and short fibular collateral ligaments. Then winding to the front of the joint, it anastomoses proximally with the superior lateral genicular, distally with the anterior tibial recurrent, and across the front of the tibia with the inferior medial genicular. It also supplies branches to the lateral and lower part of the joint.

(*e*) The **middle or azygos genicular** artery [a. genu media] arises from the deep surface of the popliteal artery, and passes, with the articular branch of the obturator nerve, through the popliteal ligament, directly into the knee-joint, where it supplies the cruciate ligaments, and the patellar synovial and alar folds. It anastomoses with the intrinsic branches of the other genicular arteries.

(3) The **terminal branches** of the popliteal are the posterior and the anterior tibial arteries.

THE POSTERIOR TIBIAL ARTERY

The **posterior tibial** artery [a. tibialis posterior] (or tibialis plantaris NK) (fig. 576), the larger of the two branches into which the popliteal divides at the distal border of the popliteus muscle, runs distally on the flexor aspect of the leg between the superficial and deep muscles to the back of the medial malleolus. Midway between the tip of the malleolus and the calcaneus, and under cover of the origin of the abductor hallucis as it arises from the laciniate (internal annular) ligament, it divides into the medial and lateral plantar arteries.

The artery is first situated midway between the tibia and fibula, and is deeply placed beneath the muscles of the calf. As it passes distally it inclines to the medial side and at the distal third of the leg is superficial, being covered only by the skin and fasciæ. At the ankle it lies beneath the laciniate ligament, and at its bifurcation also beneath the abductor hallucis. A line drawn from the center of the popliteal fossa to a spot midway between the medial malleolus and point of the heel will indicate its course. In addition to the branches named below it supplies the muscles between which it passes, and the integument of the lower medial region of the leg.

Relations.—Anteriorly, it is in relation successively with the tibialis posterior, the flexor digitorum longus, the posterior surface of the tibia, and the deltoid ligament of the ankle-joint.

Posteriorly, it is covered by the skin and fascia, the gastrocneumius and soleus, and the deep or intermuscular fascia of the leg, by which it is tightly bound down to the underlying muscles. It is crossed by tibial nerve about 4 cm. (1¾ in.) beyond its origin, after it has given off its peroneal branch; the nerve first lies on the medial, and for the rest of its course on the lateral side of the vessel. It is accompanied by two veins, which send numerous anastomosing branches across it. In the distal third of the leg the artery is superficial, being covered only by the skin and by the superficial and deep fasciæ.

At the **medial malleolus** it lies beneath the laciniate (internal annular) ligament and the abductor hallucis, upon the deltoid ligament of the ankle-joint. Here it has the tibialis posterior and flexor digitorum longus in front of it, and the tibial nerve and the flexor hallucis longus behind and to its lateral side. On account of its close relation to these tendons, the posterior tibial artery is liable to be injured in the older methods of tenotomy. At times the tibial nerve divides higher than usual, when one branch lies on the medial side of the artery and the other branch on the lateral side.

Ligature of the posterior tibial in the middle of the leg.—The following are the chief points in the technic. An incision, 7.5 to 10 cm. (3 to 4 in.) long, is made 1.2 cm. (½ in.) behind the medial border of the tibia, to avoid the great saphenous vein. The deep fascia being freely opened, the medial head of the gastrocnemius is drawn backward. The tibial attachment of the soleus, thus exposed, is cut through carefully, so as to allow of identification of its central membranous tendon, which must not be confused with the deep intermuscular septum over the flexor. Any sural vessels are now tied. The above-mentioned special septum is next made out, passing between the bones (vertical line descending from oblique line of tibia and oblique line of fibula). On division of this septum the nerve usually comes into view, the artery

lying more laterally. The needle is passed from the nerve; the venæ comitantes may be included. The muscles should now be fully relaxed by flexion of knee and plantar flexion of foot. The ligature will be placed below the peroneal artery. The posterior tibial in its upper part may also be ligated through a straight incision down the middle of the leg posteriorly. Ligation of the posterior tibial is followed by gangrene in a large percentage of cases.

The **branches of the posterior tibial artery** (figs. 576, 577) are:—(1) The fibular; (2) the peroneal; (3) the tibial nutrient; (4) the communicating; (5)

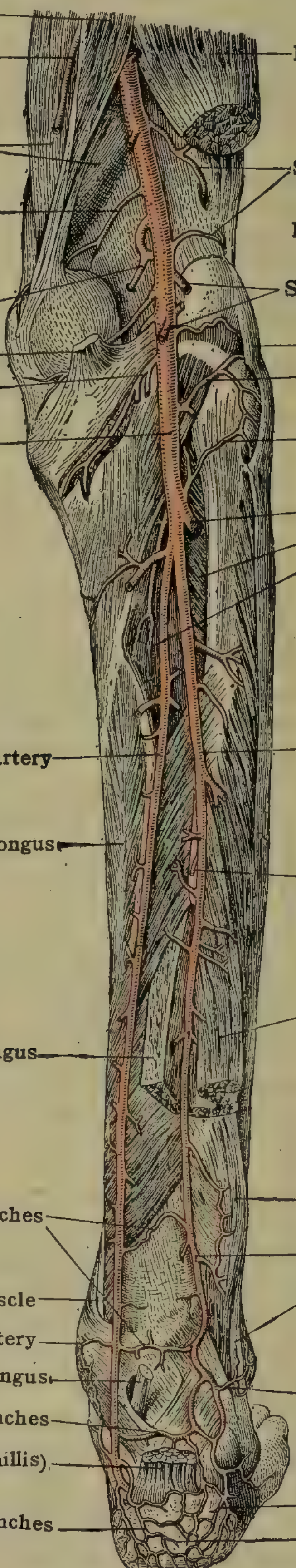


Fig. 577.—The Popliteal, the Posterior Tibial, and the Peroneal Arteries. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

the posterior medial malleolar; (6) the medial calcanean; and (7) the terminal, medial and lateral plantar. The anastomoses of the posterior tibial branches are shown in fig. 575.

(1) The **fibular** or superior fibular branch [r. fibularis], usually arises from the beginning of the anterior tibial or from the posterior tibial recurrent (see fig. 577). It runs laterally

toward the head of the fibula. It is small and gives twigs to the soleus, peroneus longus, and extensor digitorum longus, and anastomoses with the inferior lateral genicular and the lateral sural arteries.

(2) The **peroneal** artery [a. peronea] is a large vessel which (figs. 576, 577) arises from the posterior tibial about 2.5 cm. (1 in.) below the distal border of the popliteus muscle. It first curves laterally on the tibialis posterior and beneath the soleus muscle, and reaches the fibula at the proximal margin of the flexor hallucis longus muscle. It then dips beneath that muscle and enters a canal bounded by the fibula and the flexor longus hallucis and tibialis posterior muscles. At the distal margin of the latter muscle it lies upon the interosseous membrane where it gives a large perforating (anterior peroneal) branch. It now passes over the tibiofibular syndesmosis to run, under the name of the posterior lateral malleolar (posterior peroneal) branch, upon the posterior aspect of the lateral malleolus. It terminates upon the lateral surface of the tuber calcanei by breaking up into lateral calcaneal branches.

The **branches of the peroneal** artery (fig. 577) are:—(*a*) The fibular nutrient; (*b*) the communicating; (*c*) the perforating; (*d*) the lateral malleolar; and (*e*) the lateral calcaneal.

(*a*) The *fibular nutrient* artery [a. nutritia fibulæ] enters the nutrient canal of the fibula.

(*b*) The *communicating* branch [r. communicans] passes between the interosseous membrane and the tendon of the flexor hallucis longus in the supramalleolar region and joins the communicating branch of the posterior tibial artery.

(*c*) The *perforating* (or anterior peroneal) branch [r. perforans] arises usually a short distance below, but sometimes above, the communicating branch, and passes through the interosseous membrane (fig. 577). It supplies the tibiofibular syndesmosis and anastomoses with the lateral tarsal, arcuate and anterior lateral malleolar arteries.

(*d*) The *lateral posterior malleolar* artery [a. malleolaris posterior lateralis] (or malleolaris plantaris fibularis NK) is the terminal part of the peroneal. It crosses the posterior aspect of the tibiofibular syndesmosis and lateral malleolus to reach the lateral aspect of the tuber calcanei. It gives off branches on the malleolus which anastomose with branches of the anterior *lateral malleolar rete;* also (*e*) the *lateral calcaneal* branches [rr. calcanei laterales] (or fibulares NK) which enter into the formation of the *rete calcaneum.*

(3) The **tibial nutrient** artery [a. nutritia tibiæ], a vessel of large size, leaves the proximal part of the posterior tibial, pierces the tibialis posterior, and enters the nutrient foramen in the proximal third of the posterior surface of the tibia. In the interior of the bone it divides into two branches: a smaller branch, which runs toward the head of the bone; and a larger, which courses toward the distal end. It gives off two or three muscular twigs to the tibialis posterior before it enters the foramen. The nutrient artery of the tibia is the largest artery of its kind in the body, and is accompanied by a nerve given off by the nerve to the popliteus.

(4) The **communicating** branch [r. communicans] arises from the posterior tibial about 5 cm. (2 in.) above the medial malleolus, and, passing transversely across the tibia beneath the flexor hallucis longus, anastomoses with the communicating branch of the peroneal.

Frequently another branch of communication between the posterior tibial and peroneal arteries is likewise present in the loose connective tissue behind the flexor hallucis longus tendon.

(5) The **posterior medial malleolar** branch [a. malleolaris posterior medialis] (or a. malleolaris plantaris tibialis NK) divides for distribution over the medial malleolus, anastomosing with the anterior medial malleolar artery in the *medial malleolar rete* [rete malleolare mediale]. It runs beneath the flexor digitorum longus and tibialis posterior muscles.

(6) The **medial calcanean** branches [rr. calcanei mediales] (or calcanei tibiales NK) are distributed to the soft parts over the medial side of the calcaneus. These branches come off more frequently from the lateral plantar artery than from the posterior tibial; they enter the rete calcaneum and anastomose with the lateral calcaneal and posterior medial malleolar arteries.

(7) The **terminal branches** are the lateral and medial plantar arteries.

As a general rule, in **amputation of the** leg 2.5 cm. (1 in.) below the head of the fibula, only one main artery—the popliteal—is divided. In amputations 5 cm. (2 in.) below the head of the fibula, two main arteries—the anterior and posterior tibials—are divided. In amputations 7.5 cm. (3 in.) below the head, three main arteries—the two tibials and the peroneal—are divided. (Holden.) In an amputation through the middle of the leg, the anterior tibial artery would be found cut on the interosseous membrane between the tibialis anterior and the extensor hallucis longus, the deep peroneal nerve here lying in front of the vessel. The posterior tibial would be between the superficial and deep muscles at the back of the leg lying on the tibialis posterior, its nerve being to the lateral side. The peroneal would be close to the fibula in the flexor hallucis longus.

THE LATERAL PLANTAR ARTERY

The **lateral plantar** artery [a. plantaris lateralis] (or a. plantaris tibialis NK) (figs. 577, 578)—the larger of the two branches into which the posterior tibial divides beneath the laciniate (internal annular) ligament—passes at first laterally and forward across the sole of the foot to the base of the fifth metatarsal bone, where it bends medially, and still running forward sinks deeply into the foot and terminates at the proximal end of the first interosseous space by anastomosing with the deep plantar (communicating) branch of the dorsal artery of the foot.

In its course to the fifth metatarsal bone the artery runs in a more or less straight line obliquely across the foot; while its deep portion, extending from the fifth metatarsal bone to the proximal end of the first interosseous space, forms a slight curve with the convexity forward, and is known as the **plantar arch** [arcus plantaris]. The plantar arch is comparable to the deep volar arch formed by the deep branch of the ulnar anastomosing with the radial through the first interosseous space. The lateral plantar artery is accompanied by two veins. The course of the artery is indicated by a line drawn across the sole of the foot from a point midway between the tip of the medial malleolus and the medial tubercle of the calcaneus to the base of the fifth metatarsal bone, and thence to the lateral side of the base of the first metatarsal.

Fig. 578.—The Plantar Arteries, Left Foot.
(From a dissection in the Museum of St. Bartholomew's Hospital.)

The lateral plantar artery, besides the branches named below, gives twigs to supply the muscles between which it passes, and the tarsal joints. It almost invariably also gives off a number of medial calcaneal branches. These branches occasionally arise from the posterior tibial artery, and are described with the other branches of that vessel.

Relations.—In the **first part of its course** from the medial malleolus to the base of the fifth metatarsal bone, the artery is covered successively by the abductor hallucis and the flexor digitorum brevis, by which it is separated from the plantar aponeurosis, and may be slightly overlapped in muscular subjects by the abductor quinti digiti. As it approaches the base of the fifth metatarsal bone it lies, as it turns medially before sinking into the foot, in the interspace between the flexor digitorum brevis and the abductor quinti digiti, and is here covered only by the skin and superficial fascia and the plantar aponeurosis. It lies upon the calcaneus, the quadratus plantæ (flexor accessorius), and the flexor digiti quinti brevis. It is accompanied by the lateral plantar nerve, the smaller of the two divisions into which the tibial nerve divides. In this part of its course it gives off small branches to the contiguous muscles and to the heel.

In the **second part of its course** the artery, which is here known as the **plantar arch** [arcus plantaris], sinks into the sole, and is covered, in addition to the skin, superficial fascia, plantar aponeurosis, and flexor digitorum brevis, by the tendons of the flexor digitorum longus, the lumbricales, branches of the medial plantar nerve, and the adductor hallucis. It lies upon the

proximal ends of the second, third, and fourth metatarsal bones and the corresponding interosseous muscles.

The **branches of the lateral plantar artery** are: (1) perforating; and (2) plantar metatarsal (digital).

(1) The **perforating** branches [rr. perforantes], three in number, ascend through the proximal end of the second, third, and fourth spaces, between the two heads of the correspondingly named dorsal interosseous, muscles, and communicate with the proximal ends of the first, second, and third dorsal metatarsal (interosseous) arteries (fig. 581).

(2) The **plantar metatarsal** arteries [aa. metatarseæ plantares] are usually four in number and pass forward in the four intermetatarsal spaces, which are numbered from the medial side. They rest upon the interosseous muscles of their spaces, and are at first under cover of the lumbricals, but as they approach the clefts of the toes each divides into two branches, the **plantar digital** arteries [aa. digitales plantares], which supply the contiguous sides of the toes. The plantar digital branch for the medial side of the great toe is usually given off by the first plantar

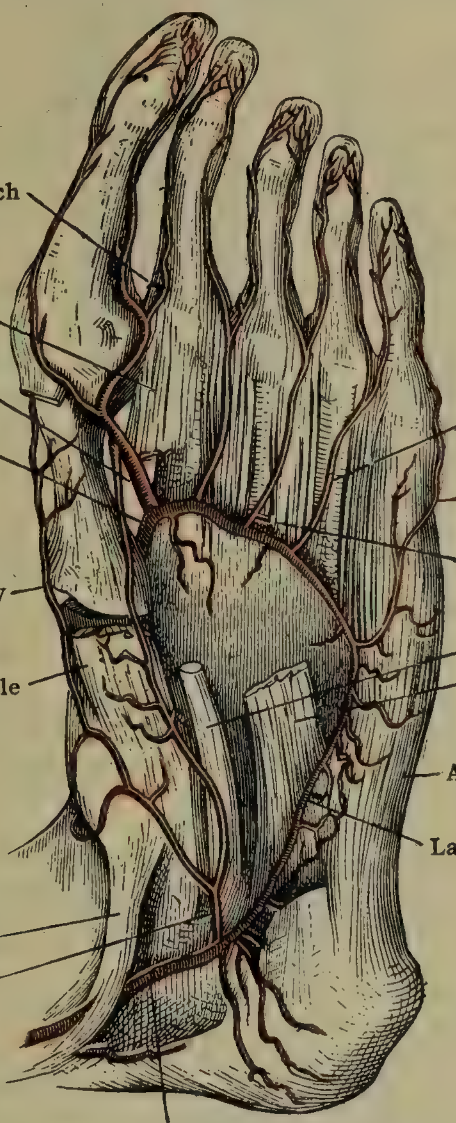


FIG. 579.—DEEP PLANTAR ARTERIES. (After Henle.)

metatarsal; that for the lateral side of the little toe is usually a separate branch from the latera end of the plantar arch.

The plantar metatarsal arteries, immediately before they bifurcate, send to the dorsum of the foot a perforating branch each to the corresponding dorsal metatarsal artery. They anastomose by many small twigs with the dorsal metatarsal arteries. Immediately below each phalangeal joint the plantar digital vessels communicate by cross branches, forming a rete for the supply of the articular end of the phalanges and the contiguous joints. At the distal end of the toes they also freely anastomose with each other, forming a rete beneath the pulp and around the matrix of the nail. The metatarsal and digital arteries are each accompanied by two small veins.

THE MEDIAL PLANTAR ARTERY

The **medial plantar** artery [a. plantaris medialis] (or a. plantaris fibularis NK) (figs. 578, 579)—much the smaller of the two divisions into which the posterior tibial divides—passes forward along the medial side of the sole of the foot usually to the first interosseous space. Here it ends by anastomosing either with the first plantar metatarsal artery derived from the plantar arch, or with the branch given off by the first plantar metatarsal to the medial side of the great toe.

Relations.—The artery is at first under cover of the abductor hallucis, but afterward lies in the interval between that muscle and the flexor digitorum brevis. It is covered by the skin and superficial fascia, but not by the plantar aponeurosis, since it lies between the central and medial portions of that structure.

The **branches of the medial plantar** are:—(1) The deep and (2) the superficial.

(1) The **deep** branch [r. profundus], which at once divides—or it may come off as several branches—to supply the muscles, articulations, and integument of the medial side of the sole. Some of these branches form an anastomosis around the medial margin of the foot, with branches of the dorsalis pedis.

(2) The **superficial** branch [r. superficialis] breaks up into very small twigs which accompany the digital branches of the medial plantar nerves, and anastomose with the plantar metatarsal arteries in the first, second, and third spaces. At times a twig from one of these branches joins the lateral plantar artery to form a superficial plantar arch.

THE ANTERIOR TIBIAL ARTERY

The **anterior tibial artery** [a. tibialis anterior] (or a. tibialis dorsalis NK) (fig. 580)—the smaller of the two branches into which the popliteal artery divides at the distal border of the popliteus muscle—at first courses forward between the two heads of origin of the tibialis posterior, and, after passing between the tibia and fibula above the proximal part of the interosseous membrane, runs on the front and lateral aspect of the leg, between the anterior muscles, as far as the front of the ankle-joint. Beyond the joint the artery is known as the dorsalis pedis. The course of the vessel is indicated by a line drawn from the front of the head of the fibula to a point midway between the two malleoli.

The artery is accompanied by two veins which communicate with each other at frequent intervals across it. It is also accompanied in the distal three-fourths of its course by the deep peroneal nerve. The nerve, which winds round the head of the fibula, and pierces the extensor digitorum longus, first comes into contact with the lateral side of the artery about the proximal third of the leg; in the middle third it is a little in front of the artery, and in the distal third again lies to its lateral side. In addition to the named branches the anterior tibial artery supplies muscular twigs to the extensors of the toes and the tibialis anterior muscle.

Relations.—The artery at first lies in the triangle formed by the two heads of the tibialis posterior and the popliteus muscle; and, as it passes above the interosseous membrane, it has the tibia on one side and the fibula on the other. It is separated from the deep peroneal (anterior tibial) nerve at its commencement by the neck of the fibula and the extensor digitorum longus.

Posteriorly it lies in its proximal two-thirds upon the interosseous menbrane, to which it is closely bound by fibrous bands; and in its distal third upon the tibia and the ankle-longus.

To its **medial side** along its proximal two-thirds is the tibialis anterior muscle; but at the distal third it is crossed by the tendon of the extensor hallucis longus and for the rest of its course has this tendon to its medial side.

On its **lateral side** it is in contact in its proximal third with the extensor digitorum longus muscle; in its middle third with the extensor hallucis longus; but, as this muscle crosses to the medial side of the artery, the vessel usually for a very short part of its course comes again into contact with the extensor digitorum longus. At the proximal and distal thirds of its course on the front of the leg the artery has the deep peroneal (anterior tibial) nerve to its lateral side.

In front the artery is covered by the skin, superficial and deep fascia. In its proximal two-thirds it is deeply placed in the cellular interval between the tibialis anterior on the medial side and the extensor digitorum longus and extensor hallucis longus on its lateral side; and in its distal third it is crossed in the lateromedial direction by the tendon of the extensor hallucis longus, and lies beneath the cruciate (anterior annular) ligament of the ankle-joint. The deep peroneal nerve is usually in front of the artery in the middle third of the leg.

Ligature of the anterior tibial artery at the junction of the upper and middle thirds of the leg. The limb being flexed and rotated medially, an incision is made, 7.5 to 10 cm. (3 to 4 in.) long, in the line of the artery, distant 2.5 cm. (1 in.) or more (according to the size of the leg) from the crest, and beginning about 5 cm. (2 in.) below the head of the tibia. If, on exposure of the deep fascia, the intermuscular septum between the tibialis and long extensor of the toes is not well defined, the fascia must be freely slit up in the line of the artery, and the sulcus felt for. A small muscular artery may lead down to the trunk. The foot is now dorsiflexed and the artery sought for deep on the interosseous membrane. The nerve should be drawn to the outer side. The venæ comitantes may be included in the ligature.

In **senile gangrene** the liability of the tibial arteries to disease and consequent thrombosis and interference with the collateral circulation accounts both for the extension of the disease and the difficulty in detecting pulsation.

The **branches of the anterior tibial artery** are:—(1) The posterior tibial recurrent; (2) the anterior tibial recurrent; (3) the medial anterior malleolar; and (4) the lateral anterior malleolar. In addition, ten or twelve muscular branches are given off irregularly to the adjacent muscles along the artery.

(1) The **posterior tibial recurrent** artery [a. recurrens tibialis posterior] (or a. rec. tib. plantaris NK) passes between the popliteus muscle and the tibia to the popliteal ligament of the knee-joint, supplying these structures and the tibiofibular joint. It anastomoses with a branch of the inferior medial genicular branch of the popliteal artery anterior to the popliteus muscle. In some limbs this vessel arises from the posterior tibial artery.

(2) The **anterior tibial recurrent** artery [a. recurrens tibialis anterior] (or a. rec. tib. dorsalis NK) is given off from the anterior tibial artery immediately after that vessel has passed above

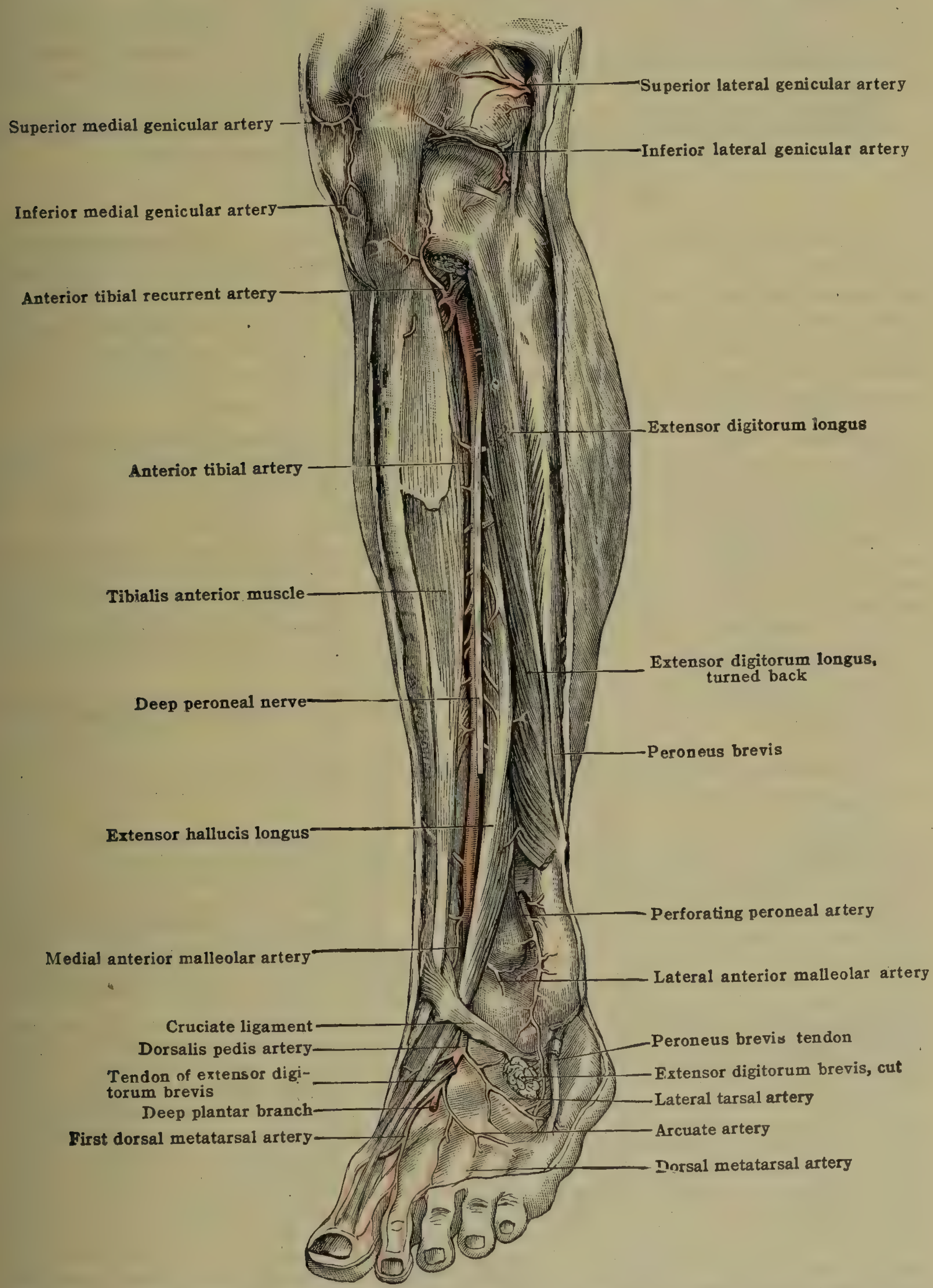


Fig. 580.—The Anterior Tibial, Dorsalis Pedis and Perforating (Anterior) Peroneal Arteries.

the interosseous membrane. It winds tortuously through the substance of the tibialis anterior muscle, over the lateral condyle (tuberosity) of the tibia close to the bone; and, perforating the deep fascia, ramifies on the lower and lateral part of the capsule of the knee-joint. It anastomoses with the inferior and superior lateral genicular branches of the popliteal, with the descending branch of the lateral circumflex, and somewhat less freely with the medial genicular branches of the popliteal and with the genu suprema (anastomotica magna). It

gives off small branches to the tibialis anterior, the extensor digitorum longus, the knee-joint, and the contiguous fascia and skin.

(3) The **medial anterior malleolar** artery [a. malleolaris anterior medialis] (or a. mal. dorsalis tibiolis NK) arises from the distal part of the anterior tibial artery, usually near the place at which the tendon of the extensor hallucis longus crosses the anterior tibial artery. It winds over the medial malleolus, passing beneath the tibialis anterior, and joins the **medial malleolar rete** anastomosing with branches from the posterior tibial artery.

(4) The **lateral anterior malleolar** artery [a. malleolaris anterior lateralis] (or a. mal. dorsalis fibularis NK), larger than the medial, arises from the lateral side of the anterior tibial artery, usually beyond the level of the medial malleolar. It winds distally and laterally round the lateral malleolus, passing beneath the extensor digitorum longus and peroneus tertius, and joins the **lateral malleolar rete** by anastomosing with the perforating peroneal, the termination of the peroneal, and the lateral tarsal branch of the dorsalis pedis (figs. 577, 580).

The anastomosis between the lateral malleolar and perforating peroneal is sometimes of considerable size, supplying the blood to the dorsal artery of the foot; the anterior tibial, then much reduced in size, usually ends at the place of origin of the lateral malleolar.

THE DORSALIS PEDIS ARTERY

The **dorsalis pedis** artery [a. dorsalis pedis] (figs. 580, 581) is a continuation of the anterior tibial. It extends from the front of the ankle-joint to the proximal end of the first interosseous space, where it divides into the first dorsal metacarpal artery and the deep plantar branch, which joins the lateral plantar artery to complete the plantar arch. It is accompanied by two venæ comitantes. The course of the artery is indicated by a line drawn from a point midway between the two malleoli to the proximal end of the first metatarsal space.

Relations.—Below, the artery lies successively on the talus (astragalus), navicular, second cuneiform, and the base of the second metatarsal bone, and the ligaments uniting these bones. At times its course is a little more lateral, lying either partly on the second cuneiform bone, or on the dorsal ligaments uniting the second cuneiform to the first cuneiform. It is more or less bound down to the bones by aponeurotic fibers derived from the deep fascia.

Above, the artery is covered by the cruciate (anterior annular) ligament, sometimes by the extensor hallucis longus, by the skin, the superficial and deep fascia, and, just before its termination, by the tendon of the extensor hallucis brevis. The angle formed by this tendon with the extensor hallucis longus is the best guide to finding the artery in the process of ligature (fig. 580).

To its **lateral side** is the most medial tendon of the extensor digitorum longus, and more distally the tendon of the extensor hallucis brevis. The deep peroneal (anterior tibial) nerve is also to its lateral side.

To its **medial side** is the extensor hallucis longus, except at times for the distal half inch where the tendon of the extensor hallucis brevis, having crossed the artery, may lie between it and this tendon.

The **branches of the dorsalis pedis artery** (figs. 580, 581) are:—(1) The tarsal; (2) the arcuate; and (3) the deep plantar.

(1) The **tarsal branches** may be divided into (*a*) the lateral and (*b*) the medial. (*a*) The **lateral tarsal** artery [a. tarsea lateralis] (or a. tarsea fibularis NK) runs laterally over the navicular and cuboid bones beneath the extensor digitorum brevis. It supplies branches to that muscle, and to the bones and the articulations between them, and anastomoses with the lateral malleolar and perforating (anterior) peroneal, with the arcuate (metatarsal) and, over the lateral border of the foot, with the anastomotic branches of the lateral plantar artery. (*b*) The **medial tarsal** arteries [aa. tarseæ mediales] (or tibiales NK) consist of a few small branches which run over the medial side of the foot, supplying the skin and articulations, and anastomose with the medial malleolar arteries and with branches of the medial plantar.

(2) The **arcuate** (**metatarsal**) artery [a. arcuata] (figs. 580, 581) runs laterally across the foot, in a slight curve with the convexity forward, over the bases of the metatarsal bones, and beneath the extensor tendons and the extensor digitorum brevis. At the lateral border of the foot it anastomoses with the lateral tarsal artery and with branches of the lateral plantar.

From the convexity of the arch it gives off the second, third and fourth **dorsal metatarsal** (interosseous) arteries, which run forward on the dorsal interosseous muscles in the center of the four interosseous spaces to the cleft of the toes, where they bifurcate for the supply of the contiguous sides of the toes. The first metatarsal artery arises from the termination of the dorsalis pedis. It is large, and gives off the digital artery to the medial side of the great toe, and is commonly known as the **dorsalis hallucis** artery. The most lateral of the interosseous branches gives off a small vessel for the supply of the lateral side of the little toe. At the proximal end of the second, third and fourth interosseous spaces each artery receives a perforating branch from the lateral plantar and, a second perforating artery passes through the distal end of the interosseous space from the corresponding plantar metatarsal.

The **dorsal digital** arteries [aa. digitales dorsales], into which the dorsal metatarsal arteries divide at the cleft of the toes, run along the side of each toe toward the dorsal aspect, anastomosing with each other across the dorsum of the toes and by frequent branches with the digital branches of the plantar metatarsal arteries, which also run along the sides of the toes, but nearer the plantar surface. At the end of the toes they anastomose with each other around the quick of the nail.

(3) The **deep plantar** branch [r. plantaris profundus] (a. metatarsea perforans NK) comes from the dorsalis pedis with the first dorsal metatarsal artery. At the proximal end of the

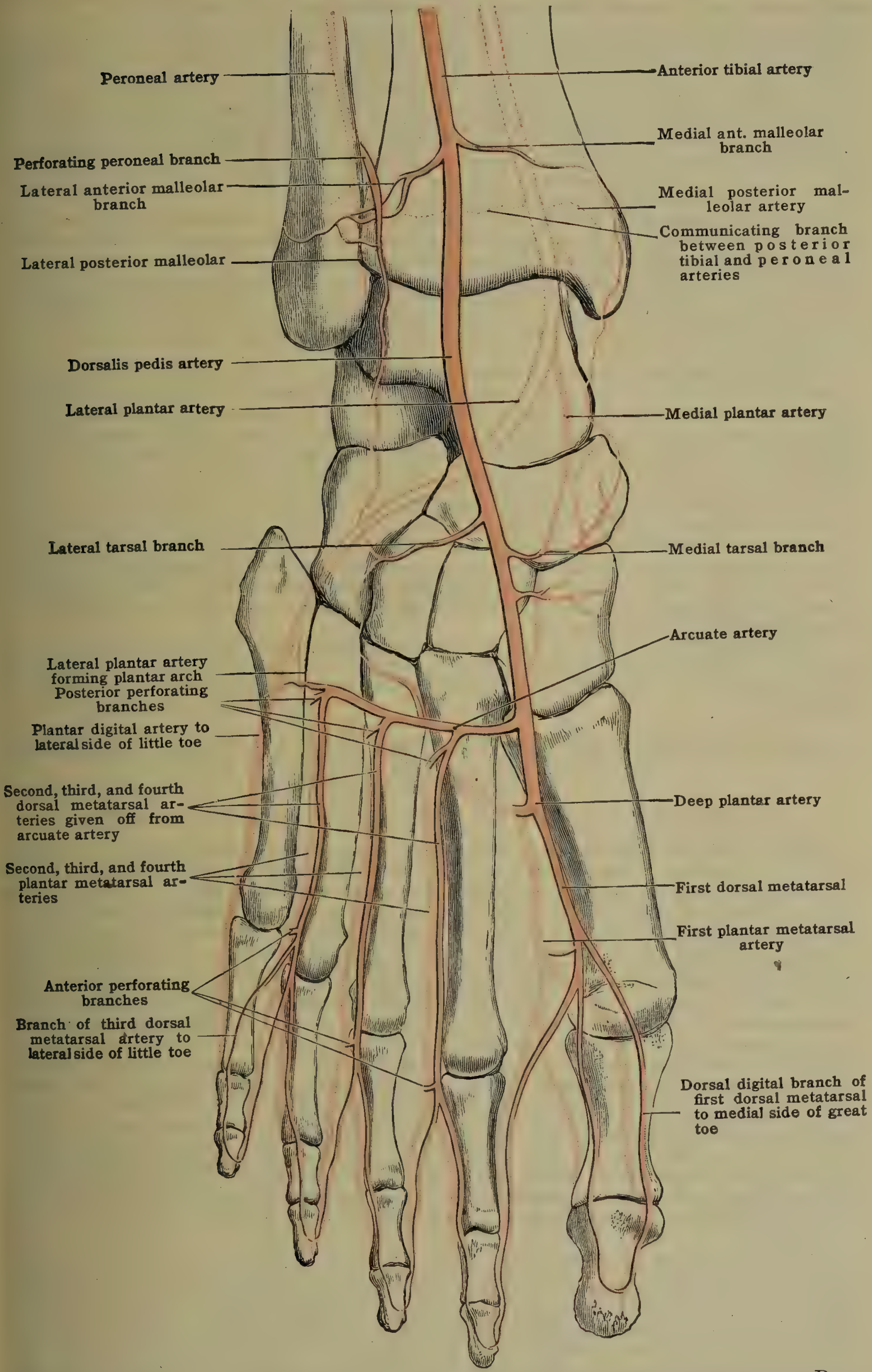


Fig. 581.—Scheme of the Distribution and Anastomoses of the Arteries of the Right Foot. (Walsham.)
(The plantar arteries are shown in dotted outline; the dorsal in solid red.)

first interosseous space it dips into the sole between the heads of the first dorsal interosseous muscle and joins the lateral plantar artery, thus completing the plantar arch.

MORPHOGENESIS AND VARIATIONS OF THE ARTERIES

When first recognizable as a continuous vessel, the primitive aorta consists of a single layer of endothelium continuous with the arterial end of the endocardial tube. Its proximal part (the truncus arteriosus) divides almost immediately after leaving the myoepicardium into two branches, each of which turns at first dorsally in the mandibular arch and then passes caudally throughout the length of the embryo, on the dorsal aspect of the gut. The part of each vessel in the mandibular arch is known as the first aortic arch while the remainder is the dorsal aorta of the side of the body to which it belongs.

Each dorsal aorta gives a series of branches which run in the intersomital spaces to the central nervous system, the dorsal segmental arteries. It also gives a series of ventral branches which ramify and anastomose around the gut and yolk-entoderm and in the body stalk. These branches are less regularly arranged than those of the dorsal series but are generally known as the ventral segmental arteries. The number of segmental arteries of both series increases with the addition of new somites. The two dorsal aortæ soon approach the median plane of the embryo and gradually coalesce, except in the cervical region where they permanently remain separate.

The dorsal segmental arteries of the right and the left side, whether they arise from the paired or unpaired part of the aorta, tend to remain paired, as do those of an intermediate or lateral segmental series which gradually become recognizable. The lateral segmental arteries of the abdominal region, appear to be derivatives of the arteries of the ventral segmental series; while others, going to the body wall and extremities seem to arise independently or to be derivatives of the dorsal segmental arteries. The ventral segmental arteries of the right and left side tend to coalesce, with the coalescence of the right and left dorsal aortae, to form median unpaired arteries. The connections of these with the aorta migrate in a caudal direction as new ventral segmental arteries are added during the continued growth of the embryo, the newly-formed vessels taking over the function of these previously active. The roots of the two umbilical arteries migrate in this manner also, and the right and the left artery eventually connect with the definitive aorta between the third lumbar segment and the fourth lumbar, or last segment of the aorta. The caudal portion of the vessel formed by the union of the primitive dorsal aortæ is the middle sacral artery.

The morphogenesis and variations of the arterial system will be considered under four headings: (a) the aortic arch system and the arteries of the head and neck; (b) the arteries of the thoracic and abdominal parieties; (c) the visceral arteries and, (d) the arteries of the extremities.

A. THE AORTIC ARCH SYSTEM AND THE ARTERIES OF THE HEAD AND NECK

1. MORPHOGENESIS OF THE AORTIC ARCH SYSTEM

To the first or mandibular pair of aortic arches is almost immediately added a second or hyoid pair of arches. These spring from the truncus arteriosus immediately caudad of the first arches and reach the paired dorsal aorta some distance caudally to them. A third pair soon follows, which, with regard to its position on the truncus arteriosus and the dorsal aortæ is related to the second pair of arches as the second pair is related to the first. During the formation of the third pair of aortic arches, the first two pairs tend to become plexiform and they eventually lose their continuity. Soon after the completion of the third, a fourth pair of arches is established. The part of the truncus arteriosus giving on to the ventral ends of the aortic arches forms a flattened and laterally expanded sac, recently described by Congdon as the **saccus aorticus.** From either side of the caudal periphery of this, there appears at about this stage an artery leading into a vascular net which surrounds the developing lung buds and is drained by a single pulmonary vein into the right atrium. The proximal part of these two arteries becomes the ventral part of the next succeeding pair of aortic arches, having become connected with the dorsal aortæ. These last aortic arches skirt caudally around the fourth pharyngeal pouches and since each of them gives origin to a pulmonary artery (as do the sixth arches of anamnia having lungs) they are generally called the sixth pair. The dorsal end of one or both of the sixth arches is often connected at a later stage by a smaller intercalated arch either with the ventral end of the fourth arch or with the aortic sac. This intercalated arch or pair of arches is transitory, if present and may groove the fourth pharyngeal pouches. It is generally regarded as representing the fifth pair of the anamnia which has become vestigial in the mammals.

The network of small vessels persisting after the loss of the first two pairs of aortic arches becomes associated mainly with the cephalic end of the aortic sac and out of it are developed the branches of the external carotid artery. Out of the part of this network retaining its connection with the dorsal aorta is formed the temporary **stapedial artery,** which is eventually taken over by the external carotid to become internal maxillary. The parts of the paired dorsal aortæ extending from the original site of the first aortic arches to the third aortic arches, together with the third arches themselves, become the **internal carotid** arteries. The part of the dorsal aortæ between the third and fourth pairs of arches disappears. The left fourth aortic arch and the part of the left dorsal aorta between the fourth and the sixth aortic arch becomes the definitive **arcus aortæ.** The corresponding part of the right fourth aortic arch becomes the proximal part of the **right subclavian artery.** The part of the left sixth arch between the pulmonary artery and the dorsal aorta remains patent as the **ductus arteriosus** until birth, but becomes impervious shortly afterwards and persists as the **ligamentum arterio-**

sum. The corresponding part of the right sixth arch has disappeared in embryos about 12 mm. long. The remainder of the left dorsal aorta, together with the entire, now unpaired part of the aorta becomes the **aorta descendens,** while nearly the whole of the right dorsal aorta disappears. The **innominate artery,** both **common carotid arteries** and both **external carotid arteries** appear to be derivatives of the aortic sac. The **ascending aorta** and the **main pulmonary artery** are derivatives of both the saccus aorticus and the truncus arteriosus, which are divided internally by the aortic septum in such a way as to leave the sixth pair of aortic arches in connection with the right ventricle and the other aortic arches in connection with the left.

While the system of aortic arches has been undergoing these changes, the heart has migrated from the upper cervical region into the thorax. The seventh cervical arteries of the dorsal

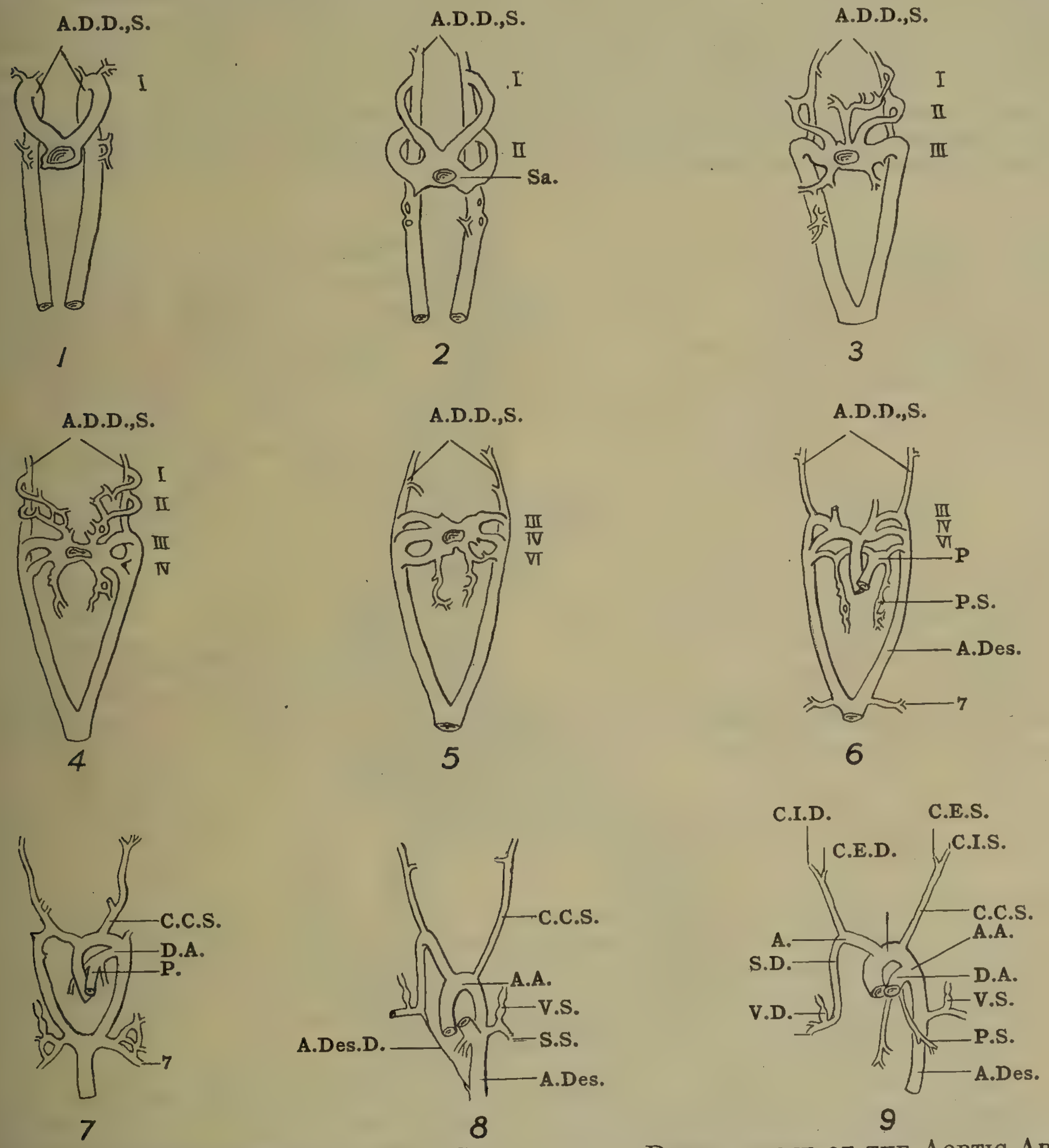


Fig. 582.—Reconstructions of Nine Stages in the Development of the Aortic Arch System. (After Congdon 1922.)

1, embryo 3 mm. long; 2, 3, mm. (older); 3, 4 mm.; 4, 4 mm. (older); 5, 6 mm.; 6, 11 mm., 7, 14 mm.; 8, 16 mm.; 9, 18 mm.
A.A., aortic arch; A.D.D., S., dorsal aorta, right, left; A.Des.D., vestige of right dorsal aorta; C.C.S., left common carotid; C.E.D., S., external carotid, right, left; C.I.D., S., internal carotid, right, left; D.A., ductus arteriosus; P., pulmonary artery; P.S., left pulmonary artery; Sa., aortic sac; S.D., S., subclavian, right, left; V.D., S., vertebral, right, left.

segmental series have meanwhile migrated upward from the unpaired part of the dorsal aorta to the paired part of that vessel. They finally take a position between the fourth and sixth pairs of aortic arches and form part of the **subclavian arteries.** The higher cervical segmental arteries by this time have lost their original connection with the internal carotid arteries. The second to the sixth segmental arteries of the dorsal series are connected by a large postcostal anastomosis which becomes the second part of a **vertebral artery.** The large lateral segmental arteries which become the axial arteries of the upper extremities are usually associated with the seventh pair of dorsal segmentals. With these the sixth segmental arteries are connected on either side by a precostal anastomosis which becomes the first part of the corresponding vertebral and arises from the subclavian. The left subclavian artery is of segmental origin throughout. The proximal part of the right subclavian is a derivative of the right fourth aortic arch and the adjacent part of the right dorsal aorta. The eighth pair of dorsal segmentals form the proximal

part of the **deep cervical** arteries. The precostal anastomoses between these and the subclavians form the *costocervical* trunks, with which also the upper two or three pairs of thoracic lateral segmentals are connected by precostal anastomoses to form the **superior intercostal** arteries. The third part of the vertebral artery appears to be a postvertebral anastomosis between the second cervical segmental and a vascular rete in the cranium from which the **basilar artery** and its branches are developed. From the anastomosis between this rete and the intracranial part of the internal carotids are formed the **cerebral, choroidal** and **communicating arteries.**

2. VARIATIONS OF THE AORTIC ARCH SYSTEM

The aortic arch may be normal in arrangement but *higher than usual*, its descent having been arrested. In two cases reported by Adachi ('28) this condition was associated with the presence of cervical ribs. A **right aortic arch** may take the place of the left, with or without situs inversus. In this case the contribution of the left and right embryonic arches in the production of the great vessels of the thorax has been reversed. There may be **two aortic arches**, the ascending aorta bifurcating distally into two branches which reunite to form the descending aorta. The left arch passes anteriorly to the trachæa and gives origin to the left common carotid artery and the left subclavian. The right, passing posteriorly to the esophagus

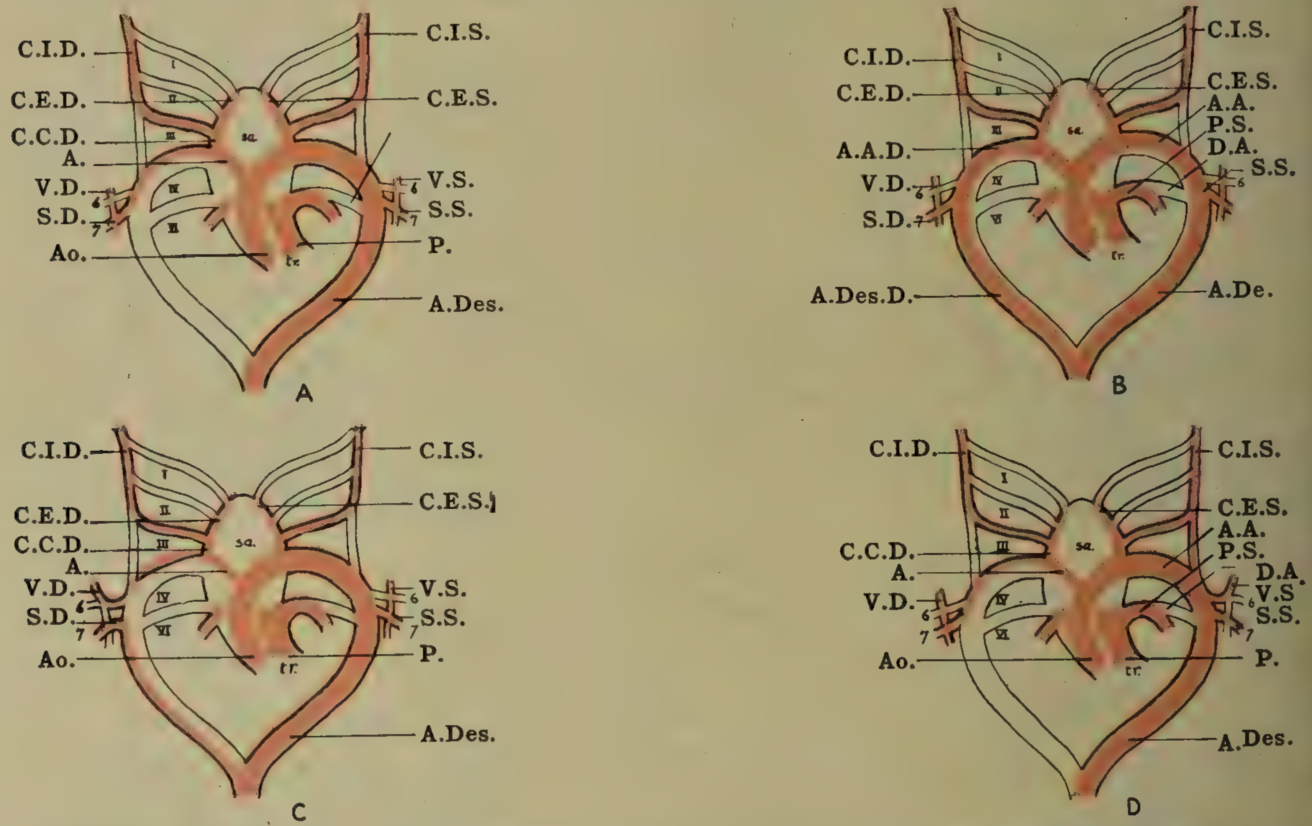


FIG. 583.—DIAGRAMS OF THE EMBRYONIC AORTIC TRUNK, SAC AND ARCHES (OUTLINED IN BLACK) AND THE ADULT ARTERIES DEVELOPED FROM THEM (RED).

A, normal, the others abnormal. B, two aortic arches; C, the right subclavian is the last branch of the aortic arch, the right vertebral arises from the right common carotid; D, the left external and internal carotid, arising directly from the aorta, are connected by a cord below which the superior laryngeal nerve passes.

I–IV, embryonic aortic arches; 6–7 sixth and seventh segmental arteries; A.A., aortic arch; A.A.D., right aortic arch; A.Des., descending aorta; A.Des. D., right descending aorta; Ao, ascending aorta; C.C.D., C.C.S., common carotid, right, left; C.E.D., C.E.S., external carotid, right, left; C.I.D., C.I.S., internal carotid, right, left; D.A., ductus arteriosus; P., pulmonary artery; P.D., right pulmonary artery; S.D., S.S., subclavian artery, right, left; s.a., aortic sac; tr., aortic trunk; V.D., V.S., vertebral artery, right, left.

gives the right common carotid and the right subclavian. The right fourth aortic arch has persisted in such cases and the right subclavian artery is equivalent to the left in composition. Several examples have been reported of a persistent right fourth aortic arch giving origin in turn to the left common carotid, right common carotid, right subclavian, left subclavian (the last by Pensa, '30). The left subclavian is dilated at its origin and connected beyond the dilation with the pulmonary artery by a ligamentum arteriosum, around which the recurrent nerve passes. In these cases, the part of the left dorsal aorta below the sixth aortic arch has persisted as far as its junction with the right to form the proximal part of the left subclavian artery (see fig. 583). Other cases have been recorded in which a vessel resembling the persistent right aortic arch crosses between the esophagus and trachea to the left side of the vertebral column to become the descending aorta. Since the right fourth embryonic arch does not occupy this position, the existence of an abnormal vessel of this kind is not explicable on ordinary embryological grounds. Malacarne has reported a case (1788) in which the ascending aorta having given origin to the coronary arteries divided at once into two vessels which passed backwards on either side of the pulmonary artery and rejoined behind the esophagus. Each of them gave off in turn the subclavian, external carotid and the internal carotid of its own side, which persistent fourth aortic arches could not have done. This order of branching and the fact that the aorta contained five semilunar valves suggests abnormality of the aortic septum.

This structure seems to have divided the aortic trunk and sac in such a way as to connect the sixth aortic arches with the left ventricle and the other aortic arches with the right. The sixth aortic arches in this case appear to have persisted in their entirely, the right and left pulmonary arches having retained their connection with the pulmonary division of the aortic sac.

The **branches of the aortic arch** are apt to vary in number and there may be a **single branch, the brachiocephalic.** This ended in the left common carotid in a case recorded by Klinz (1787) and gave origin to the right innominate opposite to the left subclavian. The origin of the innominate and left common carotid by a common trunk depends on the differentiation of the parts of the aortic sac uncommon in man but usual in some other mammals. The mechanism of the separate origin of the left subclavian from the brachiocephalic trunk is not easy to follow. The left dorsal aorta between the third and fourth arches may have persisted in part, to connect with a subclavian derived from a higher dorsal segmental artery than usual. If so, the proximal part of the subclavian must then have migrated from the left internal to the left common carotid artery. Some such migration must occur also in the rare examples of **two branches** of the arch (Biume, Malacarne), in which the left subclavian and left common carotid are associated in the formation of a left innominate. **Three branches** of the aorta may differ

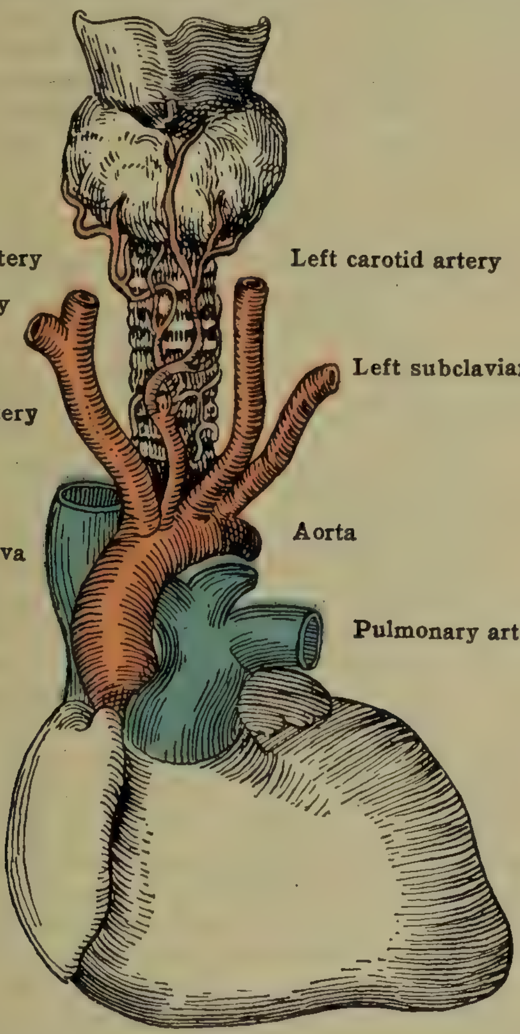


FIG. 584.—THE THYROIDEA IMA. (After Henle.)

from the normal in being the right subclavian, an innominate giving origin to both common carotids, and the left subclavian. In this case the two subclavians are developed normally but the differentiation of the aortic sac has followed an unusual course. **Four branches** may be the right subclavian, right common carotid, left common carotid and left subclavian in turn, or right common carotid, left common carotid, left subclavian and right subclavian. In the first case, the outcome of the development of the aortic arches is as usual but the differentiation of the aortic sac is abnormal. In the second case the right subclavian crosses dorsally to the esophagus and has no relation to the right recurrent nerve, which is not then recurrent. The proximal part of the right subclavian artery is here the persisting part of the right dorsal aorta below the sixth arch, the right fourth arch having disappeared (fig. 583). Four branches may be in turn the innominate, the left external carotid, the left internal carotid and left subclavian. The probable explanation of these cases is revealed by a case published recently by Schmeidel ('30) in which the left internal and external carotids were united by a cord opposite the third thoracic vertebra. This author identifies the proximal part of the left internal carotid as a persistence of the part of the left dorsal aorta between the third and fourth aortic arches. He identifies the proximal part of the left external carotid as the element which usually functions as the left common carotid, and the connection between the two carotids as a vestige of the third aortic arch (fig. 583). The addition of one vertebral, usually the left, or the thyroidea ima artery may make a fourth branch of the arch The mechanism of the origin of the **a. thyroidea ima** from the aortic arch or from the innominate has not been followed in detail but depends no doubt, upon the definitive importance of an unusual connection between the plexus around the embryonic thymus and the aortic sac (fig. 584).

There may be **more than four direct branches** of the arch, as for instance when the right subclavian artery and the right common carotid arise separately and the left vertebral is added.

The left vertebral arising from the aorta separately, is usually medially placed with regard to the subclavian. In this case the sixth left cervical segmental has retained its original connection with the dorsal aorta, not being connected by the usual precostal anastomosis with the seventh (subclavian) segmental artery. The vertebral in a lateral position with regard to the subclavian is the result of a reversal in the definitive connections of the segmental arteries of the region.

The above-mentioned deviations from the usual outcome of the development of the aortic arch system are found in adult subjects. There are many others, associated with gross defects or absence of the aortic, interventricular or interatrial septum, that are incompatible with extrauterine life. Such cases are dealt with in the text-books on Pathology.

3. MORPHOGENESIS AND VARIATIONS OF THE CAROTID AND SUBCLAVIAN ARTERIES

In all the cases hitherto reported of absence of the **common carotid**, this vessel appears actually to be represented by the proximal part of the external carotid. The proximal part of the so-called internal carotid is the part of the dorsal aorta between the third and fourth aortic arches (see p. 706). In 70 out of 295 cases examined by Quain ('44) the common carotid bifurcated higher than the thyroid cartilage, 10 of them above the hyoid bone. Of the 31 that bifurcated lower, 5 did so as low as the cricoid. The branch most commonly given by the common carotid, in addition to the internal and external, is the superior thyroid. In examples of high bifurcation, almost all of the branches of the **external carotid** may arise from the parent trunk except the maxillary and the superficial temporal. The superior thyroid may be absent on one side with compensation through the cricothyroid of the other. The external maxillary may end as the submental or as the inferior labial, the deficiency being supplied through the external maxillary of the other side through the infraorbital, the transverse or the ophthalmic of the same side. The tonsillar artery is frequently absent, as is the ascending palatine occasionally, there being compensatory variation between these and the ascending pharyngeal. The ascending pharyngeal artery may be represented by several small branches or take origin from the bifurcation of the common carotid or from the internal carotid or the occipital.

These compensatory variations of the branches of the external carotid and neighboring arteries arise through the major or minor share taken by a generally constant number of stems in the supply of an originally indifferent arterial rete. The internal maxillary, however, is taken over relatively late in development by the external carotid. The **internal carotid**, which is prone to little variation in branching, is subject to a hitherto unexplained tortuosity immediately below the cranium which may occur even in young subjects. Its caroticotympanic branch is a vestige of the large embryonic artery, the **stapedial**, later taken over by the external carotid as the internal maxillary. This embryonic vessel arises usually in the carotid canal (sometimes a little lower) and passes upwards over the promontory of the tympanum. It then runs between the crura of the stapes and enters the middle cranial fossa through the petrosquamous fissure. Here it divides into a supraorbital branch (the anterior branch of the middle meningeal, which communicates with the ophthalmic artery) and a branch which leaves the skull through the foramen spinosum. Outside the skull this branch subdivides into the infraorbital (which becomes most of the first part and all of the second and third parts of the internal maxillary artery) and the inferior alveolar branch. A communication between the external carotid and the point of subdivision of the extracranial branch now furnishes the remainder of the first part of the internal maxillary from which the middle meningeal then arises. The direction of flow in the last having become reversed, the tympanic part of the stapedial artery ceases to be a through channel, the intracranial part becomes the superior tympanic branch of the posterior branch of the middle meningeal. The tympanic part of the stapedial artery may persist in adult life but usually ends as the middle meningeal, the foramen spinosum being absent and the internal maxillary lacking that branch. Quain observed a case in which the accessory meningeal artery, reinforced by a branch through the foramen rotundum, gave origin to the ophthalmic artery and all the intracranial branches of the left internal carotid; the extracranial part of the internal carotid and the carotid canal, being absent. The communication from the external carotid appears in this case to have taken over the supraorbital branch of the stapedial and the intracranial part of the internal carotid, and to have superseded the extracranial part of the latter.

The **subclavian artery** occasionally pierces or lies anterior to the anterior scalene muscle. The right subclavian in four cases out of 25 examined by Quain ascended from 1 to 1½ inches above the clavicle. Variations of the origin of the subclavian have been noted on p. 706. The vertebral artery may arise directly from the arch of the aorta (p. 707). In some cases in which the right subclavian is the last branch of the arch, the right vertebral arises from the right common carotid. In this case the fourth aortic arch participates in the formation of the vertebral (fig. 583). The **vertebral** artery may arise by two roots from the subclavian or one from the subclavian and one from the aortic arch. One of these roots may ascend as high as the fourth cervical vertebra before entering the arterial foramen and joining its fellow. The two vessels represent two intersegmental anastomoses, a pre- and a postcostal. A vertebral artery arising by a single root may be composed partly of a precostal anastomosis between the lower cervical dorsal segmental arteries, in which case it will enter the transverse foramina at higher level than usual. The place of origin of the branches of the subclavian artery does not vary greatly in position although two of them may be united by means of a common trunk of origin. For example, the inferior thyreoid and vertebral, the internal mammary and thyreocervical or the internal mammary and suprascapular may be so united. The inferior thyreoid may arise from the common carotid and the descending branch of the transverse cervical artery not uncommonly arises from the third part of the subclavian (it is practically the only vessel that ever does so).

The **basilar artery** is a longitudinal anastomosis between the dorsal segmental arteries of the occipital region, originally continuous with the anterior spinal arteries. It retains its

connection with the first cervical segmental arteries through the two vertebrals and with the internal carotids through the posterior cerebral and posterior communicating and middle cerebral arteries. Owing to the wide choice of routes by which blood may reach the arteries of the brain through the circulus arteriosus, either of the internal carotid or vertebral arteries may be small. There may be great inverse variation in size, and this may be further increased by ligature of one of the four supplying vessels without apparent loss of function.

B. THE MORPHOGENESIS AND VARIATIONS OF THE ARTERIES OF THE THORACIC AND ABDOMINAL WALLS

The arteries of the dorsal segmental series gradually become recognizable as the somites make their appearance in the cranio-caudad direction. Arising from the posterior aspect of the at first paired dorsal aortæ, they supply the rapidly developing central nervous system. In the adult thorax and abdomen they are represented by the main stem and the dorsal ramus of the intercostal and lumbar arteries, the latter supplying the longitudinal muscles of the back and the integument in their neighborhood. The original spinal branch is represented by spinal branches arising from the costocervical, thoracic, lumbar, iliolumbar and lateral sacral arteries. A few of these on either side are large and reinforce the anterior and two posterior spinal arteries which are formed by intersegmental anastomoses. There is also a more irregularly distributed series of lateral parietal arteries. Some of these may arise originally from the arteries of the dorsal segmental series, but many of them are found to arise in early stages directly from the aortae. Those which persist, however, are found to soon become associated with the larger

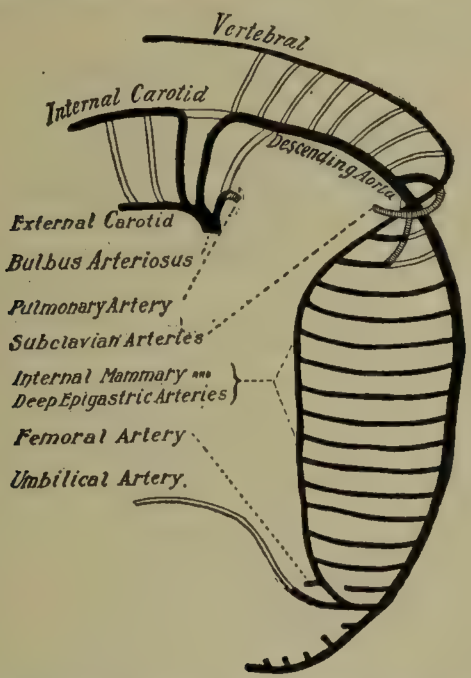


Fig. 585.—Diagram to Show the Development of the Arteries of the Trunk from the Aortic Arches and the dorsal Segmental Arteries.
The arteries which persist are black; those which degenerate are in outline; those newly formed are shaded. (After Mall.)

arteries of the dorsal series. They enlarge with the growth of the body walls and become the anterior rami of the intercostal and lumbar arteries.

The anterior rami of the intercostal and lumbar arteries are connected beneath the developing mammary line by a longitudinal anastomosis which later becomes the internal mammary and inferior epigastric arteries (fig. 585). The former receives its blood through the lateral ramus of the 7th cervical artery of the dorsal segmental series (the subclavian) and the latter through the inferior epigastric branch of the external artery or, occasionally, through the obturator branch of the hypogastric. The first two or three pairs of intercostal ventral rami become joined to the subclavian by a precostal anastomosis to form the superior intercostal artery and the costocervical trunk, the lower six thoracic anterior rami anastomose with the musculophrenic branch of the internal mammary. More laterally placed longitudinal anastomoses between the intercostal and lumbar anterior rami may be provided by the lateral costal connection with the internal mammary artery (p. 642) and the lateral epigastric branch of the deep circumflex iliac (p. 686).

The common iliac-hypogastric trunk is a lateral branch arising between the fourth segment of the aorta and the beginning of the middle sacral artery. Its course is comparable to that of the other lateral lumbar and sacral segmental arteries but it soon takes over the umbilical artery, the proximal part (ventral root) of which disappears early in development. The umbilical artery and the visceral pelvic arteries thus come to arise from the hypogastric but the parietal pelvic arteries (including the embryonic sciatic artery) are derivatives of the common iliac-hypogastric trunk.

The **costocervical and superior intercostal** arteries may traverse the foramen in the transverse process of the seventh cervical vertebra and pass between the first two thoracic transverse processes and the neck of the corresponding ribs. In this case the intersegmental union has been effected by a postcostal in place of the usual precostal anastomosis. The number of **intercostal or lumbar arteries** of either side may be reduced through the supply of two or more of them from a single segment, through a precostal anastomosis.

The **external iliac** artery, usually the first branch of the common iliac-hypogastric trunk may arise directly from the aorta, in which case the **common iliac** artery, as such, is absent. The external iliac may be the last, or nearly the last branch of the common iliac-hypogastric trunk, in which case the **hypogastric** artery is said to be absent (it is really larger than usual). When this occurs, the common iliac is continued as the hypogastric into the pelvis, the abnormal external iliac mounts from there into its usual position and is continued as the femoral. Through the anastomosis between the pubic branch of the inferior epigastric and that of the obturator, the proximal part of the latter may be wanting and a short **obturator** artery arises from the inferior epigastric or, sometimes from the external iliac (p. 686). Apart from the large size of the **inferior gluteal** in the very rare cases in which it is continued as a sciatic artery (p. 713) supplying the parts below the knee, the general distribution of the branches of the hypogastric artery is prone to little variation. The internal pudendal artery, however, is sometimes very small in its perinaeal part and is then reinforced by an **accessory pudendal.** The latter may arise from the hypogastric from the inferior vesical, the obturator or from the internal pudendal itself or more rarely from the external iliac or inferior epigastric. It runs forward on either side of the lower part of the bladder and the prostate and enters the urogenital diaphragm to end as the artery of the penis or clitoris. The internal pudendal proper ends under these circumstances as the superficial perineal or as the artery to the bulb, and usually anastomoses with the accessory pudendal near the prostate. The variability of the site of **origin of the branches of the hypogastric** artery has been referred to on p. 677. This appears to be the outcome of the free anastomosis occurring in the embryo between the parietal branches of the common iliac-hypogastric trunks and the pericloacal branches from the primary root of the umbilical arteries.

C. THE MORPHOGENESIS AND VARIATIONS OF THE VISCERAL ARTERIES

The **lateral visceral segmental arteries** take origin from the aorta in series, intermediate in position between the lateral parietal segmental arteries and the ventral segmentals. They reach their fullest development in embryos of about 8 mm., when they extend from the seventh cervical to the twelth thoracic segment and supply the mesonephros. At this stage Broman found twenty arteries on each side, many of which were non-segmental. As the suprarenals and gonads develop, they each receive branches from several mesonephric arteries. The arteries at the cephalic end of the mesonephric series now undergo rapid retrogression and the suprarenal and gonadic branches are shifted caudally through the series to newly formed (non-segmental) arteries opposite the upper lumbar segments. Finally there remain three suprarenal arteries opposite the twelfth thoracic and first and second lumbar segments and a gonadic artery (*ovarian or internal spermatic* of the adult) opposite the third lumbar segment. All of these vessels now appear to be direct branches from the aorta. Of the three suprarenal branches, the upper and lower each gives a large branch to diaphragm and kidney respectively and become the *inferior phrenic* and *renal arteries* of the adult. The middle becomes the *middle suprarenal.* Felix regards the visceral lateral segmental arteries as having arisen from longitudinal anastomoses connecting the members of the ventral segmental series. He places a different interpretation upon the vessels which persist in the lumbar region after the disappaearance of the thoracic mesonephric arteries. He finds in an embryo of 18 mm. nine arteries on either side, extending from the ninth thoracic to the third lumbar segment, all of which he looks upon as mesonephric. These arteries he classifies into three groups: Cranial, which reach the mesonephros by passing dorsally to the suprarenal; caudal which pass ventrally to the suprarenal, and middle which pass through it. Inasmuch as the arteries anastomose in the mesonephros there is great liability to variation in the number and position of the stems which persist in the adult. The suprarenal arteries are usually derived from the caudal group, the renals from the caudal or middle and the spermatics from the middle. When accessory, renals or spermatics occur in the adult their place of origin and course indicate the group from which they have been derived.

The **ventral segmental arteries** appear very early. In an embryo of seven somites (ca. 2 mm.) described by Dandy there is a right and a left series of twelve arteries, each arising from the still ununited dorsal aortæ, the artery at the caudal end of each series being the umbilical, and the remainder vitelline arteries. In an embryo of 4.9 mm. (35 somites) described by Ingalls the originally paired vitelline arteries have united (as have the dorsal aortæ in part) to form unpaired vessels. There are unpaired ventral segmental arteries as follows: one opposite the seventh cervical segment (celiac); five opposite the first four thoracic (omphalomesenterics, united by a longitudinal anastomosis), and one vessel of doubtful significance opposite the fifth and sixth thoracic segments. The paired umbilical arteries are opposite the first lumbar segment.

It has been found from more fully developed stages that the inferior mesenteric artery is distinguishable at a stage of 8 mm. opposite the second lumbar segment. Also that the ventral segmental vessels undergo a process of apparent migration until they reach their definitive positions, the *celiac* opposite the twelfth thoracic segment; the *superior mesenteric* opposite the first, the *inferior mesenteric* opposite the third, and the umbilicals between third and fourth lumbar segments, respectively. The umbilical arteries are connected in the earlier stages of development with branches of the omphalomesenteric artery on the yolk-sac. This connection is effected by the *subintestinal* artery, which usually disappears as soon as the hind-gut begins to become tortuous. The esophageal and bronchial arteries of the adult do not appear to arise directly from any of the arteries of the ventral series but are probably derived from the same common source.

The *umbilical arteries* become connected by anastomosis with the common iliac-hypogastric trunks. The original (or ventral) roots of the umbilical arteries soon disappear and the umbilical arteries are subsequently supplied through the common iliac-hypogastric trunks alone.

Multiple **renal arteries** occur with great frequency and represent unusual persistences of arteries of the mesonephric series. The supernumerary arteries may enter through the anterior convexity of the organ instead of the hilus; occasionally they enter posteriorly. They are usually branches of the aorta but may, particularly when the kidney is lower than usual, arise from the common iliac artery or from the middle sacral. The **spermatic or ovarian** arteries may be reduplicated and may arise from another member of the mesonephric series, particularly the renal. The **phrenic** arteries, and thus the **superior suprarenal** arteries may arise from a common stem with the celiac. One or even two members of the suprarenal series, on either side, may be absent, with compensatory enlargement of the one or two that are present.

The right **bronchial** artery may arise from the left instead of the right first intercostal, and there are rarely two right bronchials. The bronchial arteries for the two lungs may arise by a common stem from the aorta. All of these variations are dependent upon the free anastomosis which occurs between the local visceral and parietal arteries of the embryo. This anastomosis accounts also for the occasional origin of one or both of the bronchial arteries from branches of the subclavian, such as the costocervical, internal mammary or thyrocervical.

The **coeliac** and **superior mesenteric** arteries may arise as a single celiomesenteric trunk as in some other mammals. Anastomatic connections between these two arteries occur in many cases near the aorta and their enlargement may alter the site of origin of one or more of their branches. The **hepatic** is particularly liable to arise from the superior mesenteric, in which case the celiac is reduced to a **gastrolienal trunk,** or the left or the right hepatic may so arise. The superior mesenteric may give origin by the same means to a right or left **accessory hepatic.** In some cases the medium of transfer of the hepatic artery to the superior mesenteric artery is furnished by the pancreaticoduodenal arterial arch, but this means of transfer is less common than that effected by a more proximal communication. Any or all of the usual branches of the celiac may arise independently from the aorta, as may the **gastroduodenal,** which may arise directly from the celiac, independetly of the hepatic. The artery, besides the additional branches referred to above, may give origin to the inferior **mesenteric.** The jejunal and ileal branches leading to the first series of mesenteric arterial arcades may vary considerably in number. Blood may enter the continuous arterial arch extending from the termination of the superior mesenteric to the left colic artery by a varying number of direct branches of the superior mesenteric. When they are diminished in number, the **ileocolic** and the **right colic** or the right colic and the **middle colic** may be united by a common stem or origin. The apparent absence of the ileocolic, the right colic or the middle colic is due in this case to differences in the number of the direct routes from the aorta through which the arterial plexus of the embryonic mesentery eventually receives its supply.

A few cases have been recorded in which the superior mesenteric artery crossed to the navel and was continued through the somatic mesoderm of the umbilical cord to the placenta. Hafferl has given a careful description of the conditions in an adult female cadaver which throws light on cases of this kind. An ileal branch of the superior mesenteric crossed the intestine and joined the right umbilical ligament. The connection between the superior mesenteric and the cord representing the right umbilical artery is, no doubt, a persisting **subintestinal** artery, which in this case retained its lumen. The persisting **omphalomesenteric** artery sometimes found at birth, runs in the funicular coelom to the vestigial yolk-sac and has no connection with the placenta. A large branch of the aorta is sometimes found at birth (usually associated with imperforate anus and other anomalies preventing viability) to go through the somatic mesoderm of the cord to the placenta. This vessel, since it does not pass through the mesentery, is not a persistent omphalomesenteric (as it has been regarded). It is an **umbilical** artery which, not having been taken over by the common iliac-hypogastric trunk, has retained its original connection with the aorta.

The branches of the **inferior mesenteric** artery arise from the superior mesenteric in the rare cases in which the former is absent. The branches themselves vary little in distribution. The middle and left colic have been recorded by Hyrtl as arising from a 'middle mesenteric' which arose in this case from the common iliac.

D. THE MORPHOGENESIS AND VARIATIONS OF THE ARTERIES OF THE EXTREMITIES

Of the several small lateral segmental arteries originally supplying the embryonic limb, one gains ascendency over the others, and becomes the axial artery of the extremity. This gives origin to innumerable small branches leading into an anastomosing network drained originally into the umbilical vein. A drainage system is soon established which consists of a superficial marginal vein. The ulnar limb of the marginal vein of the upper extremity becomes the basilic, axillary and subclavian veins; the fibular vein of the lower extremity becomes the v. saphena parva.

The axial artery of the **upper extremity** persists until maturity and becomes the subclavian, axillary, and brachial arteries continued as the part of the ulnar artery beneath the m. pronator teres, the common and volar interoseous arteries, the volar carpal rete and the deep arteries of the palm. The distal perforating branch of the axial artery persists as the perforating branch of the volar interoseous, and its continuation forms the dorsal carpal rete and dorsal interoseous and digital arteries. To these the radial and dorsal interoseous arteries, the remaining part of the ulnar and the superficial volar arch are added during the progress of development.

The chief **variations** due to the unusual persistence of normal embryonic arteries are: (1) the origin of the **radial** artery in the wrist from the volar interoseous through the volar or dorsal radial carpal, or both, the radial artery in the forearm being small or absent; and (2) a **median** artery of unusual size. The median artery is large in the embryo but dwindles after having been instrumental in forming the superficial volar arch. The other principal variations consist of the persistence of abnormal arteries that do not appear to occur normally at any stage of development. These abnormal vessels include the following. 1. The **caudal axillary** artery

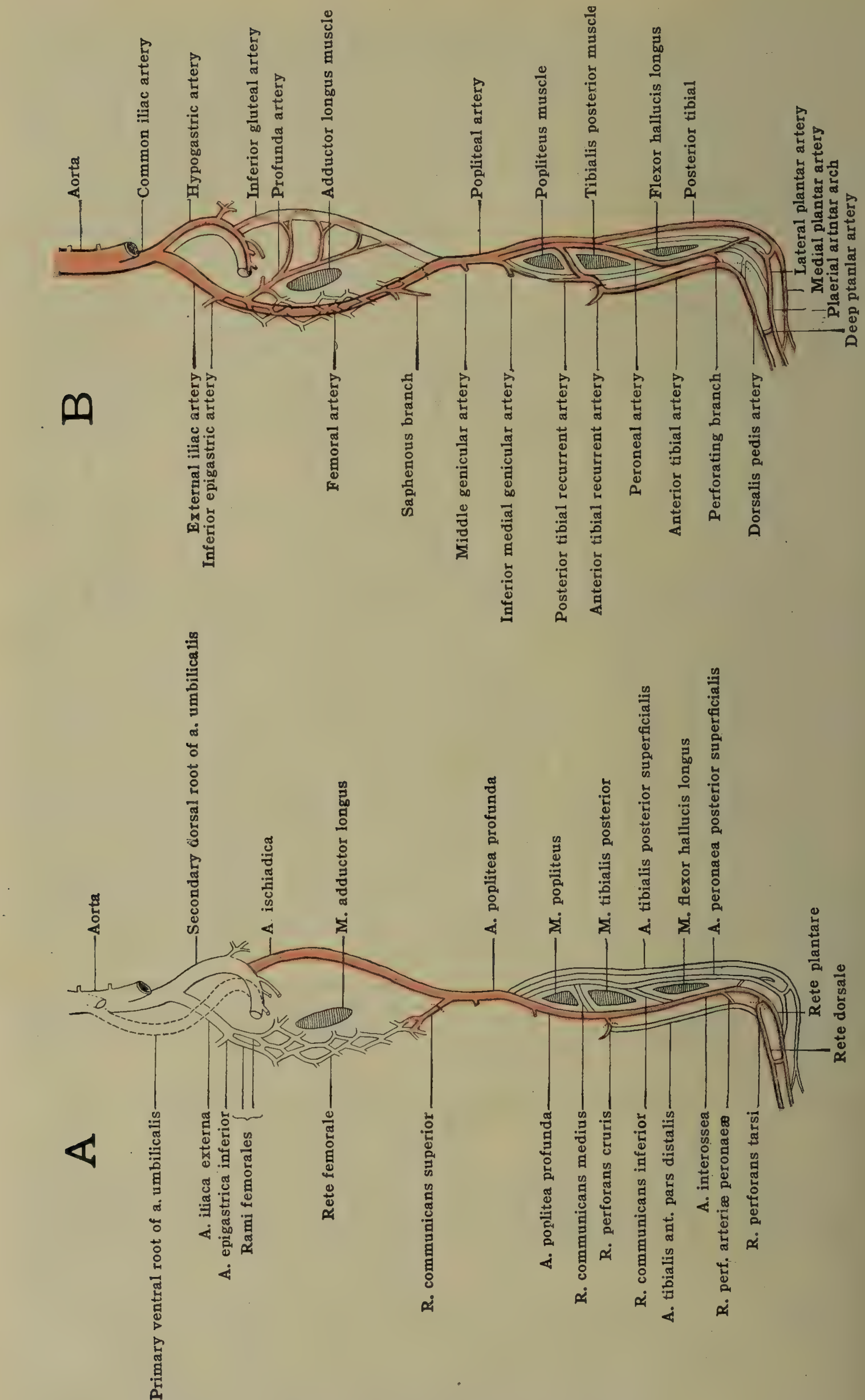


Fig. 586.—Diagram Indicating the Method of Development of the Arteries of the Right Lower Extremity.

The embryonic arteries are outlined in black. In *A*, the axial artery of the developing limb, and some of its branches are colored red; the original, or ventral, root of the umbilical artery is indicated by a broken line. In *B*, the adult arteries are colored red.

which does not traverse the ventral plate of the brachial plexus in the ventro-dorsal direction, above the loop of the median nerve, as does the axillary part of the axial artery. It reaches the dorsal side of the ventral plate by curving around the caudal aspect of the plexus. 2. The **superficial brachial** artery. This vessel may arise from the axillary above, and cross superficially to, the median nerve loop (a. brachialis superficialis superior) or it may arise from any part of the brachial (a. brachialis superficialis inferior). In either case it crosses the median nerve superficially in the arm, to reach its medial side. Both the superior and inferior superficial brachial may rejoin the brachial artery proper (forming a vas aberrans); or may be continued as a normal radial artery. In the latter case the superficial brachial may or may not be connected at the bend of the elbow with the brachial, which is continued as a normal ulnar artery. In some cases the superficial brachial is continued as a superficial antibrachial artery, or as the radial and a superficial antibrachial. The **superficial antibrachial** artery passes across the muscles arising from the medial epicondyle (occasionally going deep to the palmaris longus) and ends either as a large median artery or as the ulnar artery, in the hand. In the latter case the part of the ulnar artery not included in the original axial artery is absent. In other cases, the superficial brachial artery is very large and supplies the entire limb beyond the elbow. In this case it has a large branch (known as the **profunda axillaris**), which represents the brachial part of the axial artery of the embryo and passes deeply above the loop of the median nerve. This branch gives origin to the circumflex humeral arteries, the subscapular, the profunda brachii and the superior ulnar collateral and ends as the inferior ulnar collateral.

The caudal axillary and the superficial brachial artery, either superior or inferior, arise in the embryo as accessory vessels which may definitively supplant or accompany a part of the original axial trunk. Since they appear to be abnormal, not only in the adult but in the embryo, the study of normal development as such, throws no light on the manner or the time of their appearance. The superficial antibrachial artery supplants the part of the ulnar artery which does not form part of the axial, but it, also, does not seem to occur during the usual course of development.

In limbs in which there is a supracondylar hook on the humerus, the brachial artery and the median nerve pass behind it (and deep to an accessory head of the m. pronator teres which is generally present in these cases) before reaching their usual position in the antecubital fossa. Such a course, normal in some other mammals, appears to be inherited from a common ancestor in which the brachial artery passed through a supracondylar foramen.

The **lower extremity** offers a contrast to the upper in that all of the commoner and more important variations represent persistencies of arteries that occur normally in the embryo. The axial artery arises from the common iliac-hypogastric trunk (the secondary root of the umbilical artery) and forms the sciatic, which is continued in turn as the popliteal and the interoseous artery of the embryo and the deep arteries of the sole. The distal perforating branch (a. perforans tarsi) traverses the sinus tarsi and its continuation forms the dorsal tarsal and metatarsal arteries (fig. 586). The sciatic part of the axial artery is represented at maturity only by the inferior gluteal artery and the anastomosis between the perforating arteries. Of the popliteal part only the portion between the hiatus tendineus and the popliteus muscle persists; the remainder, which passes between the popliteus muscle and the tibia, ceases to act as a through channel. The interoseous part is lost entirely, except for the small portion of it which enters into the formation of the anterior tibial artery and another small part incorporated in the definitive peroneal artery. The external iliac artery, the femoral, the posterior tibial and the remaining part of the anterior tibial and peroneal arteries are all secondarily formed vessels. The distal part of the popliteal artery (like the neighboring part of the posterior tibial) is formed by the proximo-distal union between the predecessor of the posterior tibial and that of the greater part of the peroneal artery (fig. 586).

The **sciatic** artery persists rarely to supply the parts beyond the knee, at the expense of the **femoral** which is small. The embryonic (deep) popliteal may persist either as a popliteal artery anterior to the popliteus muscle, or as a part of the **anterior tibial.** In the latter case the **popliteal artery** divides behind the knee into an anterior tibial-peroneal trunk and a posterior tibial artery which does not give origin to the peroneal. It divides more rarely into an anterior tibial which passes anteriorly to the popliteus muscle and a posterior tibial artery which branches in the usual way. The predecessor of the greater part of the peroneal (the a. peronaea posterior superficialis) which takes over the supply of the sole from the interoseous artery, may persist in its entirety to be continued as the lateral plantar artery, the **posterior tibial** being small or absent. Or, the posterior tibial being small or absent, that embryonic artery may enter in the usual way into the formation of a peroneal artery, which is continued as the lateral plantar. Besides irregularities of the origin of the **anterior tibial,** the artery may be small. The **dorsalis pedis** in this case arises from the peroneal, through the perforating peroneal branch of the interoseous part of the axial.

Only two of the definitively abnormal arteries of the lower extremity are, like the majority of those of the upper extremity, anomalous alike in the embryo and in the adult. These are the abnormal **great saphenus** and **great sural** arteries. The former arises from the a. genu suprema and assists in the supply of the medial region of the foot. The latter is a large superficial sural branch of the popliteal which helps to supply the lateral region of the foot. Neither of these has yet been found in the embryonic limb so that their history is unknown. The irregularities in the origin of the larger muscular branches of the femoral artery are referred to on page 690.

3. THE SYSTEMIC VEINS

The **systemic veins** are naturally divided into three groups—(A) the veins of the heart; (B) the vena cava superior and its tributaries, namely the veins of the head, neck, upper extremity, and thorax; and (C) the vena cava inferior and its

tributaries; namely, the portal system, and the veins of the abdomen, pelvis, and lower extremity.

A. THE VEINS OF THE HEART

The veins of the heart have already been described (p. 598).

B. THE VENA CAVA SUPERIOR AND ITS TRIBUTARIES

THE VENA CAVA SUPERIOR

The **vena cava superior** (or cranialis NK) (fig. 587) carries to the heart the blood returned from the head and neck and upper extremities through the right

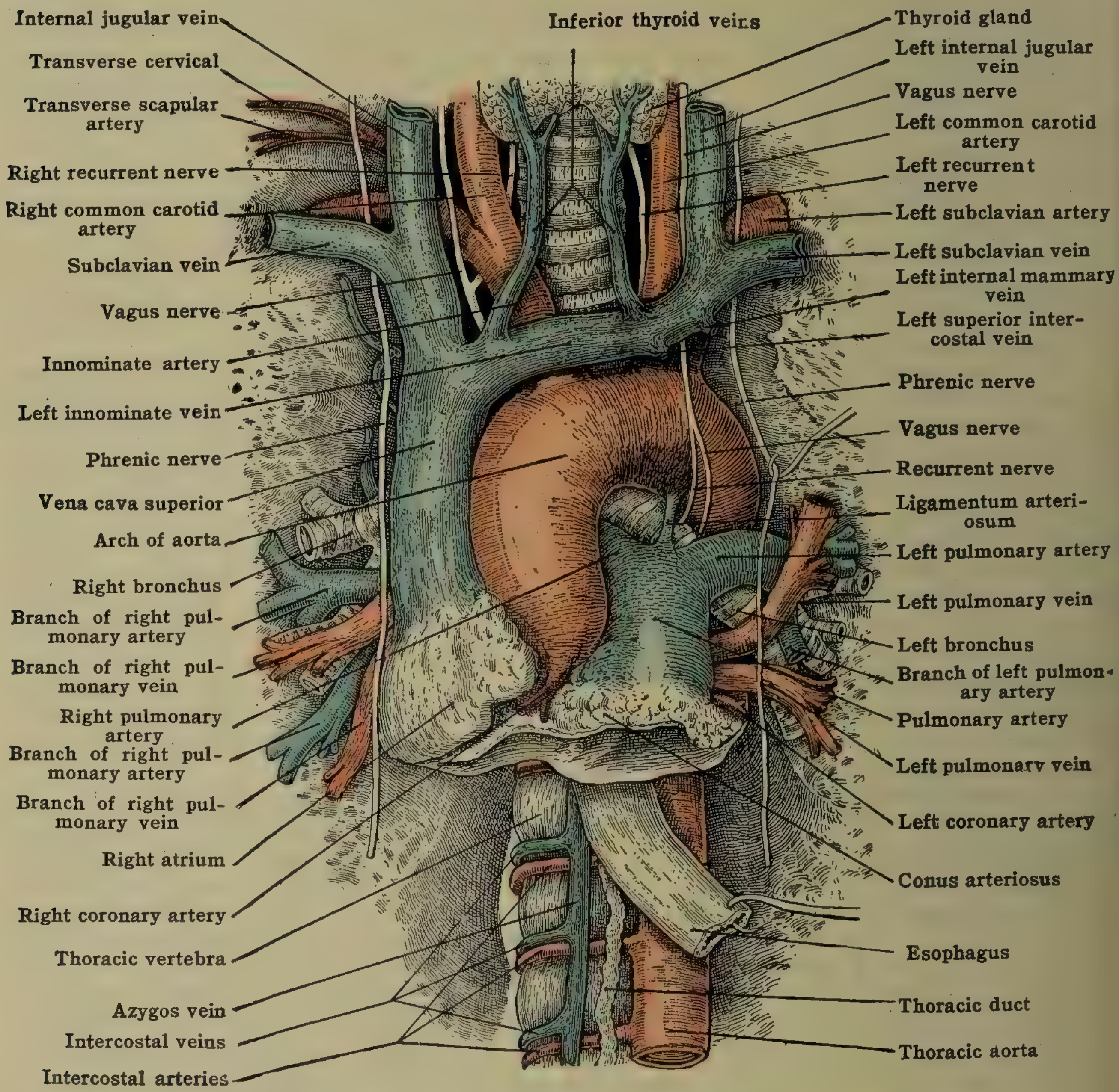


Fig. 587.—The Vena Cava Superior and the Innominate Veins. (Modified from a dissection in St. Bartholomew's Hospital Museum.)

and left innominate veins, and from the walls of the thorax, either directly through the azygos vein, or indirectly through the innominate veins. It is formed by the confluence of the right and left innominate veins behind the first right sterno-chondral articulation. Descending from its origin in a gentle curve with its convexity to the right and in a direction slightly backward behind the sternal end of the first and second intercostal spaces and second costal cartilage, it terminates in the right atrium of the heart on a level with the third right costal cartilage in front and the seventh thoracic vertebra behind. It measures about 7 to 8 cm. (3 in.) in length. A little more than its lower half (4 cm.) is contained within the pericardium, the serous layer of that membrane being reflected obliquely over it immediately below the spot where it is joined by the vena azygos, and

on a lower level than the reflection of the pericardium on the aorta. The vena cava superior contains no valves.

Relations.—**In front,** in addition to the first and second intercostal spaces and the second costal cartilage, it is covered by the remains of the thymus gland, the intrathoracic fascia, and the pericardium, and is overlapped by the right pleura and lung.

Behind are the vena azygos (major), the right bronchus, the right pulmonary artery, and the superior right pulmonary vein; and below, the fibrous layer of the pericardium. The serous layer is reflected over the front and sides of the vessel, but not over its posterior part.

To the **right side** are the right lung and pleura and the phrenic nerve.

To the **left side** are the innominate artery and the ascending aorta.

Tributaries.—In addition to the right and left innominate veins and the vena azygos it receives small veins from the mediastinum and pericardium.

THE INNOMINATE VEINS

The **innominate** veins [vv. anonymæ] return the blood from the head and neck and upper extremity. They are formed on each side by the confluence of the internal jugular and subclavian veins behind the sternal end of the clavicle. They terminate behind the first costal cartilage on the right side by uniting to form the vena cava superior. The innominate veins have no valves.

The **right innominate** vein [v. anonyma dextra] (fig. 587) measures about 2 to 3 cm. (1 to 1½ in.) in length, and descends from its origin behind the sternal end of the clavicle, very slightly forward and medially, along the right side of the subclavian and innominate arteries, to its junction with the left vein behind the first costal cartilage close to the sternum. It is superficial to the innominate artery.

Relations.—**In front** are the origins of the sternohyoid and sternothyroid muscles, the clavicle, the first costal cartilage, and the remains of the thymus gland. **Behind** are the pleura and lung. To the **right** are the right pleura and lung and the phrenic nerve. To the **left** are the right subclavian artery, the innominate artery, the right vagus nerve, and the trachea.

The **left innominate** vein [v. anonyma sinistra] (fig. 587) measures 6 to 7.5 cm. (2½ to 3 in.) in length, and extends from its origin behind the sternal end of the left clavicle obliquely across the three main branches of the arch of the aorta to unite with the right innominate vein behind the cartilage of the first rib close to the sternum to form the vena cava superior. In this course it runs from left to right with an inclination downward and slightly backward. A line drawn obliquely across the upper half of the manubrium of the sternum, from the sternoclavicular articulation on the left side to the lower border of the first costal cartilage at its junction with the sternum on the right side, will indicate its course. The left innominate vein is on a level with the top of the sternum at birth.

Relations.—**In front,** in addition to the manubrium of the sternum, it has the origins of the sternohyoid and sternothyroid muscles, and the remains of the thymus gland, the sternal end of the left clavicle, and the sternoclavicular articulation. **Behind** are the three chief arteries arising from the arch of the aorta, the trachea, and the left phrenic and left vagus nerves. **Below** it is the arch of the aorta. **Above** it are the cervical fascia, the inferior thyroid, and thyroidea ima veins.

Tributaries.—In addition to the internal jugular and subclavian veins, by the confluence of which the innominate veins are formed, each vein receives on its upper aspect the vertebral, the deep cervical, and inferior thyroid veins; and on its lower aspect the internal mammary vein. The left vein, moreover, is joined by the thyroidea ima, the left superior intercostal, and by the thymic, tracheal, esophageal, superior phrenic, anterior mediastinal, and pericardiac veins. At the confluence of the internal jugular and subclavian veins on the right side the three lymphatic trunks or the right lymphatic duct open; on the left side the thoracic duct.

THE VEINS OF THE HEAD AND NECK

The **veins of the head and neck** may be divided for purposes of description into the **superficial,** which return the blood from the external parts of the head and neck; and the **deep,** which return the blood from the deeper structures. All the veins, whether superficial or deep, terminate in the internal jugular or subclavian, or open directly into the innominate veins at the root of the neck. Through the latter all the blood from the head and neck ultimately passes on its way to the heart.

THE SUPERFICIAL VEINS OF THE HEAD AND NECK

The venous blood from the anterior part of the scalp and integument of the face is returned, through the **anterior and posterior facial** veins, to the **common facial,** a tributary of the internal jugular vein. From the posterior part of the scalp and from the integument of the neck venous blood is returned, through the **external jugular** and its tributaries, to the subclavian vein.

A. The Anterior Facial Vein

The **anterior facial** vein [v. facialis anterior] (v. facialis NK) (fig. 588) begins a little below the medial end of the eyebrow where it is formed by the union

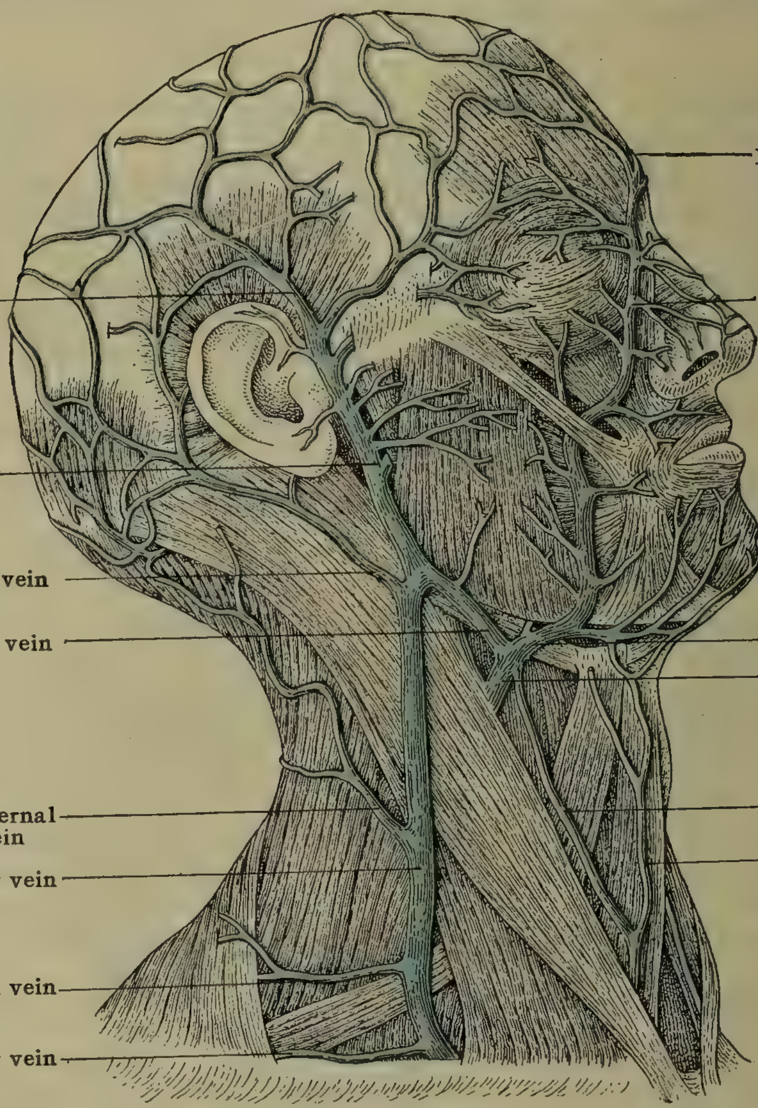


Fig. 588.—The Superficial Veins of the Face and Scalp. (After Quain.)

of the frontal and supraorbital veins. It descends near the medial angle of the orbit, and then by the side of the nose to the cheek, which it crosses obliquely, to the anterior edge of the masseter muscle. Thence it passes through the digastric triangle to the upper border of the hyoid bone, where it terminates in the common facial vein. In this course it is reinforced by numerous collateral veins, and gradually increases in size. It has, moreover, numerous communications with the deep veins. The portion of this vein above the lower margin of the orbit is called the **angular** [v. angularis]. In the remainder of its course over the face and neck it is termed the **anterior facial** vein.

The angular vein skirts around the medial margin of the orbit, lying with the angular artery on the frontal (nasal) process of the maxillary bone slightly medial to the lacrimal sac. Branches pass from the posterior part of the angular vein into the orbit to join the ophthalmic.

The angular, the facial, and the ophthalmic veins contain no valves. The blood, therefore, can pass either forward from the ophthalmic into the angular, or backward through the facial and angular into the ophthalmic, and so on to the cavernous and other venous sinuses of the cranium.

The anterior facial vein runs in a more or less direct line behind its corresponding artery, the external maxillary (facial), which itself pursues a tortuous

course. It usually passes deep to the zygomatic muscle, the zygomatic head of the quadratus labii superioris, and the risorius, but superficial to the other muscles. At the anterior edge of the masseter it meets the external maxillary artery, lying immediately posterior to it. In the neck it lies beneath the platysma and cervical fascia, and is usually separated from the external maxillary artery by the submaxillary gland and the stylohyoid and posterior belly of the digastric muscles, below which it is joined by the posterior facial, to form the **common facial vein.**

Tributaries.—It receives, from above downward:—(a) the frontal vein; (b) the supraorbital vein; (c) the superior palpebral veins; (d) the external nasal veins; (e) the inferior palpebral veins; (f) the superior labial vein; (g) the inferior labial vein; (h) the masseteric veins; (i) the anterior parotid veins; (j) the palatine vein and (k) the submental vein.

(a) The **frontal** vein [v. frontalis] (figs. 588, 589) begins about the level of the coronal suture in a venous plexus which communicates with the anterior division of the temporal vein. Soon forming a single trunk, it passes vertically downward over the frontal bone, a short distance from the middle line and parallel with its fellow of the opposite side, to the medial end of the eyebrow where it terminates in the angular vein.

(b) The **supraorbital** vein [v. supraorbitalis] begins over the frontal eminence by intercommunication with the middle temporal vein. It receives tributaries from the forehead and eyebrow, and, running obliquely, medially and downward, opens into the termination of the frontal vein to form the angular. It communicates with the ophthalmic vein, and receives the frontal vein of the diploë as the latter vein issues from the bone at the bottom of the supraorbital notch.

(c) The **superior palpebral** veins [vv. palpebrales superiores] (vv. palp. frontales NK) arise in the upper eyelid and open into the lateral side of the angular vein. They communicate with the middle temporal vein.

(d) The **external nasal** veins [vv. nasales externæ] form three or four stems on either side. The upper veins run upward into the angular and the lower, from the ala, pass more horizontally into the anterior facial vein.

(e) The **inferior palpebral** veins [vv. palpebrales inferiores] (vv. palp. malares NK) arise in the lower eyelid, and, passing medially and downward over the cheek from which they receive tributaries, open into the lateral side of the anterior facial vein. They communicate with the infraorbital vein.

(f) The **superior labial** vein [v. labialis superior] (v. lab. maxillaris NK) and (g) the **inferior labial** vein [v. labialis inferior] (v. lab. mandibularis NK) arise from venous plexuses in the upper and lower lips. They run laterally to open into the medial side of the facial vein.

(h) The **masseteric** veins [vv. massetericæ] and (i) the **anterior parotid** veins [vv. parotidæ anteriores], of small size, drain the cheek over the masseteric and parotid regions.

(j) The **palatine** vein [v. palatina] accompanies the ascending palatine or tonsillar artery from the venous plexus about the tonsil and soft palate, and joins the anterior facial vein just below the body of the mandible.

(k) The **submental** vein [v. submentalis] lies on the mylohyoid muscle superficial to the submental artery. Running back in the submental triangle, it joins the anterior facial vein just after the latter has passed over the body of the mandible. It communicates with the anterior jugular vein.

Communications.—The tributaries of the anterior facial vein communicate freely with the anterior and middle temporal, ophthalmic, infraorbital and anterior jugular veins. The main trunk has a large **communicating branch with the pterygoid plexus.** This vein, sometimes known as the deep facial, opens into the anterior facial below the zygomatic bone under cover of the zygomaticus muscle.

B. The Posterior Facial Vein

The **posterior facial** vein [v. facialis posterior] (v. retromandibularis NK) (figs. 588, 589) is formed in the region of the root of the zygoma by the union of the superficial and middle temporal veins. It passes downward behind the ramus of the mandible through the substance of the parotid gland—here lying lateral to the superficial temporal and external carotid arteries. At the angle of the mandible it runs medially and somewhat forward, and, passing either deep or superficial to the stylohyoid and digastric muscles, joins the anterior facial to form the common facial vein.

The **tributaries** received by the posterior facial vein are:—(a) the superficial temporal vein; (b) the middle temporal vein; (c) the transverse facial vein; (d) the articular veins; (e) the posterior parotid veins; (f) the anterior auricular veins; (g) the stylomastoid vein; and (h) the internal maxillary vein or veins, through which occurs the principal drainage of the pterygoid plexus.

(a) The **superficial temporal** vein [v. temporalis superficialis] returns blood from the parietal region of the scalp. It is formed by the union of an anterior and a posterior branch: the former communicates with the supraorbital and frontal veins; the latter with the posterior auricular and occipital veins and the temporal vein of the opposite side. These branches lie superficial to the corresponding branches of the superficial temporal artery, which they roughly

though not accurately follow. Like the artery, they lie between the skin and the galea aponeurotica, and descend over the temporal fascia to unite a little above the zygoma, and just in front of the auricle, to form the superficial temporal trunk. The vein thus formed continues its course downward with the trunk of the temporal artery, and opposite the zygoma is joined by the middle temporal vein to form the common temporal vein.

(b) The **middle temporal** vein [v. temporalis media] communicates in front with the ophthalmic vein, the external palpebral veins, and the infraorbital veins, and then runs backward between the layers of the temporal fascia to join the superficial temporal vein. The middle temporal vein communicates with the deep temporal veins, and through them with the pterygoid venous plexus.

(c) The **transverse facial** vein [v. transversa faciei] corresponds to the transverse facial artery. (d) **Articular** veins [vv. articulares mandibulæ] form the plexus around the temporomandibular joint; this plexus receives the **tympanic** veins [vv. tympanicæ], which, together

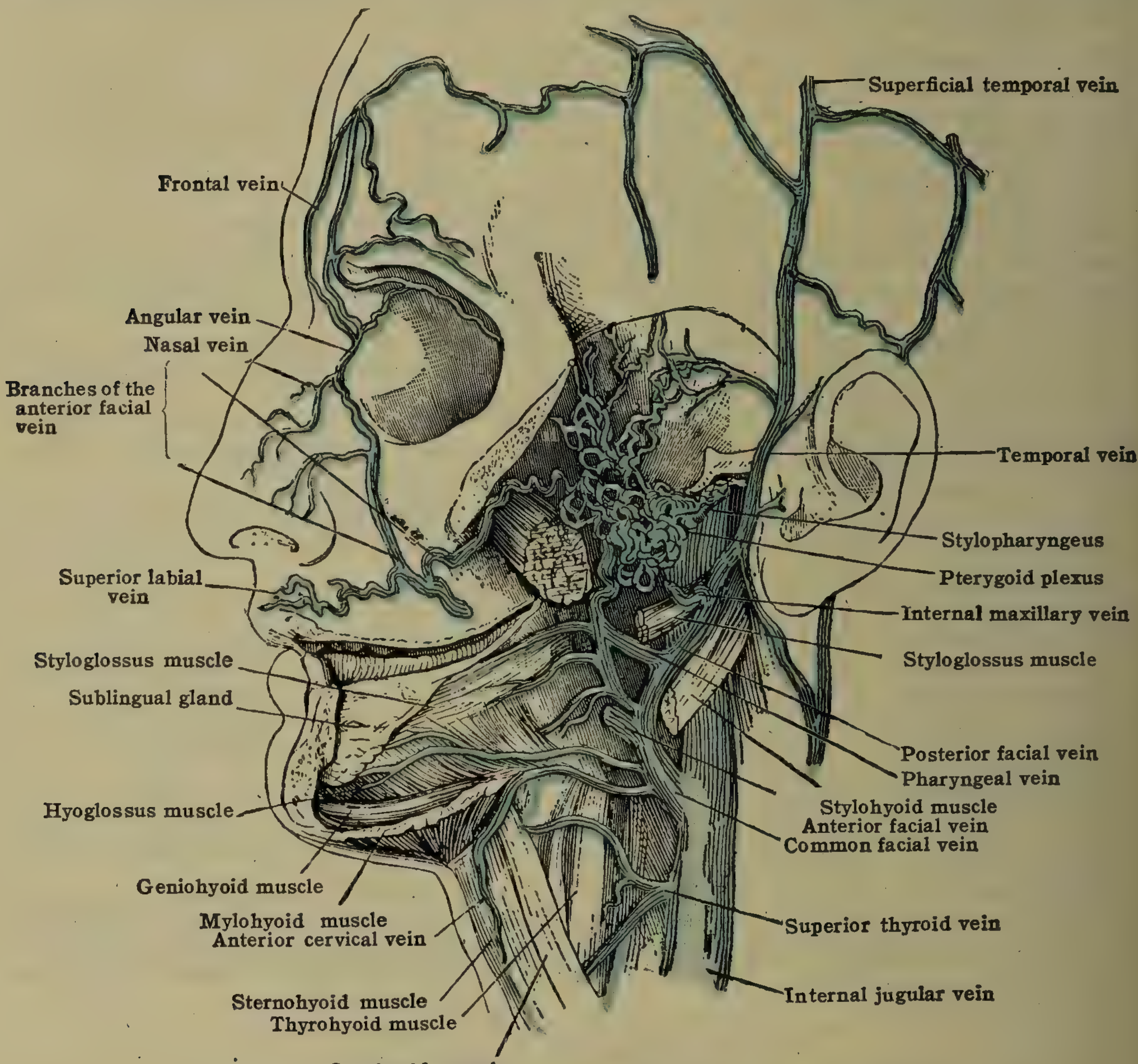


Fig. 589.—The Internal Jugular Vein. (After Henle.)

with the corresponding artery, passes through the petrotympanic fissure. (e) **Posterior parotid** veins [vv. parotideæ posteriores] emerge from the substance of the parotid gland. (f) **Anterior auricular** veins [vv. auriculares anteriores] (vv. praeauriculares NK), from the auricle. (g) **Stylomastoid** vein [v. stylomastoidea] from the facial canal. (h) The **internal maxillary** veins begin at the posterior confluence of the veins forming the pterygoid plexus, and pass backward between the stylomandibular ligament and the neck of the mandible to join the posterior facial vein.

Deeper tributaries of the common facial vein.—The **pterygoid plexus** [plexus pterygoideus] is formed by the veins which correspond to the branches of the internal maxillary artery. It is situated, partly on the medial surface of the internal pterygoid muscle, and partly around the external pterygoid muscle. The veins entering into this plexus are:—the two **middle meningeal** veins [vv. meningeæ mediæ] (vv. men. temporales NK), which accompany the artery of that name; the **posterior superior alveolar** (dental); the **inferior alveolar** (dental); the **masseteric**; the **buccal**; the **pterygoid** veins from the pterygoid muscles; the **deep temporal** veins [vv. temporales profundæ], by which the plexus communicates with the temporal plexus; the **sphenopalatine** vein; the **infraorbital**; the **superior palatine**; a branch of communication with the lower branch of the **ophthalmic** vein, which courses through the inferior orbital (sphenomaxillary) fissure; and the **rete foraminis ovalis** and **Vesalian** vein, through which the plexus communicates with the cavernous sinus. The plexus ends posteriorly in a vein, or veins accompanying the internal maxillary artery, and joining the posterior facial vein. It is drained

by a communicating vessel (the deep facial vein), which passes forward and downward between the buccinator and masseter muscles to join the anterior facial vein.

The veins forming by their confluence the pterygoid plexus correspond in their course so nearly with that of their companion arteries that a detailed description is not necessary. Although for convenience described with the superficial veins, they are all deeply placed.

Near the angle of the mandible there is almost always a communicating branch between the posterior facial and the external jugular veins. When large, this branch may drain the greater part of the blood from the posterior facial.

C. The Common Facial Vein

The **common facial** vein [v. facialis communis] (fig. 588) is a short thick stem contained within the carotid triangle. It is formed, just below the angle of the mandible, by the union of the anterior and posterior facial veins. It ends opposite the hyoid bone, by opening into the internal jugular vein. In addition to the vessels which form it, sometimes it receives the superior thyroid, the pharyngeal, and the lingual or the sublingual veins. According to the NK terms, the common facial is considered as a part of the facial vein.

D. The External Jugular Vein

The **external jugular** vein [v. jugularis externa] (v. jug. superficialis dorsalis NK) (fig. 588) is formed by the confluence of the posterior auricular and a short communicating trunk from the posterior facial vein. It runs obliquely downward and backward across the sternomastoid muscle to a point opposite the middle of the clavicle, where it terminates as a rule in the subclavian vein. A line drawn from a point midway between the mastoid process and angle of the mandible to the middle of the clavicle will indicate its course. It is covered by the skin, superficial fascia, and platysma, and is crossed by a few branches of the cervical plexus, the great auricular nerve running parallel with it at the upper part of the neck. It is separated from the sternomastoid by the anterior layer of the deep cervical fascia.

Just above the clavicle it perforates the cervical fascia, by which it is prevented from collapsing, the fascia being attached to its walls. It then opens into the subclavian vein, occasionally into the internal jugular, or into the confluence of the subclavian and internal jugular veins. It contains a pair of valves about 2.5 to 5 cm. (1 to 2 in.) above the clavicle, and a second pair where it enters the subclavian vein. Neither of these valves is sufficient to prevent the blood from regurgitating, or injections from passing from the larger vein into the external jugular.

Tributaries and communications.—These include:—(a) The posterior auricular vein; (b) the occipital vein; (c) a branch of communication with the posterior facial vein; (d) the posterior external jugular vein; (e) the transverse scapular vein; and (f) the anterior jugular vein. The transverse cervical vein (p. 742) is also included in many cases.

(*a*) The **posterior auricular** vein [v. auricularis posterior] (v. retroauricularis NK) begins in a venous plexus on the posterior part of the parietal bone. This plexus communicates with the vein of the opposite side across the sagittal suture, and with the posterior branch of the superficial temporal vein in front, and with the occipital vein behind. It descends over the back part of the parietal bone and the mastoid process of the temporal bone, lying with its artery behind the ear, and joins a branch from the posterior facial vein to form the external jugular.

(*b*) The **occipital** vein [v. occipitalis] begins at the back of the skull in a venous plexus which anastomoses with the posterior auricular and the posterior branch of the superficial temporal veins. It passes downward over the occipital bone, and usually perforates the trapezius with the occipital artery, to join a plexus drained by the deep cervical and vertebral veins. It also communicates with the posterior auricular, and in many cases this forms the chief path of drainage. One of its branches, usually the most lateral, receives a **mastoid emissary** vein [emissarium mastoideum] which issues through the mastoid foramen of the temporal bone, and in this way forms a communication with the transverse sinus.

(*c*) The branch of **communication with the posterior facial** vein occurs a short distance below the point at which the posterior facial receives the internal maxillary vein. It is very constant and is placed immediately behind the angle of the mandible. Through it the external jugular usually receives a considerable proportion of the blood returning from the temporal and pterygoid regions.

(*d*) The **posterior external jugular** vein (fig. 588) descends from the upper and back part of the neck, receiving small tributaries from the superficial structures and muscles. At times it communicates with the occipital, or may appear as a continuation of that vein. It opens into the external jugular as the latter vein is leaving the sternomastoid muscle.

(*e*) The **transverse scapular** vein [v. transversa scapulæ] corresponds to the transverse scapular (suprascapular) artery. If double, these venæ comitantes usually form one trunk before they open into the external jugular vein. They contain well-marked valves.

(*f*) The **anterior jugular vein** [v. jugularis anterior] (v. jug. superficialis ventralis NK) begins below the chin by communicating with the mental, submental, inferior labial, and inferior hyoid veins. It descends near the mid-line, receiving branches from the superficial structures at the front and side of the neck, and occasionally a branch from the larynx and thyroid gland. Just above the clavicle it turns laterally, and, piercing the fascia, passes beneath the sternomastoid muscle and opens into the external jugular vein just before the latter joins the subclavian; at times it opens into the subclavian vein itself. In its course down the neck it communicates with the external jugular; and, as it turns laterally beneath the sternomastoid, sends a branch across the trachea, between the layers of cervical fascia, to join the anterior jugular of the opposite side. This communicating vein, the **jugular venous arch** [arcus venosus juguli], may open directly into the external jugular or into the internal jugular vein; occasionally one or both ends may open into the subclavian or innominate vein. It may be divided in the operation of tracheotomy, and is then often found greatly engorged with blood. Another branch, often of considerable size, courses along the anterior margin of the sternomastoid and joins the anterior facial vein. When the anterior jugular vein is large, the external jugular is small, and *vice versa*. It is usually also of large size when the corresponding vein on the opposite side is absent, as is frequently the case. It contains no valves.

THE DEEP VEINS OF THE HEAD AND NECK

The **deep veins of the head and neck** may be divided into:—(1) the veins of the diploë; (2) the venous sinuses of the dura mater encephali; (3) the veins of

Fig. 590.—The Veins of the Diploë.
(From a specimen in St. Bartholomew's Hospital Museum.)

the brain; (4) the veins of the nasal cavities; (5) the veins of the ear; (6) the veins of the orbit; (7) the veins of the pharynx and larynx; and (8) the deep veins of the neck. The veins of the diploë terminate partly in the superficial veins already described, partly in the venous sinuses of the cranium, and partly in the deep veins of the neck. The venous sinuses open into the deep veins of the neck. The veins of the brain terminate in the venous sinuses. The veins of the nasal cavities terminate partly in the deep, and to some extent in the superficial veins. The veins of the ear join both the superficial and deep veins and the venous sinuses. The veins of the orbit terminate partly in the superficial veins, but chiefly in the venous sinuses. The veins of the pharynx and larynx enter the deep veins of the neck.

1. THE VEINS OF THE DIPLOË

The **veins of the diploë** [venæ diploicæ] (fig. 590) are contained in bony channels in the cancellous tissue between the laminæ of the cranial bones. They are of comparatively large size, with very thin walls, and form numerous irregular communicating channels. They have no valves. They terminate in four or five main descending channels, which open, some outward through the external cranial lamina into some of the superficial and deep veins of the head and face, and some inward through the internal lamina into the venous sinuses. They are divided into the frontal, anterior temporal, posterior temporal, and occipital.

The **frontal diploic veins** are contained in the anterior part of the frontal bone. They converge anteriorly to a single vein [v. diploica frontalis] which passes downward, perforates the external lamina through a small aperture in the roof of the supraorbital notch, and terminates in the supraorbital vein. They also communicate with the superior sagittal sinus.

The **anterior temporal diploic veins** [vv. diploicæ temporalis ant.] are contained in the posterior part of the frontal and in the anterior part of the parietal bone. They pass downward, and end, partly in the temporal veins by perforating the greater wing of the sphenoid bone, and partly in the sphenoparietal sinus.

The **posterior temporal diploic vein** [v. diploica temporalis post.] ramifies in the parietal bone, and coursing downward to the posterior inferior angle of that bone, passes either through a foramen in its inner table, or through the mastoid foramen into the transverse sinus.

The **occipital diploic vein** [v. diploica occipitalis] ramifies chiefly in the occipital bone, and opens into the occipital vein or into the transverse sinus.

The diploic veins freely anastomose with one another in the adult; but in the fetus, before the bones have united, each system of veins is distinct.

2. THE VENOUS SINUSES OF THE DURA MATER

The **venous sinuses of the dura mater** [sinus duræ matris] are endothelial-lined blood-spaces, situated between the periosteal and meningeal layers of the

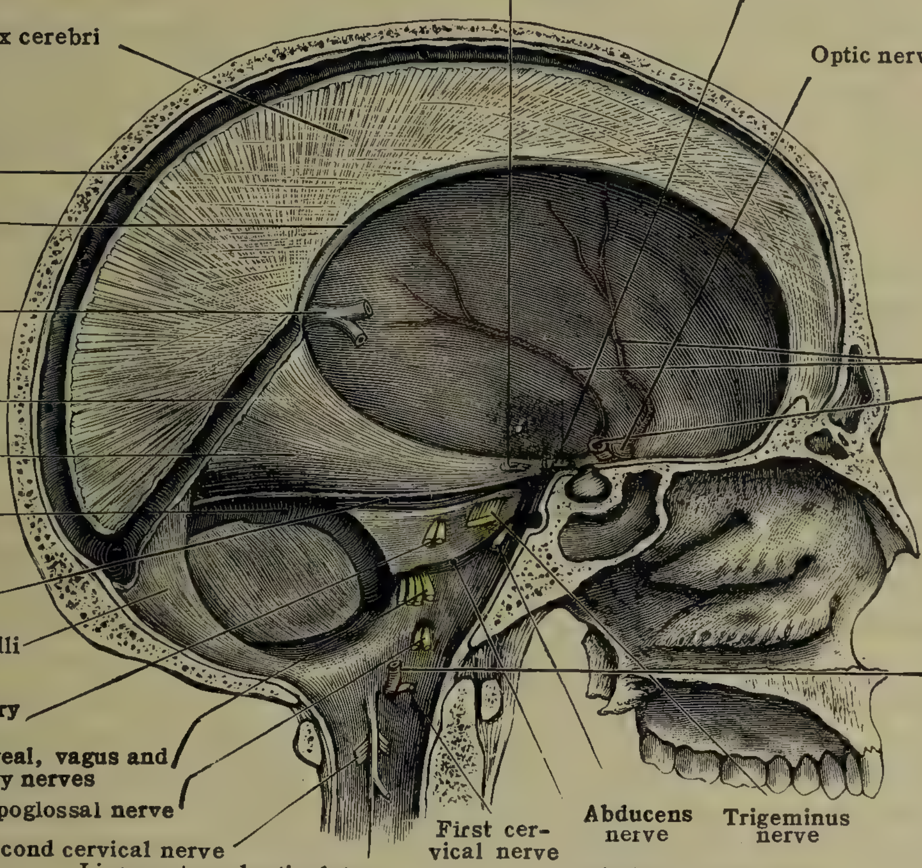


FIG. 591.—THE VENOUS SINUSES. (Midsagittal section of the head.)

dura mater. They are the channels by which the blood is conveyed from the cerebral veins, and from some of the veins of the meninges and diploë, into the veins of the neck. The sinuses at the base of the skull also carry most of the blood from the orbit. In certain places the sinuses communicate with the superficial veins by small vessels known as the emissary veins, which run through foramina in the cranial bones.

The venous sinuses are sixteen in number, six being median and unpaired, the remaining ten consisting of five lateral pairs. The median sinuses are:—(1) the superior sagittal; (2) the inferior sagittal; (3) the straight; (4) the occipital; (5) the circular; and (6) the basilar plexus. The lateral and paired sinuses are:—(7) the two transverse; (8) the two superior petrosal; (9) the two inferior petrosal; (10) the two cavernous; and (11) the two sphenoparietal. Occasionally there are two additional sinuses, the two petrosquamous.

(1) The **superior sagittal** (or longitudinal) **sinus** [sinus sagittalis superior] (or s. falcis major NK) (fig. 591) lies in the median groove on the inner surface of the cranium along the attached margin of the falx cerebri. It extends from the foramen cecum to the internal occipital protuberance. It grooves from

before backward the frontal bone, the contiguous sagittal margins of the parietal bones, and the squamous portion of the occipital bone. In the fetus, and occasionally in the adult, it communicates (through the foramen cecum) with the nasal veins. It communicates throughout life with each superficial temporal vein by means of a **parietal emissary** vein [emissarium parietale] which passes through the parietal foramen. It is triangular on section, and crossing it are a number of fibrous bands known as the *chords of Willis.* Communicating with it on either side are irregular diverticula from the main channel known as the *lacunæ laterales* into which the arachnoidal (Pacchionian) granulations project (fig. 594). In front the sinus is quite small, but it increases greatly in caliber as it runs backward. It receives at intervals the superior cortical cerebral veins and the veins from the falx. The former, for the most part, open into it in the direction opposite to that in which the blood is flowing in the sinus. They pass for some distance in the walls of the sinus before opening into it. Posteriorly, at the internal occipital protuberance, the superior sagittal sinus turns sharply, and ends usually in the right transverse (lateral) sinus; the straight sinus terminating in the left transverse sinus.

Occasionally, however, the superior sagittal sinus ends in the left transverse sinus, the straight sinus then passing into the right. At the angle of union between the superior sagittal sinus and the transverse sinus into which it empties there is a dilation, the **confluens sinuum** or torcular Herophili. At this point there is a communication between the right and left transverse sinuses. In some cases the communication is so free that the blood from the sagittal sinus flows almost equally into each transverse sinus. The confluens may communicate with the occipital vein through the **occipital emissary** vein [emissarium occipitale], which, when present passes through a minute foramen in the occipital protuberance.

(2) The **inferior sagittal** (or longitudinal) **sinus** [sinus sagittalis inferior] (s. falcis minor NK) (fig. 591) is situated at the free margin of the falx cerebri. Beginning about the junction of the anterior with the middle third of the falx, it is continued backward along the concave or lower margin of that process to the junction of the falx with the tentorium, where it ends in the straight sinus. The sinus is cylindrical in section and of small size, and receives some of the inferior frontal veins of the brain, some of the veins from the medial surface of the brain, and some of the veins of the falx.

(3) The **straight sinus** [sinus rectus] (fig. 591) lies along the junction of the falx cerebri with the tentorium cerebelli. It is formed by the union of the great cerebral vein (of Galen) and the inferior sagittal sinus. It receives in its course branches from the tentorium cerebelli and from the upper surface of the cerebellum. It runs downward and backward to the internal occipital protuberance, where it ends in the transverse sinus opposite to that joined by the superior sagittal sinus. On section it is triangular in shape, with its apex upward.

(4) The **occipital sinus** [sinus occipitalis] (fig. 592) ascends at the attached margin of the falx cerebelli, along the lower half of the squamous portion of the occipital bone from near the posterior margin of the foramen magnum to end in the confluens sinuum near the internal occipital protuberance. It usually begins in a right and a left branch, known as the **marginal sinuses.**

These proceed from the termination of each transverse sinus, run around the foramen magnum where they communicate with the venous vertebral retia, and unite at a variable distance from the internal occipital protuberance to form the single occipital sinus. Sometimes they remain separate as far as the internal occipital protuberance, then forming two occipital sinuses. It receives veins from the falx cerebelli, and from the inferior surface of the cerebellum. It communicates through the plexus of veins which surrounds the hypoglossal nerve [**rete canalis hypoglossi**] in the hypoglossal (anterior condyloid) canal with the vertebral vein and the longitudinal vertebral venous sinuses.

(5) The **circular sinus** [sinus circularis] (fig. 593) encircles the hypophysis cerebri. It consists of the two cavernous sinuses and their communications across the median line by means of the **anterior and posterior intercavernous sinuses.** The intercavernous sinuses are small and cross the median line in front of and behind the hypophysis, respectively.

(6) The **basilar plexus** [plexus basilaris] is a venous plexus in the substance of the dura mater over the basilar part of the occipital bone and the posterior part of the body of the sphenoid. It extends from the cavernous sinus to the margin of the foramen magnum below. It communicates laterally with the inferior petrosal sinus, and inferiorly with the marginal sinuses internal verte-

bral venous plexuses. One of the larger of the irregular venous channels forming the plexus passes transversely from one inferior petrosal sinus to the other. This venous plexus is serially homologous with the longitudinal vertebral venous sinuses on the posterior surfaces of the bodies of the vertebræ.

(7) The **transverse** (or lateral) **sinus** [sinus transversus] (figs. 591-592) extends from the internal occipital protuberance to the jugular fossa. In this course it lies in the corresponding groove along the squamous portion of the occipital bone, the mastoid angle of the parietal bone, the mastoid portion of the temporal bone, and the jugular process of the occipital bone. It at first runs laterally and forward horizontally between the two layers of the tentorium cerebelli, following the curve of the groove on the occipital and on the mastoid angle of the parietal bone. On reaching the groove in the mastoid portion of the temporal bone it leaves the tentorium and curves medially and downward and then forward over the jugular process of the occipital bone. It then passes through the posterior compartment of the jugular foramen and ends at the jugular fossa in the superior bulb of the internal jugular vein. The S-shaped part of the

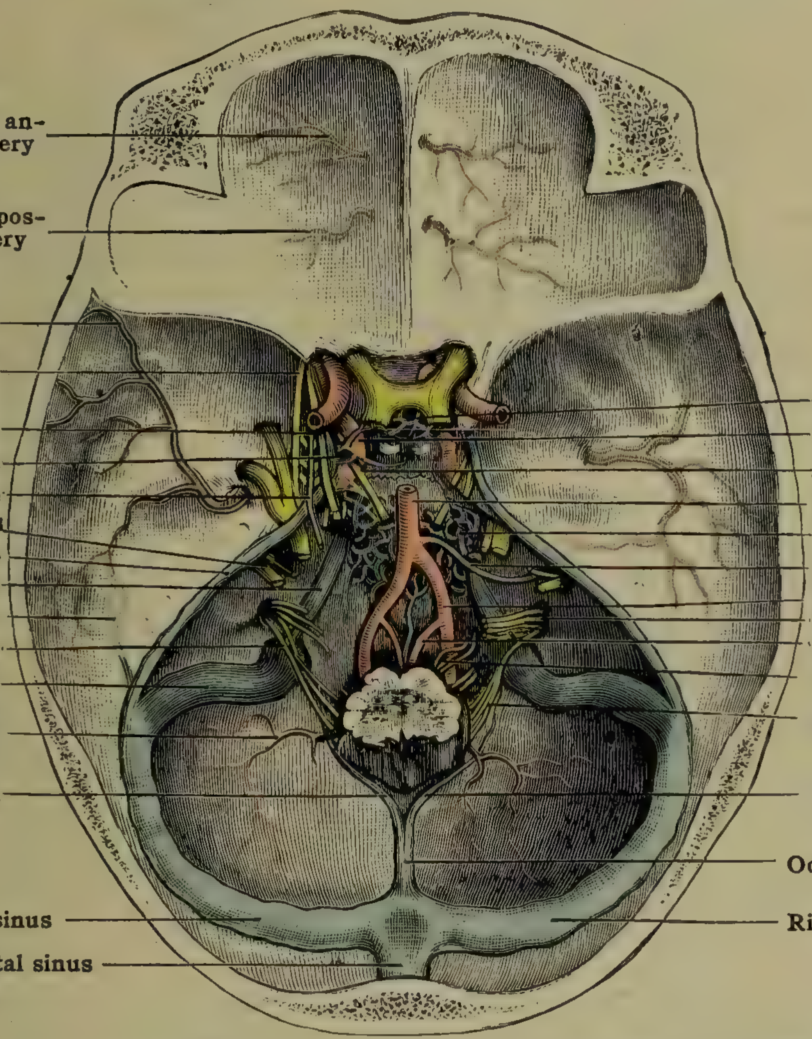


FIG. 592.—THE VENOUS SINUSES IN THE CRANIAL FLOOR.
(From a dissection by W. J. Walsham in St. Bartholomew's Hospital Museum.)

sinus which lies on the mastoid portion of the temporal and jugular portion of the occipital bone is sometimes known as the **sigmoid sinus.**

The transverse sinus receives from the labyrinth, the **internal auditory** veins [vv. auditivæ internæ] which emerge from the internal auditory meatus. It also receives veins from the temporal lobe of the cerebrum, some of the superior and inferior cerebellar veins, some of the veins of the medulla and pons, the occipital, and the posterior temporal and occipital veins of the diploë. At the point where it leaves the tentorium it drains the superior petrosal sinus and, when present, the petrosquamous sinus. It communicates with the occipital and vertebral veins through the mastoid and posterior condyloid foramina by means of the **mastoid** and **condyloid emissary** veins. As the transverse sinus lies between the layers of the tentorium it is triangular in cross-section, while the sigmoid portion is semicircular.

The **right** transverse sinus is usually the larger and forms the direct continuation of the superior sagittal sinus. It hence conveys the chief part of the blood from the cortical surface of the brain and vault of the skull. The **left** transverse sinus is usually the smaller and the direct continuation of the straight sinus, and hence returns the chief part of the blood from the central ganglia of the brain. The right and left sinuses communicate at the confluens sinuum.

The relation of the lateral sinus to the outside of the skull, especially to the mastoid process of the temporal bone, is of importance with reference to operations in this region. The course of the sinus corresponds to a line drawn from the external occipital protuberance to the base of the mastoid process, or to the asterion, and thence over the back of the mastoid process in a curved line toward its apex.

(8) The **superior petrosal sinus** [sinus petrosus superior] (figs. 591, 592) runs at the attached margin of the tentorium cerebelli, along the upper border of the petrous portion of the temporal bone. It connects the cavernous with the transverse sinus. Leaving the lateral and back part of the cavernous sinus just below the trochlear nerve, it crosses the trigeminus nerve, and, after grooving the

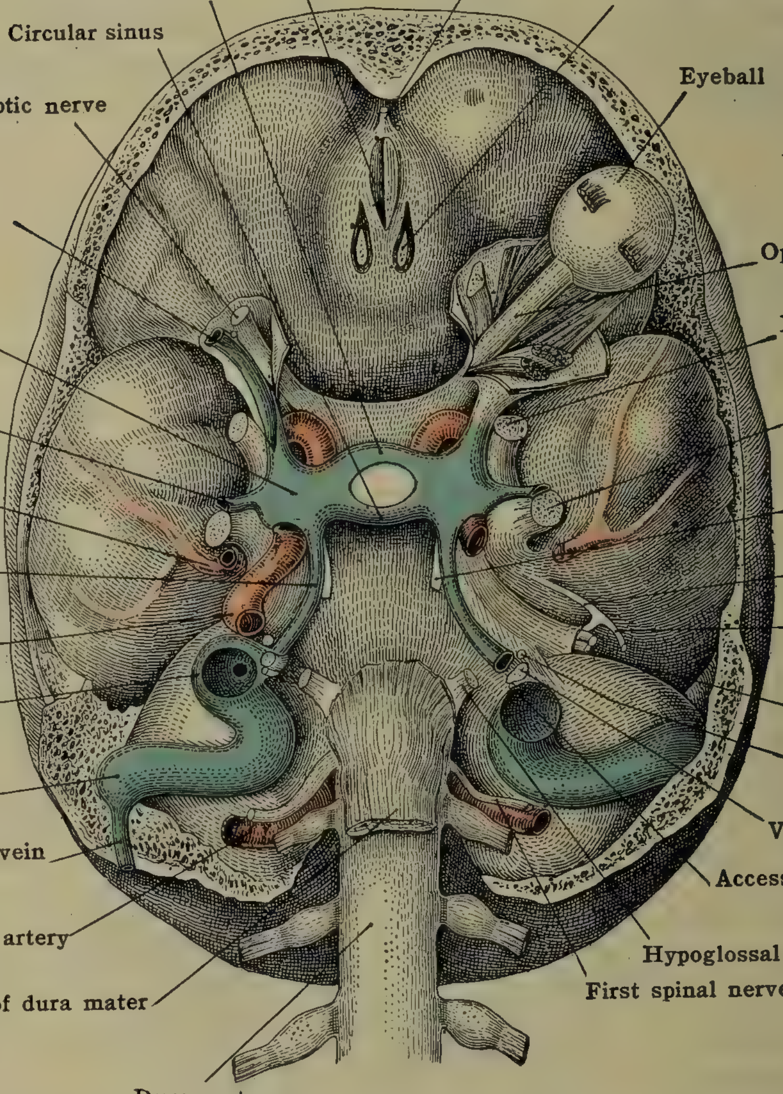


FIG. 593.—THE VENOUS SINUSES AT THE BASE OF THE BRAIN. Exposed by removal of the base of the skull; the dura mater has not been removed. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

petrous bone, ends in the transverse sinus as the latter turns downward on the mastoid portion of the temporal bone. It receives veins from the temporal lobe of the cerebrum, veins from the cerebellum, veins from the tympanum through the squamopetrosal fissure, and sometimes the anterior temporal veins of the diploë.

(9) The **inferior petrosal sinus** [sinus petrosus inferior] (s. petrobasilaris NK) (figs. 591, 592) runs posteriorly from the cavernous sinus along the line of the petro-occipital suture, and passes through the anterior compartment of the jugular foramen to terminate in the commencement of the internal jugular vein. It is shorter than the superior petrosal, but considerably wider.

As it passes to the anterior compartment of the jugular foramen, it separates the glossopharyngeal from the vagus and accessory nerves. It receives veins from the inferior surface of the cerebellum, from the medulla and pons, and from the internal ear. The **vein of the cochlear canaliculus** [v. canaliculi cochleæ], issues through the canaliculus cochleæ and terminates in the lower part of the inferior petrosal sinus or the adjacent part of the internal jugular vein.

(10) The **cavernous sinus** [sinus cavernosus] (fig. 592) is an irregularly shaped venous space situated between the meningeal and periosteal layers of the dura mater on the side of the body of the sphenoid bone. It extends from the medial end of the superior orbital (sphenoidal) fissure in front to the apex of the petrous bone behind. Its lateral wall contains the oculomotor and trochlear nerves, and the ophthalmic division of the trigeminus. The nerves take the above-mentioned order from above downward, and in the mediolateral direction. The internal carotid artery and the abducens nerve are contained in the thinner medial wall of the sinus. The right and left cavernous sinuses communicate across the middle line with the opposite sinus in front and behind the hypophysis cerebri as before mentioned.

The cavernous sinus is traversed by numerous trabeculæ or fibrous bands, so that there is no central cavity, but rather a number of endothelial-lined irregular lacunæ communicating with one another. **In front** it receives the ophthalmic vein, with which it is practically continuous, and just above the third nerve, the sphenoparietal sinus. **Medially** it communicates with the opposite sinus, and **posteriorly** it ends in the superior and inferior petrosal sinuses. It also receives veins from the inferior surface of the frontal lobe of the brain, and some of the middle cerebral veins. Through the Vesalian vein, which occasionally perforates the greater wing of the sphenoid bone the sinus may communicate with the pterygoid plexus of veins. Through the **venous plexus around the petrosal portion of the internal carotid** [plexus venosus caroticus internus], it communicates with the internal jugular vein; and through a venous rete which leaves the cranium by the foramen ovale [rete foraminis ovalis] and by small veins passing through the foramen lacerum medium, it communicates with the pterygoid and pharyngeal plexuses.

(11) The **sphenoparietal sinus** [sinus sphenoparietalis] originates in one of the meningeal veins near the apex of the lesser wing of the sphenoid and, running medially, in a slight groove on the inferior surface of the lesser wing passes through the sphenoidal fold of dura mater above the oculomotor nerve into the front part of the cavernous sinus. It generally receives the anterior temporal veins from the diploë.

The **petrosquamous sinus** is occasionally present. It lies in a groove which separates the anterior surface of the petrous from the cerebral surface of the squamous portion of the temporal bone. It opens posteriorly into the transverse sinus where the latter enters on its sigmoid course. In front it sometimes communicates, through a foramen between the mandibular fossa and the external acoustic meatus, with the deep temporal vein.

The emissary veins.—These are communications between the sinuses within, and the veins outside, the cranium. Most of them are temporary, corresponding to the chief period of growth of the brain. Thus in early life, when the development of the brain has to be very rapid, owing to the approaching closure of its case, a free escape of blood is most essential, especially in children, with their sudden explosions of laughter and passionate crying.

The gravity of these emissary veins and their free communications with others are shown by the readiness with which they become the seat of thrombosis, and thus of blood-poisoning, in cranial injuries, erysipelas, infected wounds of the scalp, and necrosis of the skull. They include the following:

1. Vein through the foramen cecum, between the anterior extremity of the superior sagittal sinus and the nasal mucous membrane. The value of this temporary outlet is well seen in the timely profuse epistaxis of children. Other more permanent communications between the skull cavity and nasal mucous membrane pass through the ethmoid foramina. The fact that the nasal mucous membrane is loose and ill-supported on the nasal conchæ (turbinate bones) allows its vessels to give way readily, and thus forms a salutary safeguard to the brain, possibly warding off attacks of apoplexy. 2. Vein through the mastoid foramen, between the transverse (lateral) sinus and the posterior auricular and occipital veins. This is the largest, the most constant, and the most superficial of the emissary veins. 3. Vein through the posterior superior angle of the parietal between the superior sagittal sinus and the veins of the scalp. 4. Vein through the condyloid foramen between the transverse (lateral) sinus and the deep veins of the neck. 5. Vein through the hypoglossal canal between the occipital sinus and the deep veins of the neck 6. Ophthalmic veins communicating with the cavernous sinus and the angular vein. These veins may be the source of fatal blood-poisoning, by transmitting septic material in acute periostitis of the orbit, or in osteitis of the jaws. 7. Minute veins through the foramen ovale between the cavernous sinus and the pharyngeal and pterygoid veins. 8. Communications between the frontal diploic and the supraorbital veins, between the anterior temporal diploic and the deep temporal veins, and between the posterior temporal and the occipital diploic veins and the transverse sinus. In addition to the veins specially mentioned, the scalp and sinuses communicate by numerous diploic veins and by those in the sutural membranes.

3. THE VEINS OF THE BRAIN

The **veins of the brain** present the following peculiarities:—(*a*) They do not accompany the cerebral arteries. (*b*) Ascending veins do not, as in other situations, run with descending arteries, but with ascending arteries, and *vice versa.*

(*c*) The deep veins do not freely communicate. (*d*) The veins have very thin walls, no muscular coat, and no valves. (*e*) The veins opening into the sagittal, and some of those opening into the transverse (lateral) sinus pour in their blood in a direction opposite to that of the current in the sinus concerned. (*f*) The flow of blood in the sinuses is further retarded by the trabeculæ stretching across their lumen.

Fig. 594.—The Veins of the Brain, Superior Surface. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

The veins of the brain may be divided into the **cerebral** and the **cerebellar.**

The Cerebral Veins

The **cerebral** veins (vv. encephali NK), like the cerebral arteries, may be divided into the **cortical** and the **central.**

The **cortical** or **superficial** veins ramify on the surface of the brain and return the blood from the cortical substance into the venous sinuses. They lie for the most part in the sulci between the gyri, but some pass over the gyri from one sulcus to another. They consist of two sets: a superior and an inferior.

(1) The **superior cerebral** veins [venæ cerebri superiores] (vv. cerebrales superficiales NK) (fig. 594), some eight to twelve in number on each side, are formed by the union of veins from the convex and medial surfaces of the cerebrum. Those from the convex surface pass medially

and forward toward the longitudinal fissure, where they are joined by the veins coming from the medial surface. After receiving a sheath from the arachnoid, they enter obliquely into the superior sagittal sinus, running for some distance in its walls. These veins freely communicate with each other, thus differing from the cortical arteries. They also communicate, with the inferior cortical veins. They may be roughly divided into (*a*) frontal; (*b*) paracentral; (*c*) central; (*d*) occipital.

(2) The **inferior cerebral** veins [venæ cerebri inferiores] (vv. cerebrales basales NK) (fig. 595), ramify on the base of the hemisphere and the lower part of its lateral surface. Those on the inferior surface of the frontal lobe pass, in part into the inferior sagittal sinus, and in part into the cavernous sinus. Those on the temporal lobe enter in part into the superior petrosal

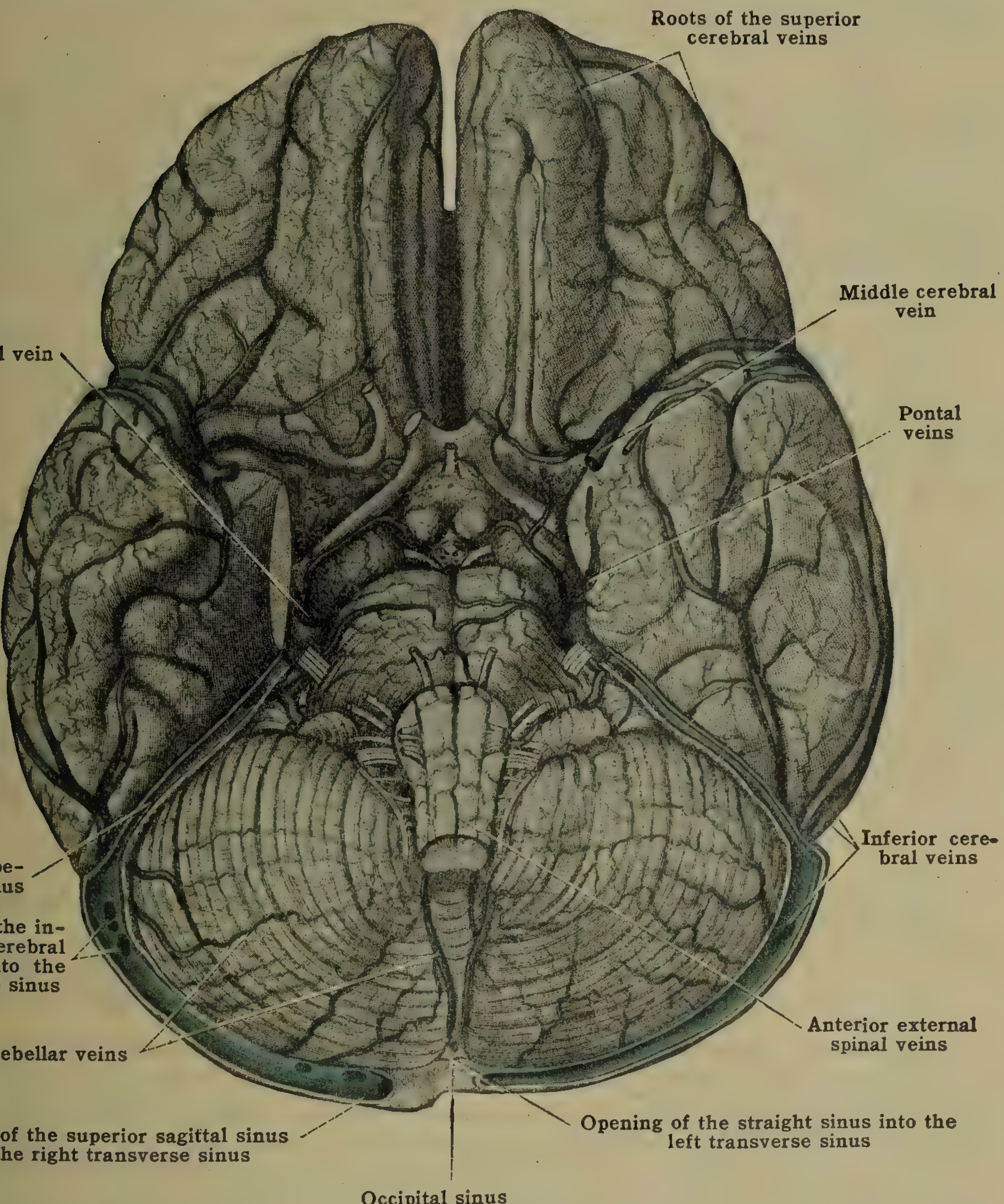


Fig. 595.—The Veins of the Brain, Inferior Surface. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

sinus, and in part into the transverse sinus, passing into the latter from before backward. A large vein from the occipital lobe winds over the cerebral peduncle and joins the great cerebral vein (of Galen) just before the latter enters the straight sinus. One of the inferior cortical veins is called the **middle cerebral** vein [v. cerebi media], it runs in the lateral fissure (of Sylvius) and ends in the cavernous sinus. This vein is sometimes called the superficial Sylvian vein. Another, the great anastomosing vein of Trolard, establishes a communication between the superior sagittal and cavernous sinuses by connecting the middle cerebral veins with one of the superior cerebral veins. A second anastomotic vein, that of Labbé, is also a tributary of the middle cerebral, and connects the veins over the temporal lobe with the transverse sinus.

A small inferior cerebral vein, the **ophthalmomeningeal vein,** establishes a communication between the cerebral veins and those of the orbit. It communicates with the veins of the base and is usually drained by the superior ophthalmic vein. It occasionally opens into the superior petrosal sinus.

The **central** or **deep** (ganglionic) veins return blood from the internal parts of the cerebrum, and converge to the great cerebral vein.

(3) The **internal cerebral** veins [vv. cerebri internæ] are two large venous trunks (the venæ Galeni) which leave the brain at the transverse fissure, that is, between the splenium of the corpus callosum and the corpora quadrigemina. In this region they unite to form the **great cerebral** vein [v. cerebri magna, Galeni], which opens into the anterior end of the straight sinus. The internal cerebral veins are formed by the union of the choroid vein with the vena terminalis near the interventricular foramen. They run backward parallel to each other, between the layers of the tela chorioidea.

Tributaries of the internal cerebral veins.—In addition to the vena terminalis and the choroidal, the internal cerebral veins also receive the basal vein, the veins of the thalamus, the vein of the choroid plexus of the third ventricle, and veins from the corpus callosum, the pineal body, the corpora quadrigemina, and posterior horn of the lateral ventricle. The united trunk, or great cerebral vein, receives veins from the upper surface of the cerebellum, and one of the posterior inferior cerebral veins.

The **choroid** vein [v. chorioidea] runs with the chorioid plexus. It begins in the inferior cornu of the lateral ventricle, and ascends on the lateral side of the chorioid plexus along the margin of the tela chorioidea to the interventricular foramen, where it unites with the vena terminalis to form the internal cerebral vein. It receives tributaries from the hippocampus, corpus callosum, and fornix.

The **terminal** vein (or vein of the corpus striatum) [v. terminalis], formed by veins from the corpus striatum and thalamus, runs forward in the groove between those structures, passing in its course beneath the stria terminalis, and joins the chorioid (choroid) vein at the interventricular foramen. **Tributaries.**—It receives, in addition to the veins from the corpus striatum, thalamus and fornix, the **vena septi pellucidi** which receives blood from the septum pellucidum, and anterior cornu of the lateral ventricle.

The **basal** vein [v. basalis], runs backward over the cerebral peduncle, and enters the internal cerebral vein near the union of that vessel with the vein of the opposite side.

Tributaries.—A vein, the deep Sylvian, from the insula and the opercular gyri; the inferior striate veins from the corpus striatum, which they leave through the anterior perforated substance; and the anterior cerebral veins from the front of the corpus callosum. It is also joined by interpeduncular veins from the structures in the interpeduncular space; ventricular veins from the inferior cornu of the lateral ventricle; and by mesencephalic veins.

The Cerebellar Veins

The **cerebellar** veins are divided into the **superior** and **inferior.**

The **superior** [vv. cerebelli superiores] (vv. cerebellares dorsales NK) ramify on the upper surface of the cerebellum; some of them run medially over the superior vermis to join the straight sinus and great cerebral vein; others run laterally to the transverse and superior petrosal sinuses.

The **inferior** [vv. cerebelli inferiores] (vv. cerebellares basiales NK) larger than the superior, run, some forward and laterally to the inferior petrosal and transverse sinuses, and others directly backward to the occipital sinus.

The Veins of the Medulla and Pons

The veins from the **medulla oblongata** and the **pons** terminate in the inferior petrosal and transverse sinuses.

4. THE VEINS OF THE NASAL CAVITIES

The venous plexuses on the inferior nasal concha (turbinate bone) and back of the septum are described with the Nose. The veins leaving the nasal cavities follow roughly the course of their corresponding arteries. Thus the sphenopalatine veins pass through the sphenopalatine foramen into the pterygoid plexus; the anterior and posterior ethmoidal veins join the ophthalmic. Small veins accompany branches of the external maxillary artery through the nasal bones and frontal processes of the maxillary bones, and end in the angular and anterior facial veins; and other small veins pass from the nose anteriorly into the superior labial, and thence to the anterior facial.

5. THE VEINS OF THE EAR

The veins from the external ear and external acoustic meatus join the posterior facial and posterior auricular veins. The veins from the tympanum open into the superior petrosal sinus and posterior facial vein. The blood from the labyrinth flows chiefly through the **internal auditory** veins [vv. auditivæ internæ], which accompany the internal auditory artery in the internal acoustic meatus, and enters the transverse or the inferior petrosal sinus.

Some of the blood from the labyrinth, however, passes through the vestibular vein, which lies in the aqueductus vestibuli, into the inferior petrosal sinus. Some also passes through the **vena canaliculi cochleæ** which traverses the canal of the same name and empties into the commencement of the internal jugular vein or the terminal portion of the inferior petrosal sinus.

6. THE VEINS OF THE ORBIT

The blood from the eyeball and orbit is returned by the superior ophthalmic vein into the cavernous sinus. This vein and its tributaries have no valves, and communicate with the frontal, supraorbital, inferior cerebral, and pterygoid veins (fig. 596).

Under certain conditions, as from pressure on the cavernous sinus, the blood may flow in the contrary direction to the normal—i.e., from behind forward into the frontal and supraorbital, and thence through the angular vein into the anterior facial; or upward into the cerebral venous system. In this way pressure on the retinal veins is quickly relieved, and little or no distension occurs in cases of obstruction in the cavernous sinus.

The **superior ophthalmic** vein [v. ophthalmica superior] (v. ophthalmica NK) (fig. 597) begins at the medial angle of the eyelid by a free communication with the frontal, supraorbital, and angular veins, and thence runs backward and laterally with the ophthalmic artery across the optic nerve to the medial end of the superior orbital (sphenoidal) fissure, where it is usually joined by the inferior ophthalmic vein. It then passes backward between the two heads of the lateral rectus muscle below the sixth nerve, leaves the orbit through the medial end of

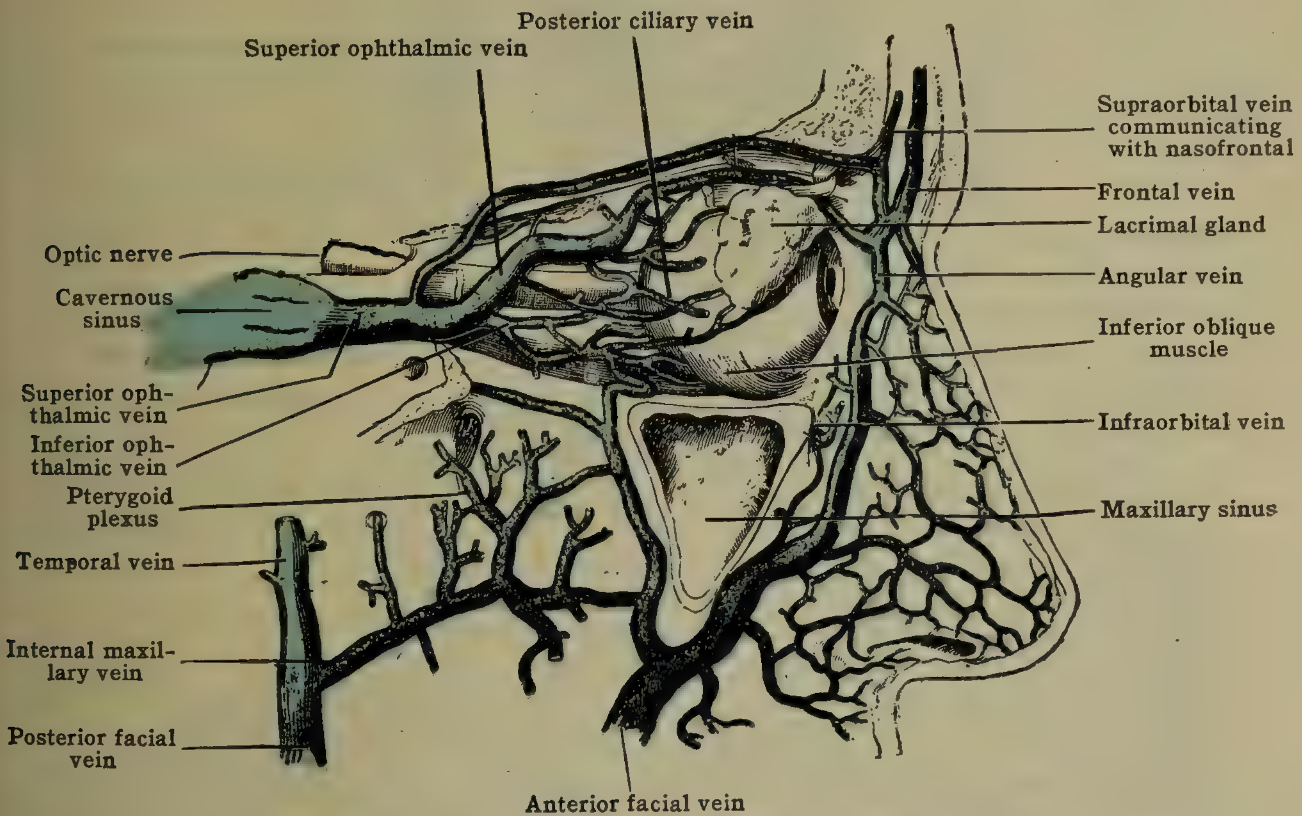


Fig. 596.—The Ophthalmic Veins. (After Quain.)

the superior orbital fissure and enters the anterior end of the canverous sinus. In this course it is superficial to the ophthalmic artery.

Tributaries.—(1) The nasofrontal vein; (2) the superior muscular veins; (3) the veins of the lids and conjunctiva; (4) the ciliary veins; (5) the anterior and posterior ethmoidal veins; (6) the lacrimal vein; (7) the central vein of the retina; and (8) the inferior ophthalmic vein.

(1) The **nasofrontal** vein [v. nasofrontalis] begins by a free communication with the supraorbital vein and enters the orbit through the frontal notch or foramen. It frequently joins the superior ophthalmic vein quite far back in the orbit (see fig. 596).

(2) The **muscular** veins [vv. musculares] are derived from the levator palpebræ, superior rectus, superior oblique, and medial rectus.

(3) The **palpebral** and **conjunctival** veins [vv. palpebrales; vv. conjunctivales ant. et post.], both anterior and posterior, open into the superior ophthalmic.

(4) The **ciliary** veins, the veins of the eyeball, are divided into anterior and posterior groups. The **anterior ciliary veins** [vv. ciliares ant.] emerge from the eyeball with the anterior ciliary arteries, and open into the muscular veins returning the blood from the four recti. They form a circumcorneal ring of **episcleral** veins [vv. episclerales]. The **posterior ciliary veins** (vv. choroideæ minores NK), which drain the **venæ vorticosæ** (vv. chorioideæ majores NK), leave the globe midway between the cornea and the entrance of the optic nerve. The upper veins of this group end in the superior, and the lower in the inferior ophthalmic vein (fig. 596).

(5) The **anterior and posterior ethmoidal** veins [vv. ethmoidales ant. et post.] (vv. ethm. olfactoria et labyrinthica NK), correspond in their course with the arteries of the same name.

They enter the orbit through the anterior and posterior ethmoidal foramina, and join either the superior ophthalmic or one of superior muscular branches.

(6) The **lacrimal** vein [v. lacrimalis] returns the blood from the lacrimal gland, and corresponds in its course to the lacrimal artery.

(7) The **central vein of the retina** [v. centralis retinæ] runs with the central artery in the optic nerve. It joins the superior ophthalmic at the back of the orbit.

(8) The **inferior ophthalmic** vein [v. ophthalmica inferior] (v. ophth. maxillaris NK) smaller than the superior, is formed near the front of the orbit by the confluence of the inferior muscular with the lower posterior ciliary veins. It runs backward below the optic nerve, along the floor of the orbit and either joins the superior ophthalmic vein, or opens separately into the cavernous sinus. A large communicating branch passes downward through the inferior orbital (sphenomaxillary) fissure to join the pterygoid plexus of veins (fig. 596). It receives muscular twigs from the inferior and lateral rectus and from the inferior oblique, and some posterior ciliary veins.

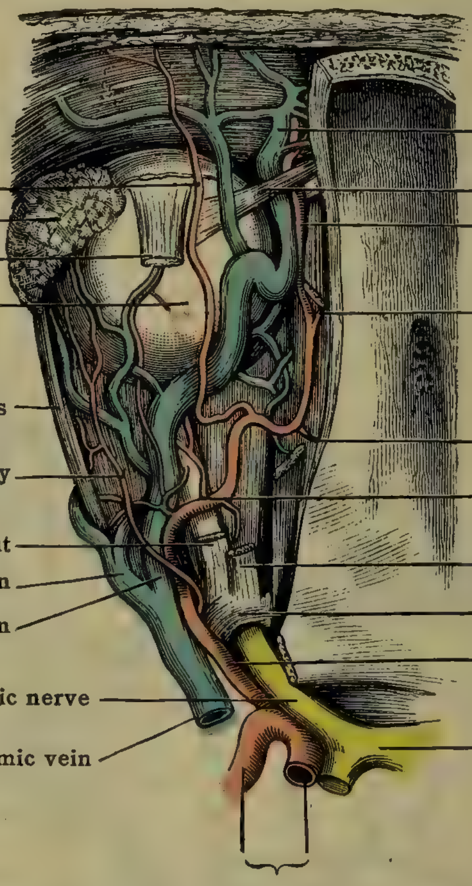


FIG. 597.—THE VEINS OF THE ORBIT. (Superior View.)

7. THE VEINS OF THE PHARYNX AND LARYNX

The **pharyngeal** veins [vv. pharyngeæ] are arranged in the form of a plexus, between the constrictor muscles and the prevertebral fascia. The **pharyngeal plexus** receives branches from the mucous membrane, the pterygoid canal [vv. canalis pterygoidei] from the soft palate, the auditory (Eustachian) tube and the anterior recti and longus colli muscles. Above, it communicates with the pterygoid plexus of veins; below it drains into the internal jugular vein.

The **veins of the larynx** end partly in the **superior laryngeal** vein [v. laryngea superior], which opens into the superior thyroid vein, and partly in the **inferior laryngeal** vein [v. laryngea inferior], which terminates in the plexus thyroideus impar. The laryngeal plexus of veins communicates with the pharyngeal plexus.

8. THE DEEP VEINS OF THE NECK

The **deep veins of the neck** include the internal jugular, vertebral, deep cervical, inferior thyroid, thyroidea ima, thymic, tracheal, and esophageal veins.

The Internal Jugular Vein

The **internal jugular** vein [v. jugularis interna] (figs. 589, 598) begins at the jugular fossa, and is the continuation of the transverse sinus. It passes down the neck, in company first with the internal carotid artery and then with the common carotid artery, to a point a little lateral to the sternoclavicular articulation, where it joins the subclavian to form the innominate vein. At its commencement in the larger posterior and lateral part of the jugular foramen, it is somewhat

dilated, forming the **superior bulb** of the jugular vein [bulbus v. jugularis superior]. This dilated part of the internal jugular vein lies in the jugular fossa of the temporal bone and is therefore in immediate relation to the floor of the tympanum. At first the internal jugular lies in front of the rectus capitis lateralis, and behind the internal carotid artery, from which it is separated by the hypoglossal, glossopharyngeal, and vagus nerves, and by the carotid plexus of the sympathetic. As it descends it passes gradually to the lateral side of the internal carotid, and

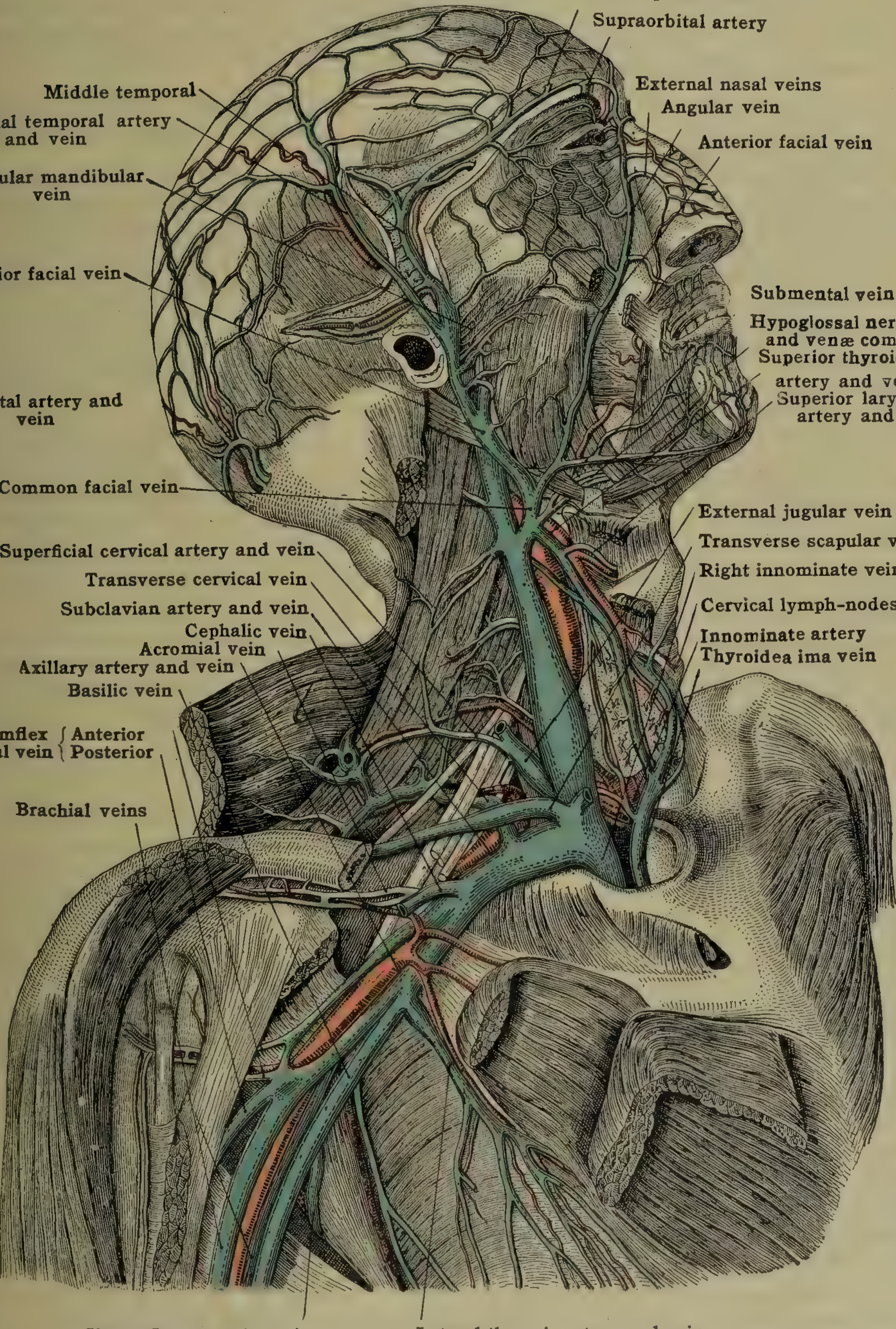


FIG. 598.—THE VEINS OF THE HEAD, NECK, AND AXILLA. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

retains this relation as far as the upper border of the thyroid cartilage. Thence it runs to its termination along the lateral side of the common carotid artery, being contained in the same sheath with it and the vagus nerve, but separated from these structures by a distinct septum. The vein generally overlaps the artery in front. About 2.5 cm. (1 in.) above its termination it contains a pair of imperfect valves below which a second dilation usually occurs in the vein. This,

the **inferior bulb** [bulbus v. jugularis inferior], extends as low as the junction of the internal jugular with the subclavian. It not infrequently receives the termination of the external jugular vein.

Tributaries.—At the superior bulb the internal jugular vein receives the inferior petrosal sinus; the vein of the cochlear canaliculus (which may join the inferior petrosal sinus), and a meningeal vein; opposite the angle of the jaw, veins from the pharyngeal plexus, and often a communicating branch from the external jugular vein; opposite the bifurcation of the carotid it is joined by the common facial, and a little lower down by the lingual, sternomastoid, and the superior thyroid veins. At the level of the cricoid cartilage the internal jugular is joined by the middle thyroid when this vein is present.

The inferior petrosal sinus is described with the other sinuses of the brain (p. 724); the pharyngeal plexus with the veins of the pharynx (see p. 730); and the common facial vein with the superficial veins of the scalp and face (p. 719).

The **lingual** vein [v. lingualis], begins near the tip of the tongue, where it accompanies the arteria profunda linguæ. It lies at first beneath the mucous membrane covering the lower surface of the tongue. After receiving the **sublingual** vein [v. sublingualis] it runs backward on the surface of the hyoglossus as the **v. comitans nervi hypoglossi** which follows the upper border of the hypoglossal nerve. The dorsal lingual veins [vv. dorsales linguæ] join a small vena comitans, which accompanies the lingual artery beneath the hypoglossus muscle and joins the main lingual trunk. The trunk finally crosses the common carotid artery and opens into the internal jugular vein. The lingual vein communicates with the pharyngeal veins and with tributaries of the anterior facial. It occasionally terminates in the posterior or in the common facial vein. The **sternomastoid** vein [v. sternocleidomastoidea] accompanies the artery of the same name and empties into the internal jugular.

The **superior thyroid** vein [v. thyroidea superior] emerges from the upper part of the thyroid gland, in which it freely anastomoses with the other thyroid veins (fig. 598). This anastomosis, the **plexus thyroideus impar,** occurs both in the substance of the organ and on its surface beneath the capsule. The vein then passes upward and laterally into the internal jugular vein, crossing the common carotid artery in its course. It may form a common trunk with the common facial vein. Its **tributaries** are the sternohyoid, sternothyroid, and thyrohyoid veins from the muscles bearing those names; and the cricothyroid and superior laryngeal veins which correspond with the cricothyroid and superior laryngeal arteries respectively. These require no special description.

A separate vein frequently passes out from the capsule of the thyroid gland near the lower part of the lateral lobe, crosses the common carotid, and opens into the main superior thyroid vein or into the internal jugular vein a little below the cricoid cartilage. In the former case it is regarded as part of the superior thyroid vein system; in the latter it is generally known as the **middle thyroid** vein.

Clinical aspects. Several structures of especial clinical importance are encountered in the region of the carotid triangles. These include the internal jugular vein, the accessory, phrenic, vagus and hypoglossal nerves, the thoracic duct, low down and deep on the left side, the esophagus and recurrent nerve in difficult operations on the thyroid gland. Of these, the internal jugular vein is, in some ways, the most important. Glands, tuberculous or carcinomatous, are often adherent to its sheath, especially those which drain the submaxillary group. When this condition is present or suspected, it is always well to begin the dissection low down in the inferior carotid triangle, where the structures are probably normal and the landmarks easy to identify. In infective thrombosis of the transverse sinus the internal jugular is often tied opposite to the cricoid cartilage, being either divided between two ligatures, or, if the thrombus has extended downward, as much of the vein as is possible is removed. This vein contains only a single pair of valves low down in the neck. In all operations here on it and the other two jugulars, the risk of entry of air is to be remembered.

The Vertebral Vein

The **vertebral** vein [v. vertebralis] does not accompany the vertebral artery in its fourth stage, that is, within the cranium, but begins in the posterior vertebral venous plexus of the suboccipital triangle. It then enters the foramen in the transverse process of the atlas, and passes with the vertebral artery through the foramina in the transverse processes of the cervical vertebræ, forming a plexus around the artery. On leaving the transverse process of the sixth cervical vertebra it crosses in front of the subclavian artery and opens into the innominate vein. It has one or two semilunar valves at its entrance into the innominate vein. In the suboccipital triangle it communicates with the internal vertebral venous plexuses, with the deep cervical, and occipital veins, and is joined by veins from the recti and oblique muscles and the pericranium.

Tributaries.—As it passes down the neck it receives (1) intervertebral veins, which issue along with the cervical nerves, from the spinal canal; (2) tributaries from the anterior and posterior vertebral venous plexus from the bodies of the cervical vertebræ and their transverse processes; and (3) tributaries from the deep cervical muscles. Just before it terminates in the innominate it is joined by (4) the anterior vertebral vein, a small vein which accompanies the ascending cervical artery, and, sometimes, by the deep cervical vein.

The Deep Cervical Vein

The **deep cervical** vein [v. cervicalis profunda], larger than the vertebral, passes down the neck posterior to the cervical transverse processes. It corresponds to the deep cervical artery from which it is separated by the semispinalis cervicis muscle.

It begins in the posterior vertebral venous plexus and receives tributaries from the deep muscles of the neck. It communicates with, or entirely drains, the occipital vein by a branch which perforates the trapezius muscle. The deep cervical vein then passes forward beneath the transverse process of the seventh cervical vertebra to open into the innominate vein near the vertebral, or into the latter near its termination. Its orifice is guarded by a pair of valves.

The Inferior Thyroid and Thyroidea Ima Veins

The **inferior thyroid** veins [vv. thyreoideæ inferiores] (fig. 598) descend from the lower part of the *plexus thyroidea impar* which invests the surface of the thyroid gland. The **right vein** crosses the innominate artery just before its bifurcation, and ends in the right innominate vein a little above the vena cava superior or joins the left to form a single vena thyroidea ima. It receives inferior laryngeal veins and veins from the trachea. The **left vein** passes obliquely over the trachea behind the sternothyroid muscle, and opens into the left innominate vein. It also receives laryngeal and tracheal veins, and may be joined by the right inferior thyroid vein. It is guarded by valves where it opens into the innominate trunk.

The **thyroidea ima** vein [v. thyreoidea ima] can be said to exist only when the veins from the lower part of the plexus thyroidea impar unite at once to form a single trunk which opens into the left innominate vein, or when the right inferior thyroid vein joins the left before the latter, which then becomes the v. thyroidea ima, opens into the left innominate.

The Thymic, Tracheal and Esophageal Veins

These small veins usually open into the left innominate vein. The **thymic** veins [vv. thymicæ], small in the adult, open into the left innominate vein or into the inferior thyroid or thyroidea ima. The **tracheal** veins [vv. tracheales] anastomose with the laryngeal and bronchial veins. The **esophageal** veins vv. œsophageæ] from the upper part of the esophagus, anastomose with the owen esophageal veins and with the pharyngeal plexus.

THE VEINS OF THE THORAX

THE SUPERFICIAL VEINS OF THE THORAX

The **superficial veins** of the front of the thorax can be seen in fig. 599. They form a plexus over the entire chest, of which the portion over the mammary gland is called the mammillary venous plexus. The lateral thoracic vein drains the mammary plexus, the costoaxillary and the thoracoepigastric veins and terminates in the axillary vein (p. 742). The veins nearer the median line are drained by the internal mammary vein and its anterior intercostal and superior epigastric tributaries. The veins over the entire thorax are in free communication with the superficial veins of the abdominal wall, which drain into the great saphenous and femoral veins and into the deeper veins of the abdomen.

The **thoracoepigastric** vein (fig. 599) joins the veins of the chest, e. g., the long thoracic above with the superficial epigastric below. Its valves directing the blood downward below and upward above (Stiles) may be rendered incompetent when this vessel is enlarged, as in interference with the portal vein (with which it communicates by a vein in the round ligament), or in blocking of the inferior vena cava.

THE DEEP VEINS OF THE THORAX

The **deep veins of the thorax** are:—the pulmonary veins, and the vena cava superior and its innominate and other tributaries. Of these veins, the pulmonary, the vena cava superior, and the innominate veins have already been described, as have the tributaries of the latter arising in the neck.

The following veins are described below:—(1) The azygos and ascending lumbar veins, which discharge their blood into the vena cava superior; (2) the veins of the vertebral column, which are tributary to the azygos veins through the intercostals; (3) the internal mammary veins, and (4) the superior phrenic, an-

terior mediastinal and pericardiac veins, all of which open into the innominate veins.

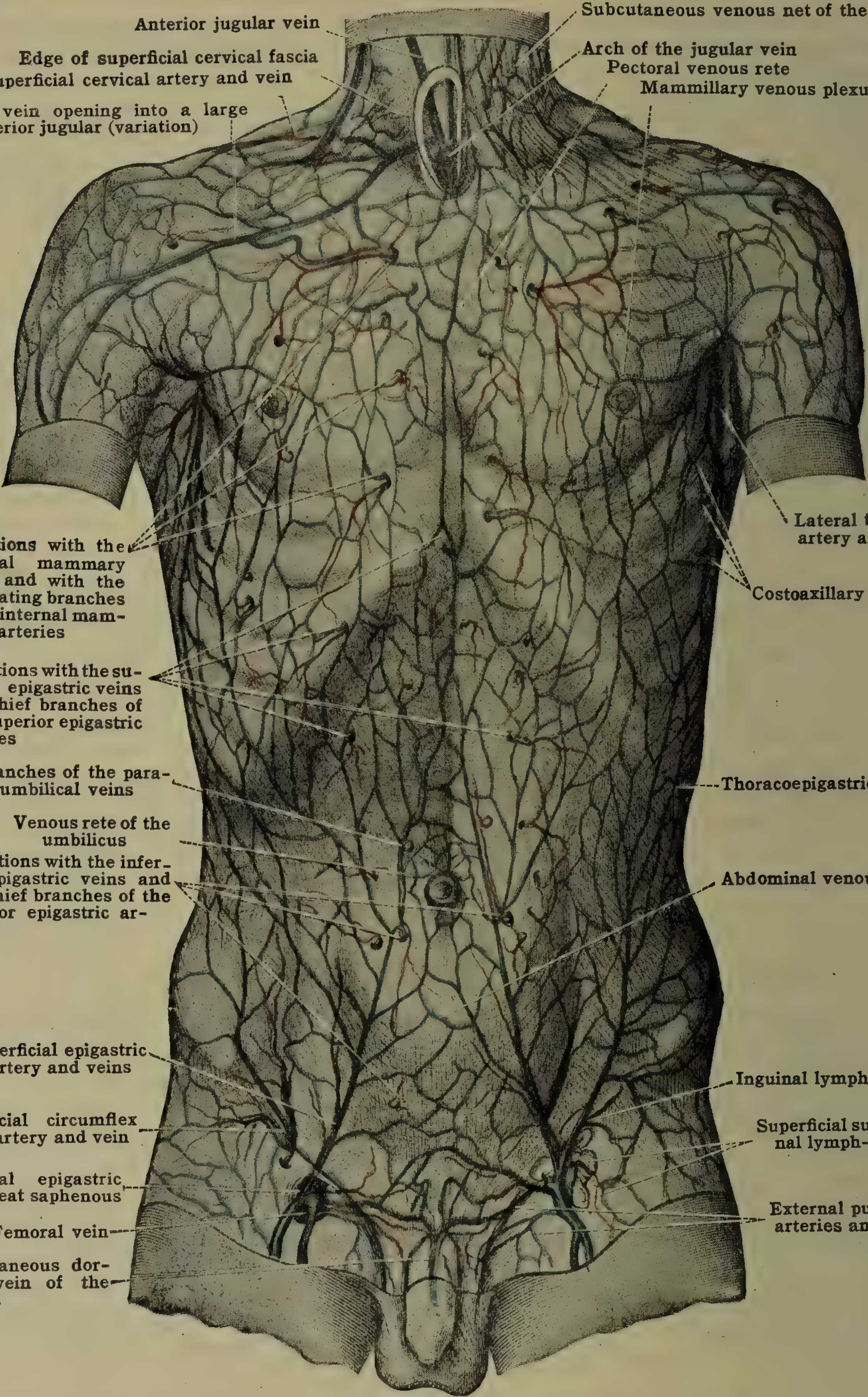


Fig. 599.—The Subcutaneous Arteries and Veins of the Anterior Body Wall. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

1. THE AZYGOS AND ASCENDING LUMBAR VEINS

The azygos system (v. thoracica longitudinalis NK) consists of a series of longitudinal collecting trunks for the *intercostal veins.* They lie along the sides of the thoracic vertebræ, and are the upward continuation of the **ascending lumbar veins** which take origin in the abdomen. The azygos veins are three in number: the azygos (azygos major) on the right side, and the hemiazygos (azygos minor) and accessory hemiazygos (azygos tertia) on the left.

The **azygos** vein [v. azygos] (v. thor. long. dextra NK) (figs. 600, 613) begins in the abdomen as the right ascending lumbar vein. It is in this way linked with the right common iliac and right renal veins and has other connections with the vena cava inferior which may become very important in cases of obstruction of the latter vessel. It runs beneath the right medial crus of the diaphragm, to the right of the aorta and the thoracic duct to reach the posterior mediastinum. Here it runs on the right side of the front of the bodies of the thoracic vertebræ as high as the fourth, still lying to the right of the aorta and thoracic duct; it then curves forward over the root of the right lung, and opens into the vena cava superior immediately before the latter pierces the pericardium.

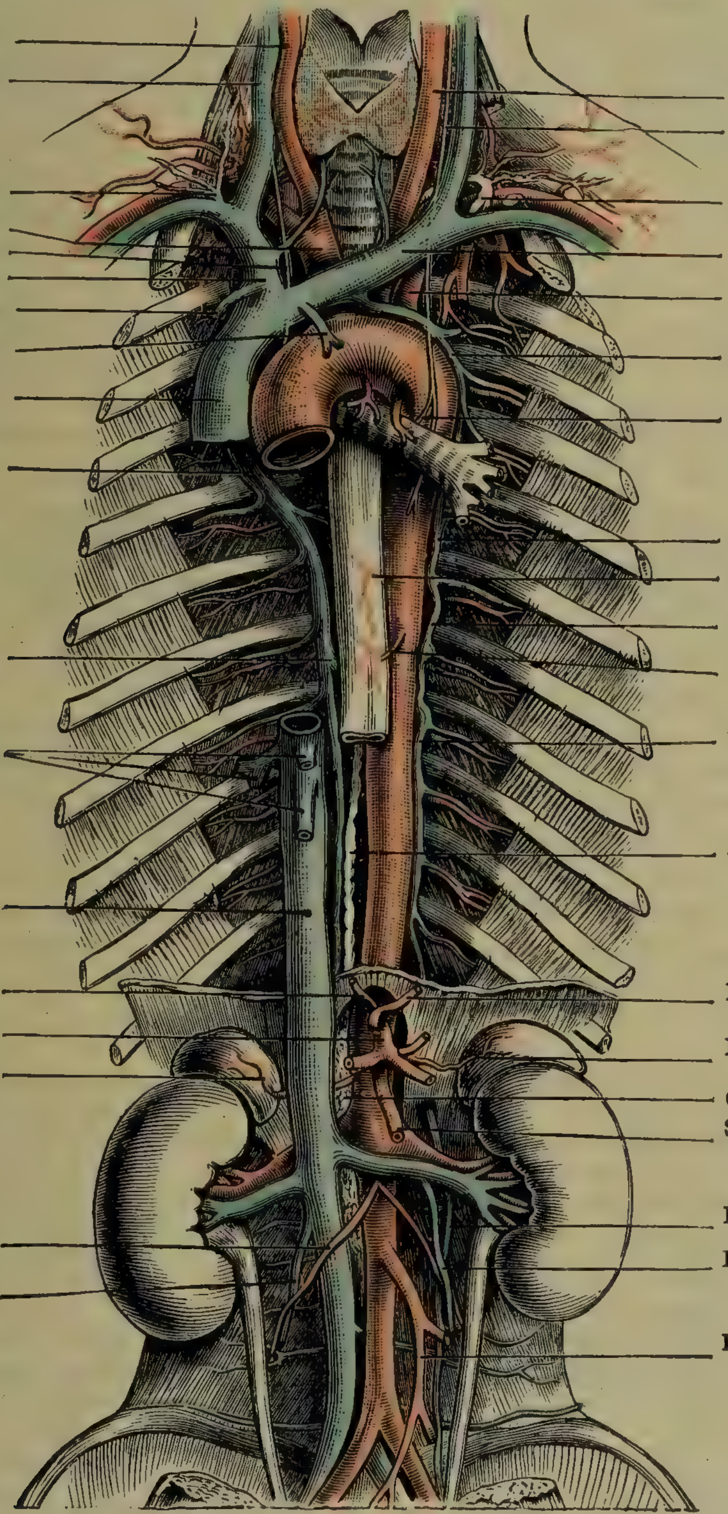


Fig. 600.—The Venæ Cavæ Superior and Inferior, the Innominate Veins, and the Azygos Veins.

The azygos vein usually contains an imperfect pair of valves at the point where it turns forward from the fourth thoracic vertebra to arch over the root of the lung; and still more imperfect valves are found at varying intervals lower down the vein.

It receives the intercostal veins of the right side, except the first two or three. These veins (usually excepting the first) are collected into a common trunk, the right superior intercostal vein, before joining the azygos. It also receives the hemiazygos and accessory hemiazygos, the right posterior bronchial vein, and small esophageal and posterior mediastinal veins.

The **hemiazygos** vein [v. hemiazygos] (v. thor. long. sinistra NK) (fig. 600) begins in the abdomen by communicating, like the azygos vein, with the ascending

lumbar vein of its own side. It passes through the left intermediate crus of the diaphragm and courses up the posterior mediastinum to the left of the bodies of the lower thoracic vertebræ as high as the eighth or ninth. Here it turns obliquely to the right and, crossing in front of the vertebral column behind the aorta and the esophagus, opens into the vena azygos. In its course it crosses over three or four of the lower left intercostal arteries, and is covered by the pleura.

The hemiazygos receives the lower four or five left intercostal veins the lower end of the accessory hemiazygos vein (sometimes), the small left mediastinal veins, and the lower left esophageal veins.

The **accessory hemiazygos** [v. hemiazygos accessoria] (v. thor. long. sin. accessoria NK) (fig. 600) varies much in size, position, and arrangement, and is often continuous with, or drained by, the left superior intercostal vein. It lies in the posterior mediastinum by the left side of the bodies of the fifth, sixth, and seventh or eighth thoracic vertebræ, and is more or less vertical in direction. It may communicate above with the left superior intercostal vein, and below either joins the hemiazygos or passes obliquely across the seventh or eighth thoracic vertebra to join the azygos vein. It crosses the corresponding left intercostal arteries, and is covered by the pleura.

The accessory hemiazygos receives the fourth, fifth, sixth, seventh, and sometimes the eighth intercostal veins, and the left posterior bronchial veins.

The **ascending lumbar** vein [v. lumbalis ascendens] (fig. 600) begins on either side in the neighborhood of the sacral promontory. It is here in free communication, by means of the anterior sacral plexus, with the middle and lateral sacral veins, and with the common iliac, hypogastric and iliolumbar veins. It ascends in front of the lumbar transverse processes communicating with the lumbar veins, the vena cava inferior and, usually, with the renal vein. The right vein enters the thorax between the aorta and the right medial crus of the diaphragm, and is continued upward as the vena azygos. The left vein pierces the left intermediate crus and becomes the hemiazygos.

The intercostal veins [vv. intercostales].—The intercostal veins are twelve in number on each side, the last one being subcostal. They accompany the intercostal arteries, the vein lying above the artery whilst in the intercostal space. Each vein receives a dorsal tributary [ramus dorsalis] which accompanies the posterior ramus of an intercostal artery between the transverse process of the vertebra and the neck of the rib. These dorsal branches not only return the blood from the muscles of the back, but receive each a spinal branch [r. spinalis] from the vertebral venous plexuses and small tributaries from the bodies of the vertebræ.

The intercostal vein from the first space may join the superior intercostal vein, but commonly opens directly into the innominate or one of its tributaries, most frequently the vertebral. All the intercostal veins, usually excepting the first, lie posteriorly to the sympathetic trunk.

On the right side.—The second intercostal vein joins, with the third or with the third and fourth to form the **right superior intercostal** vein [v. intercostalis suprema dextra]. This vein opens into the azygos vein as the latter is arching over the root of the right lung. The others join the azygos directly. The upper of these have well-marked valves where they join the azygos vein; in the lower veins these valves are imperfect. All the intercostal veins are provided with valves in their course between the muscles.

On the **left side** the second intercostal vein joins the third and fourth to form a single trunk, the **left superior intercostal** vein [v. intercostalis suprema sinistra]. This vein passes upward across the arch of the aorta and opens into the left innominate vein. It frequently communicates at its lower end with the accessory hemiazygos vein, which is occasionally tributary to it. In most cases a small tributary runs up over the front of the aortic arch to join the superior intercostal vein; it is a vestige of the embryonic left common cardinal (superior vena cava) and from it a small fibrous cord can often be traced through the vestigial fold of the pericardium to the oblique vein of the left atrium (p. 599).

The left fourth, fifth, sixth and seventh intercostal veins commonly open into the accessory hemiazygos, and the eighth or ninth and succeeding veins into the hemiazygos. The method of termination of the intercostal veins of the left side is subject to such variation that a normal arrangement can scarcely be said to exist at all. The eighth may open directly into the azygos, as may the seventh and ninth or even more or all of the veins; the hemiazygos and accessory hemiazygos veins may thus be very limited in extent or even altogether absent.

The **posterior bronchial** veins [vv. bronchiales posteriores] correspond to the bronchial arteries, but do not return the whole of the blood carried to the lungs by those vessels—that part which is distributed to the smaller bronchial tubes and the alveoli being brought back by the pulmonary veins. The posterior bronchial veins issue from the lung substance behind the structures forming the root of the lung. The right vein generally joins the vena azygos just before the latter vein enters the vena cava superior. The left vein opens into the accessory

hemiazygos vein. The bronchial veins at the root of the lung receive small tributaries from the bronchial glands, from the trachea, and from the posterior mediastinum.

The **esophageal** veins [vv. œsophageæ] from the thoracic portion of the esophagus end in part in the vena azygos, and in part in the vena hemiazygos. They anastomose with the upper esophageal veins, which empty into the left innominate vein, and with the coronary vein of the stomach (fig. 608).

The **posterior mediastinal** veins, small and numerous, open into the azygos and hemiazygos veins.

2. THE VEINS OF THE VERTEBRAL COLUMN

The venous plexuses around and within the vertebral column extending from the cranium to the coccyx (fig. 601) may be divided into two categories:—(1) the **external** and (2) the **internal vertebral venous plexuses.** The external plexuses consist of two parts, the *anterior vertebral venous plexuses* situated on the anterior aspect of the vertebral bodies and the *posterior vertebral venous plexuses* ramifying over the posterior aspect of the vertebral arches, spines, and transverse processes.

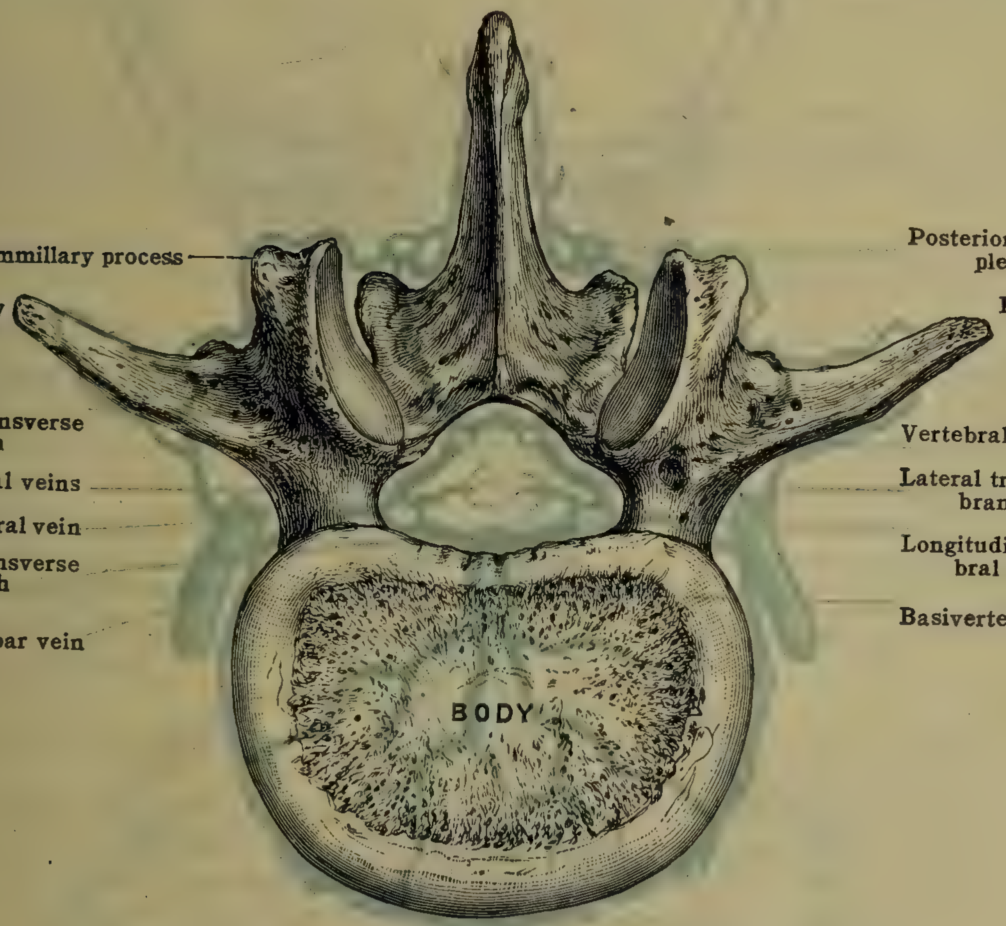


FIG. 601.—THE VEINS OF THE VERTEBRAL COLUMN.

The internal plexuses consist of *two longitudinal venous sinuses* situated between the vertebræ and the posterior longitudinal ligament, and of two *vertebral venous retia* which ramify externally to the dura mater. The sinuses of the internal plexuses communicate freely with one another and with the internal retia and external plexuses. They receive the external spinal veins and the *basivertebral veins* from the bodies of the vertebræ. The venous circulation of the vertebral column is drained by the vertebral, intercostal, lumbar and sacral veins either directly or by means of (3) the **intervertebral** veins.

1. The **external vertebral** venous plexuses [plexus venosi vertebrales externi] include the following:—

(*a*) The **anterior vertebral venous plexuses** [plexus venosi vertebrales anteriores] (fig. 601), consist of small veins ramifying in front of the bodies of the vertebræ. These veins communicate with the basivertebral veins and are larger in the cervical region than elsewhere.

(*b*) The **posterior vertebral venous plexuses** [plexus venosi vertebrales posteriores] (fig. 601) are situated around the transverse, articular, spinous processes and laminæ of the vertebræ. Communications take place between the plexuses of each segment and with the veins of the neighboring muscles and integuments. Branches are also sent, through the ligamenta flava, to the internal vertebral venous plexuses, and, between the transverse processes, to the intervertebral veins.

2. The **internal vertebral venous plexuses** [plexus venosi vertebrales interni] (figs. 601, 602):—

(*a*) The two **longitudinal vertebral sinuses** [sinus vertebrales longitudinales] run throughout the entire length of the vertebral canal. They are situated behind the bodies of the verte-

bræ on either side, between the bone and the posterior longitudinal ligament. The sinuses have extremely thin walls, and their interior is made irregular by numerous folds but no true valves are present. The caliber of the longitudinal sinuses is reduced by constrictions opposite the intervertebral disks; the constrictions alternating with dilatations opposite the vertebral bodies. At each dilatation there occurs a cross communication between the longitudinal sinuses of either side, and each receives a basivertebral vein from the corresponding vertebral body. Opposite every intervertebral foramen and anterior sacral foramen each longitudinal sinus is joined by the corresponding intervertebral vein. The longitudinal sinuses communicate very freely with one another, and with the vertebral retia. At the foramen magnum they communicate with the basilar plexus and with the occipital sinus and, by means of the **rete canalis hypoglossi,** with the internal jugular vein.

(*b*) The **venous retia of the vertebræ** [retia venosa vertebrarum] (fig. 601) extend from the foramen magnum to the coccyx. They consist of two main retia situated posteriorly and laterally to the dura between the latter and the vertebral arch. They communicate very freely with one another across the median line; with the posterior external plexus by means of twigs perforating the ligamenta flava; and with the longitudinal vertebral sinuses by means of lateral branches. At the foramen magnum they communicate with the occipital sinus.

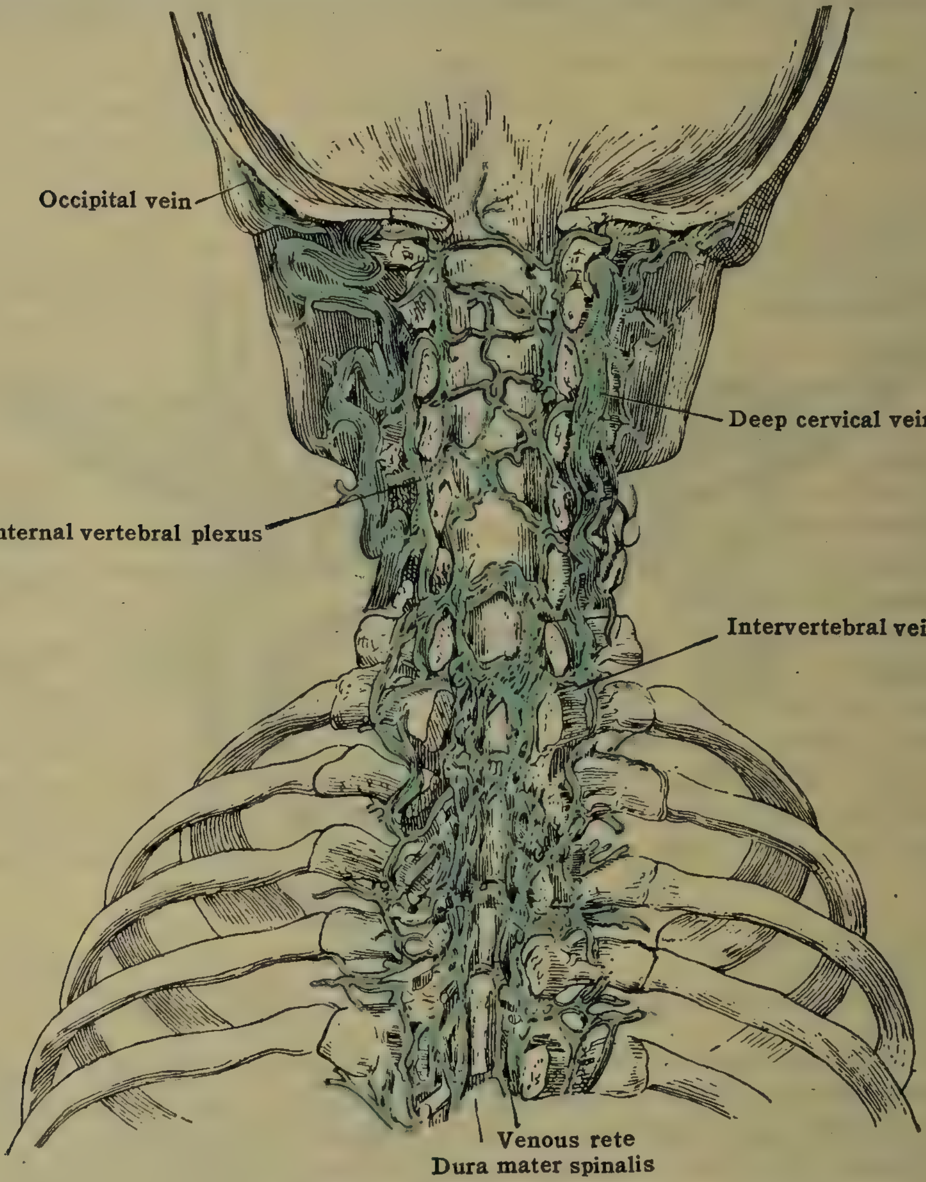


Fig. 602.—The Vertebral Venous Plexuses. (After Henle.)

(*c*) The **external spinal** veins (fig. 601) consist of two sets—anterior and posterior—which are drained by means of veins following the nerve roots, into the internal vertebral venous plexus.

The **anterior external spinal** veins [vv. spinales externæ anteriores] form a tortuous anastomosing vessel in the region of the anterior median fissure.

The **posterior external spinal** veins [vv. spinales externæ posteriores], smaller than the anterior run longitudinally on the posterior surface of the cord.

The external spinal veins form a wide-meshed plexus in the pia mater which drains the **internal spinal** veins [vv. spinales internæ] (see Spinal Cord).

(*d*) The **basivertebral** veins [vv. basivertebrales] (fig. 601) collect the blood from the cancellous tissue of the bodies of the vertebræ, and consist of a tunica intima only. They take a radial direction converging to the transverse vessels connecting the longitudinal vertebral sinuses. They communicate with the anterior external plexus and with the intercostal veins.

3. The **intervertebral** veins [vv. intervertebrales] (figs. 601, 602), emerge from each longitudinal sinus and pass out through the intervertebral or anterior sacral foramina. They open into the vertebral, intercostal, lumbar or sacral veins according to region and receive numerous tributaries from the anterior and posterior external vertebral venous plexuses. They are instrumental in draining the venous system of the vertebral column and spinal cord.

3. THE INTERNAL MAMMARY VEIN

The internal mammary vein [v. mammaria interna] (v. thoracica interna NK) (fig. 542) is formed by the union of the venæ comitantes corresponding to the superior epigastric and musculophrenic arteries. The right and left internal mammary veins pass upward, in company with the corresponding arteries, to open into the right and left innominate veins, respectively.

Tributaries.—In addition to the superficial veins of the thorax, the internal mammary veins receive the anterior intercostal, anterior bronchial and pericardiac veins.

The **superior epigastric** vein [v. epigastrica superior] assists in the drainage of the subcutaneous abdominal veins [vv. subcutaneæ abdominis].

The **anterior bronchial** veins [vv. bronchiales anteriores] arise in the bronchial walls and communicate with the tracheal and posterior bronchial veins.

4. THE SUPERIOR PHRENIC, ANTERIOR MEDIASTINAL, AND PERICARDIAC VEINS

The **superior phrenic** [vv. phrenicæ superiores], the **anterior mediastinal** [vv. mediastinales anteriores], and **pericardiac** [v. pericardiacæ] veins are small vessels, corresponding to the arteries of those names. They pass over the arch of the aorta and open into the lower and anterior part of the left innominate.

THE VEINS OF THE UPPER EXTREMITY

The **veins of the upper limb** consist of two sets—a **superficial** and a **deep.** The superficial veins ramify in the subcutaneous tissue above the deep fascia, and they do not accompany arteries. The deep veins accompany the arteries, and have practically the same relations as those vessels. The superficial and deep veins communicate at frequent intervals through the intermuscular veins which run between the muscles and perforate the deep fascia. Both sets of veins are provided with valves, but the valves are more numerous in the deep than in the superficial. There are usually valves where the deep veins join the superficial. The superficial veins are larger than the deep, and take the greater share in returning the blood.

A. THE SUPERFICIAL VEINS OF THE UPPER EXTREMITY

The **superficial veins** begin in two irregular plexuses, one in the palm and the other on the back of the hand. The plexus in the palm is much finer, and communicates with the superficial volar veins of the fingers. The latter discharge their blood into the dorsal venous rete by means of the veins of the folds between the fingers, or the **intercapitular** veins [vv. intercapitulares] (fig. 603).

The veins of the back of the hand begin in a longitudinal plexus over the fingers, and at the bases of the fingers the veins of the adjacent digits are connected by **digital venous arches** [arcus venosi digitales], from which arise the **dorsal metacarpal** veins [vv. metacarpeæ dorsales]; these form upon the back of the hand a **dorsal venous rete** [rete venosum dorsale manus] (fig. 604).

Of the veins of the arm, two stand out prominently, the basilic and the cephalic. Both of these arise from the veins of the back of the hand, curve around to the volar surface of the forearm, and pass to the arm (fig. 603).

The **basilic** vein [v. basilica],* arises on the back of the hand from the ulnar end of the dorsal venous rete, which usually forms an arch. It curves around the ulnar side of the forearm to the volar surface just distally to the elbow and reaches the arm, where it lies in the median bicipital sulcus. It extends up to about the middle third of the sulcus, and, piercing the brachial fascia, joins the brachial venæ comitantes to form the axillary vein.

The **cephalic** vein [v. cephalica],* begins at the radial end of the dorsal venous rete or arch and curves around the radial border of the forearm to the volar

* The basilic vein here described corresponds to the posterior ulnar and the basilic; the cephalic corresponds to the median, median cephalic and cephalic of the older terminology employed in English text-books. The BNA terminology has the great advantage that it can be used to describe any form of venous pattern. The older terminology applies only to cases in which the **M**-shaped arrangement occurs upon the volar surface of the elbow. Berry and Newton found the latter arrangement in only 13 per cent. of 300 cases.

surface a short distance above the wrist. It passes over the volar surface of the elbow and here receives a large tributary from the radial border of the forearm, the accessory cephalic [v. cephalica accessoria], and reaches the lateral aspect

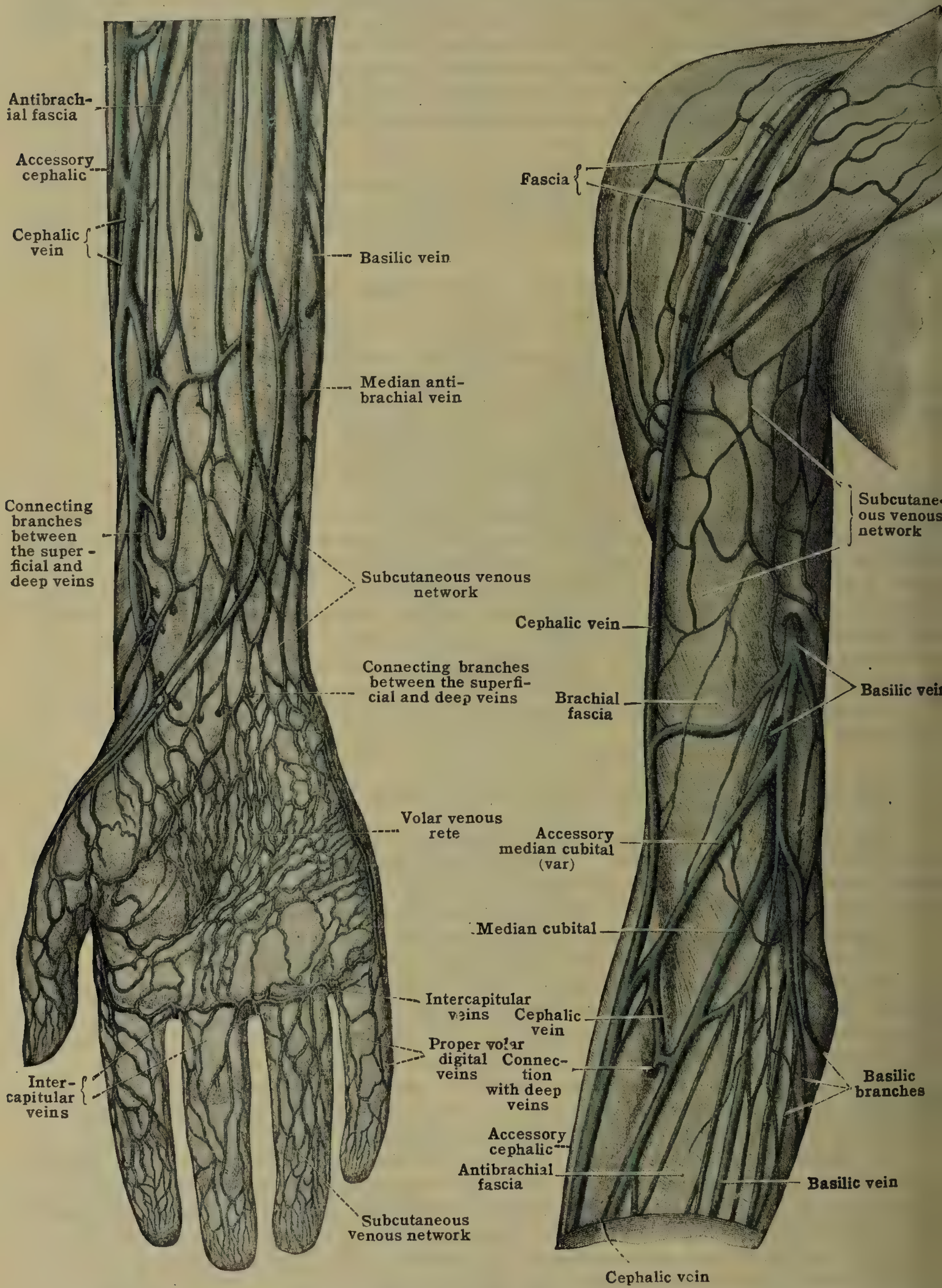


Fig. 603.—The Superficial Veins of the Arm and Forearm. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.) In this case the cephalic vein of the forearm is drained more directly (through the median cubital) into the basilic than into the proximal part of the cephalic.

of the arm. It lies at first in the lateral bicipital sulcus and then in the groove between the pectoralis major and the deltoid. Just below the clavicle it turns into the depth, and empties into the axillary vein.

At the elbow there is usually an oblique connecting branch, the **median cubital vein** [v. mediana cubiti] (figs. 603, 605) (formerly termed median basilic) which, beginning from the cephalic a little distally to the crease of the elbow, ends in the basilic just proximally to the elbow.

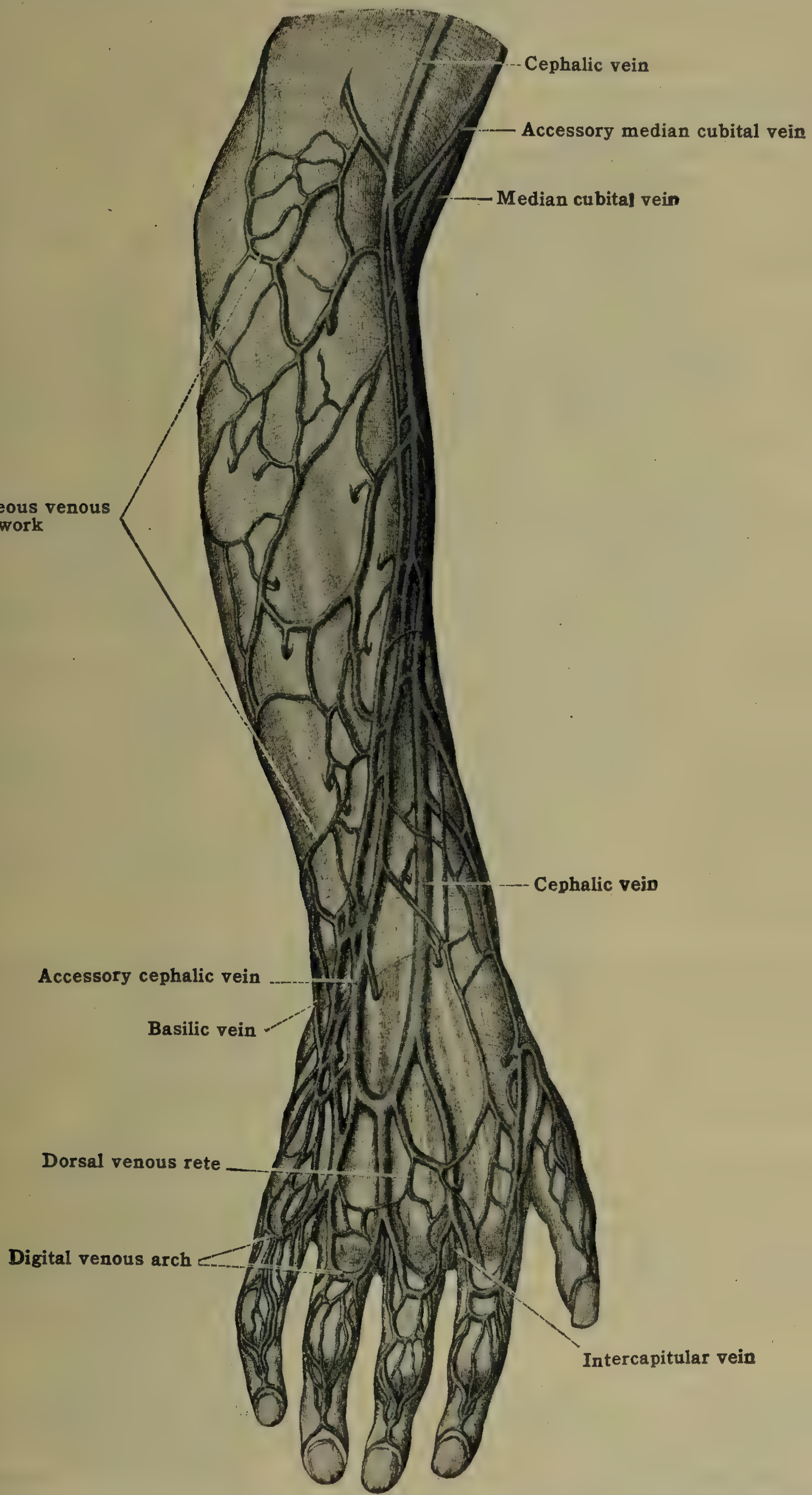


Fig. 604.—Veins of the Back of the Forearm. (After Toldt, 'Atlas of Human Anatomy' The Macmillan Company.)

B. THE DEEP VEINS OF THE UPPER EXTREMITY

The **deep veins of the upper extremity** accompany their corresponding arteries. Distal to the axilla, each artery is accompanied by two veins known as the venæ comitantes. The deep veins all contain numerous valves, and communicate at frequent intervals through intermuscular veins with the superficial vessels.

Beginning at the fingers, two minute **proper volar digital** veins [venæ digitales volares propriæ], accompany each digital artery along the sides of the fingers, and uniting at the cleft, form **common volar digital** veins [vv. digitales volares communes], which join the venæ comitantes of the superficial volar arch. In like manner the veins accompanying the deep arch receive tributaries, **the volar metacarpal** veins [vv. metacarpeæ volares], corresponding to the branches of that arch. A **superficial** and a **deep volar venous arch** [arcus volaris venosi, superficialis et profundus] are thus formed accompanying the arterial arches. The venæ comitantes from the ulnar side of the superficial and deep arches unite at the division of the ulnar artery into its superficial and deep branches to form two **ulnar venæ comitantes** [vv. ulnares]; while those at the radial end of the arches accompany the superficial volar artery and the termination of the radial artery respectively, and unite near the origin of the superficial volar to form the **radial venæ comitantes** [vv. radiales].

The ulnar and radial venæ comitantes thus formed course up the forearm with their respective arteries, receiving numerous tributaries from the muscles amongst which they run, and giving frequent communications to the superficial veins. They finally unite at the bend of the elbow to form the **brachial venæ comitantes** [vv. brachiales]. The ulnar venæ comitantes receive, before joining the radial, the companion veins of the interosseous arteries. At the bend of the elbow the deep veins are connected with the cephalic vein by a short, thick trunk (fig. 603).

The **brachial venæ comitantes** accompany the brachial artery. At the lower border of either the teres major or subscapularis muscle, the more medial vein receives the more lateral and the basilic vein, to form a single axillary vein.

The venæ comitantes of the arteries of the arm anastomose with one another by frequent cross branches.

The **axillary** vein [v. axillaris], is formed by the junction of the medial brachial vena comitans with the basilic vein at the lower border of either the teres major or subscapularis muscle. It is a vessel of large size, conveying as it does nearly all the blood returning from the upper extremity. It accompanies the axillary artery through the axillary fossa, lying to its medial side and, at the upper part of the space, on a slightly anterior plane. At the lateral border of the first rib it changes its name to subclavian. It has one or two axillary lymphatic nodes in close connection with it. The vein contains a pair of valves, usually placed near the lower border of the subscapularis muscle.

Tributaries of the axillary vein are as follows:—(1) The **subscapular** veins which accompany the subscapular artery; (2) the **circumflex** veins accompanying the circumflex arteries; (3) the **lateral thoracic** vein [v. thoracalis lateralis] a large vein which accompanies the lateral thoracic artery and receives numerous **thoracoepigastric** veins [vv. thoracoepigastricæ] from the epigastric and lower thoracic regions; (4) the **costoaxillary** veins [vv. costoaxillares] the radicles of which arise in the pectoral region from the **mammary plexus** [plexus venosus mamillæ]; and (5) the **cephalic** vein.

The **subclavian** vein [v. subclavia] (fig. 605), is the continuation of the axillary. It begins at the lateral border of the first rib and terminates by joining the internal jugular to form the innominate, opposite the sternoclavicular articulation. It lies anterior to the subclavian artery and on a lower plane, and is separated from the artery in the second part of its course by the scalenus anterior muscle. The subclavian vein, just before it is joined by the external jugular, contains a pair of valves.

Tributaries.—The subclavian vein receives the thoracoacromial vein near its distal end, and the external jugular vein near the lateral border of the sternomastoid muscle. The transverse cervical veins terminate in the subclavian near the external jugular, or in the latter vein, or in a plexiform arrangement formed between the transverse scapular, transverse cervical and external jugular veins. The external jugular vein is described with the superficial veins of the head and neck (p. 719).

The **thoracoacromial** vein [v. thoracoacromialis], receiving tributaries corresponding to the branches of the artery of the same name, terminates near the lateral border of the first rib.

The **transverse cervical** veins [vv. transversæ colli] receive tributaries corresponding in distribution to the branches of the transverse cervical artery. They emerge from beneath the trapezius muscle, cross the posterior triangle, and usually terminate in the subclavian vein. They usually terminate as a single vein the orifice of which is guarded by a pair of valves. Occasionally the cephalic vein, or a branch from the cephalic (the jugulocephalic), passes over the clavicle to the subclavian.

C. THE VENA CAVA INFERIOR AND ITS TRIBUTARIES

All the veins of the abdomen, pelvis, and lower extremities, with the exception of the superior epigastric (p. 739), and ascending lumbar vein (p. 736), which join the superior caval system, enter directly or indirectly into the vena cava

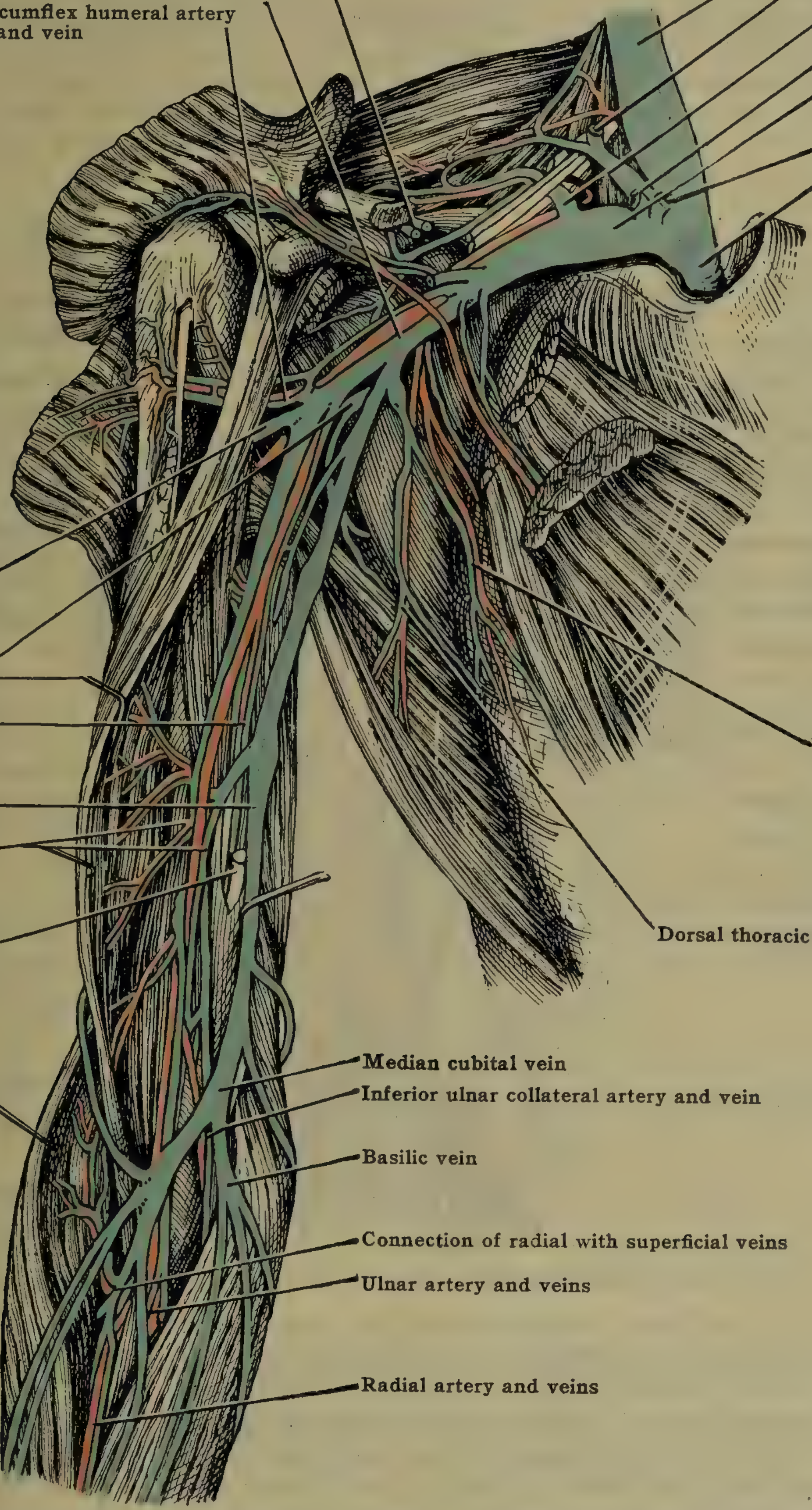


Fig. 605.—Deep Veins of the Arm and Axilla. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.) The cephalic vein, incomplete above the elbow is drained through the median basilic into the basilic.

inferior. The veins corresponding to the parietal branches of the abdominal aorta, except the middle sacral vein, open directly into the vena cava inferior; the middle sacral vein only indirectly through the left common iliac vein. Of the visceral veins corresponding to the visceral branches of the abdominal aorta, those which return the blood from the stomach, intestines, pancreas, and the

spleen end in a common trunk called the portal vein. The portal vein breaks up into capillaries (sinusoids) in the liver, whence the blood is carried by the hepatic veins to the vena cava inferior.

Of the other visceral veins, both renals, the right suprarenal, and the right spermatic or ovarian open directly into the vena cava inferior; the left suprarenal and left spermatic (or ovarian) are drained through the left renal.

Collateral circulation.—Two of the superficial veins of the lower part of the anterior abdominal wall, the superficial epigastric and superficial circumflex iliac, enter the great saphenous vein; and two of the deep veins from the like situation, the inferior epigastric and deep circumflex iliac, enter the external iliac vein. The blood in these vessels, however, can flow upward as well as in the normally downward direction. In obstruction of the vena cava inferior they become greatly enlarged, and form, with the superior epigastric vein and with other superficial veins of the thorax with which they anastomose (see *thoracoepigastric vein*, p. 733), one of the

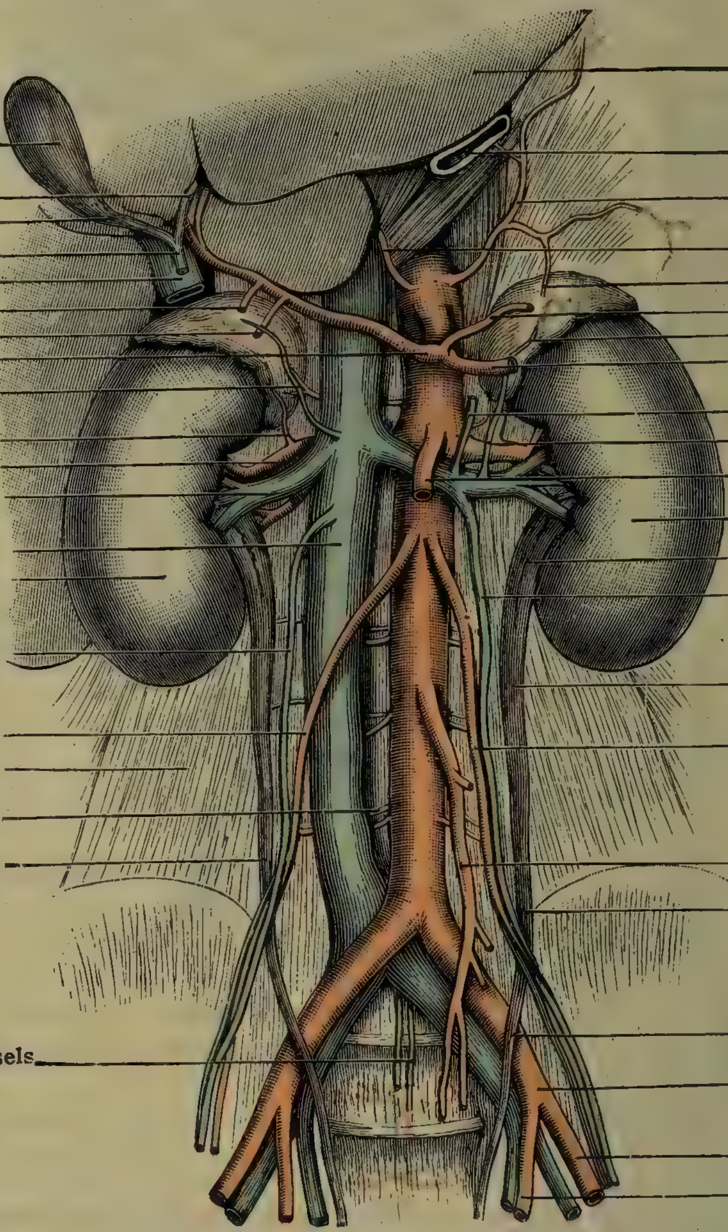


FIG. 606.—THE ABDOMINAL AORTA AND VENA CAVA INFERIOR.

chief channels for the return of the blood from the lower limbs and abdominal viscera. Especially in obstruction of the portal vein, a peculiar plexus of swollen superficial veins (*'caput Medusæ'*) may appear in the region around the umbilicus.

Most of the veins of the pelvis, the perineum and the gluteal region, join the hypogastric vein. The hypogastric on each side joins the external iliac to form the common iliac, and these in turn unite to form the vena cava inferior.

THE VENA CAVA INFERIOR

The **vena cava inferior** (or caudalis NK) (fig. 606) is the large vessel which returns the blood from the lower extremities and the abdomen and pelvis. It is formed by the confluence of the right and left common iliac veins opposite the body of the fifth lumbar vertebra, ascends in front of the lumbar vertebræ to the right of the abdominal aorta, passes through the caval opening in the diaphragm, and ends in the lower and back part of the right atrium of the heart usually about

the level of the ninth thoracic vertebra. At its origin it lies behind the right common iliac artery on a plane posterior to the aorta, but as it ascends it passes slightly forward and to the right, reaching a plane anterior to the aorta, and becomes separated from that artery by the right medial and intermediate crura of the diaphragm and the caudate lobe of the liver. While in contact with the liver it lies in a deep groove [fossa venæ cavæ] on the posterior surface of that organ, the groove being often converted into a canal by a thin portion of the hepatic substance bridging across it. As it passes through the diaphragm its walls are attached to the tendinous margins of the caval opening, and are thus held apart when the muscle contracts. On the thoracic side of the diaphragm it lies for about 1.2 cm. (½ in.) within the pericardium, the serous layer of that membrane being reflected over it (fig. 516).

Relations.—**In front** it is covered by the peritoneum, and crossed by the right spermatic artery, branches of the aortic plexus of the sympathetic, the transverse colon, the root of the mesentery, the duodenum, the head of the pancreas, the portal vein, and the liver. The right lumbar lymphatic nodes are also in front of it below, and at its commencement the right common iliac artery rests upon it. **Behind,** it lies on the lumbar vertebræ, the right lumbar arteries, the right renal artery, the right celiac (semilunar) ganglion, and the right medial crus of the diaphragm. To the **right** are the peritoneum, liver, and psoas muscle. To the **left** is the aorta, and higher up the right medial crus of the diaphragm.

Tributaries.—The vena cava inferior receives the following veins:—(1) the renal veins; (2) the right suprarenal vein; (3) the right spermatic or the right ovarian vein; (4) the lumbar veins; (5) the inferior phrenic veins; (6) the hepatic veins (which indirectly receive blood from the portal); and (7) the right and left common iliac veins.

(1) The **renal** veins [vv. renales] (fig. 606) return blood from the kidneys. They are short but thick trunks, and open into the vena cava nearly at right angles to that vessel. The vein on the left side, like the kidney, is a little higher than on the right, and is also longer, in consequence of its having to cross the aorta.

Each renal vein lies in front of its corresponding artery. The left vein crosses in front of the aorta, just below the origin of the superior mesenteric artery and is covered by the inferior portion of the duodenum. It receives the left spermatic, or the left ovarian in the female, and the left suprarenal, and sometimes the left phrenic. There are rudiments of valves in each vein where it joins the vena cava.

(2) The **suprarenal** veins [vv. suprarenales] (fig. 606).—There is usually only one suprarenal vein on each side to return the blood brought to the suprarenal body by the three suprarenal arteries. On the **right side** the vein opens directly into the vena cava, above the opening of the right renal vein. On the **left side,** it opens into the left renal.

(3) The **spermatic** veins [vv. spermaticæ] (fig. 606) return the blood from the testes. They begin by the confluence of small branches from the body of the testis and epididymis. As they proceed up the spermatic cord, in front of the internal spermatic artery and ductus deferens, they become dilated and plexiform, constituting the **pampiniform plexus** [plexus pampiniformis] (fig. 618).

The **ovarian** veins [vv. ovaricæ] begin at the plexus pampiniformis near the ovary, between the layers of the broad ligament (figs. 563, 571, 607). This plexus is larger than in the male and communicates freely with the uterovaginal plexus of veins, and with the plexus of veins which extends from the hilus of the ovary into the ovarian ligament.

After passing from between the layers of the broad ligament, the plexus unites to form at first two vessels and then a single vessel, which accompanies the ovarian artery, following a course similar to that of the spermatic veins in the male. The right ovarian veins open into the vena cava inferior, the left into the left renal. They usually contain imperfect valves in their plexiform part, and a perfect valve where they join the vena cava and renal vein respectively.

(4) The **lumbar** veins [vv. lumbales], four to five on either side accompany the lumbar arteries and collect venous blood from the muscles of the back and abdomen.

They terminate by passing beneath the tendinous arches of the psoas major, along the sides of the lumbar vertebræ, and opening into the vena cava inferior. The veins of the left side are longer than those of the right and pass behind the aorta. Each vein receives a dorsal tributary corresponding in distribution to the dorsal branch of the lumbar artery. Between the dorsal tributaries and the posterior vertebral venous plexus there occurs a free communication.

There is also an anastomosis between the main lumbar veins and the anterior vertebral venous plexus around the bodies and transverse processes of the lumbar vertebræ. By means of these communications the intervertebral veins, the internal and external vertebral and spinal plexuses are partly drained. In addition to these anastomoses the lumbar veins are connected with one another and with common iliac, hypogastric, iliolumbar, renal, azygos and hemiazygos veins, or some of these, by means of the *ascending lumbar veins* (p. 736).

(5) The **inferior phrenic** veins [v. phrenica inferior] follow the course of the inferior phrenic arteries; the right opens into the vena cava direct; the left into the suprarenal, the left renal, or the vena cava.

(6) The **hepatic** veins [vv. hepaticæ], the largest visceral tributaries of the vena cava, return the blood from the liver. Commencing in the substance of

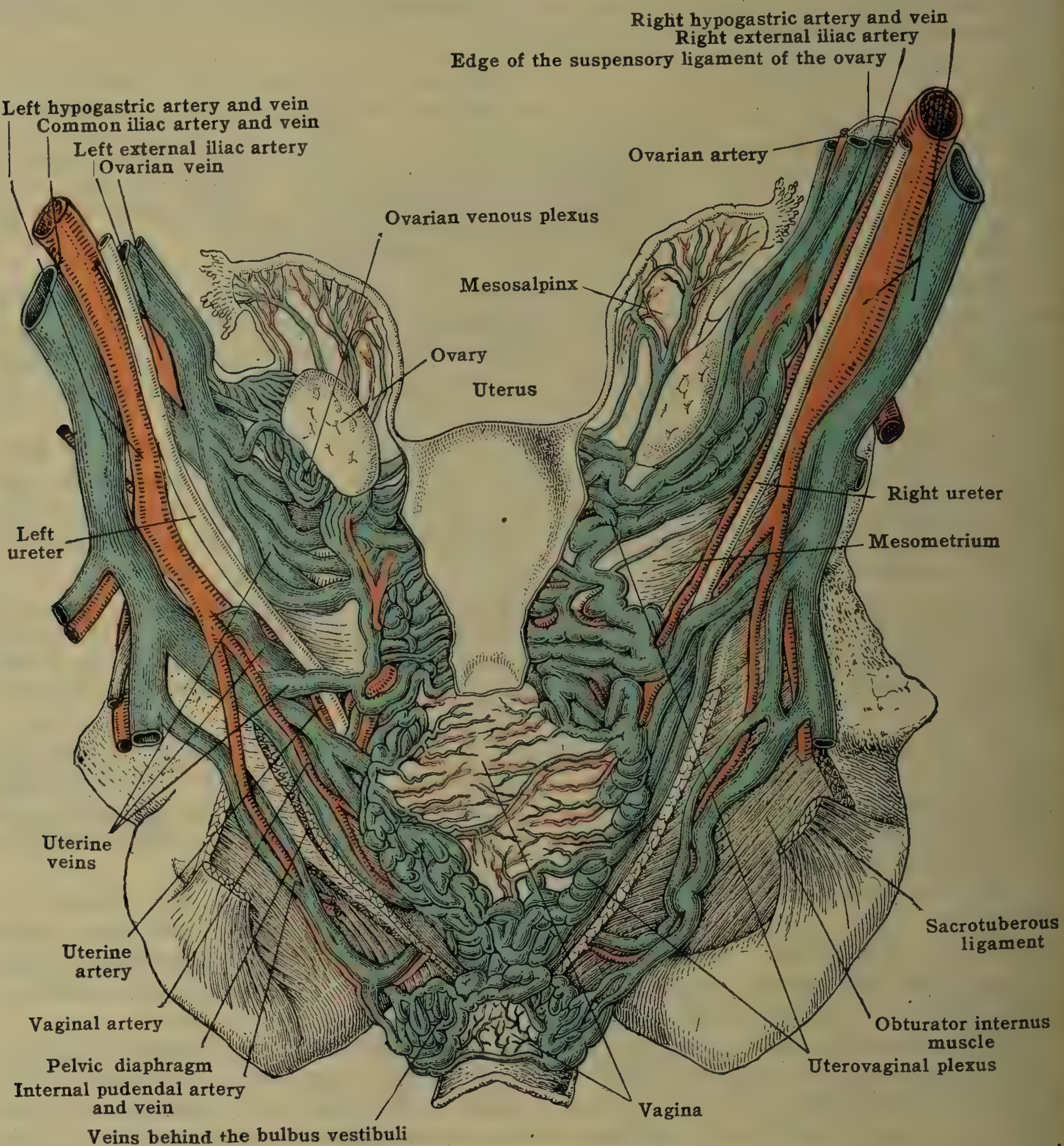


Fig. 607.—The Veins of the Female Pelvis. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

the liver (see Liver), they converge as they approach its posterior surface, and unite to form two or three large trunks, which open into the vena cava as it lies in the fossa venæ cavæ.

Some smaller vessels from the caudate lobe, and other parts of the liver in the neighborhood of the caval fossa, open directly into the vena cava. The hepatic veins contain no valves, but, in consequence of opening obliquely into the vena cava, a semilunar fold occurs at the lower margin of each orifice. The hepatic veins transmit the blood brought into the liver by both the hepatic artery and the portal vein.

THE PORTAL VEIN

The veins corresponding to the inferior mesenteric, the superior mesenteric, and to some of the branches of the celiac artery, do not join the vena cava infe-

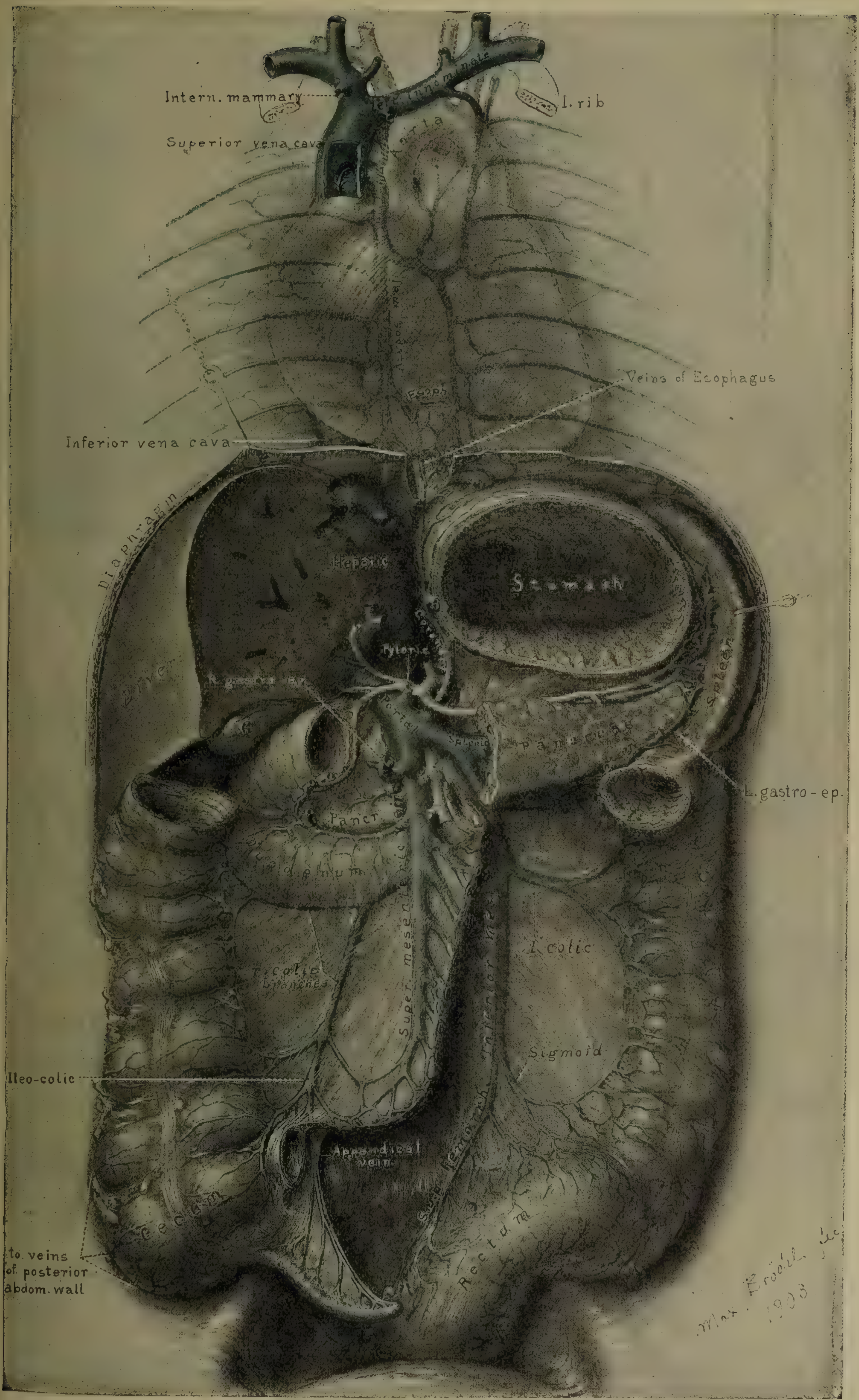


FIG. 608.—THE PORTAL VEIN. (From Kelley, by Brödel.)

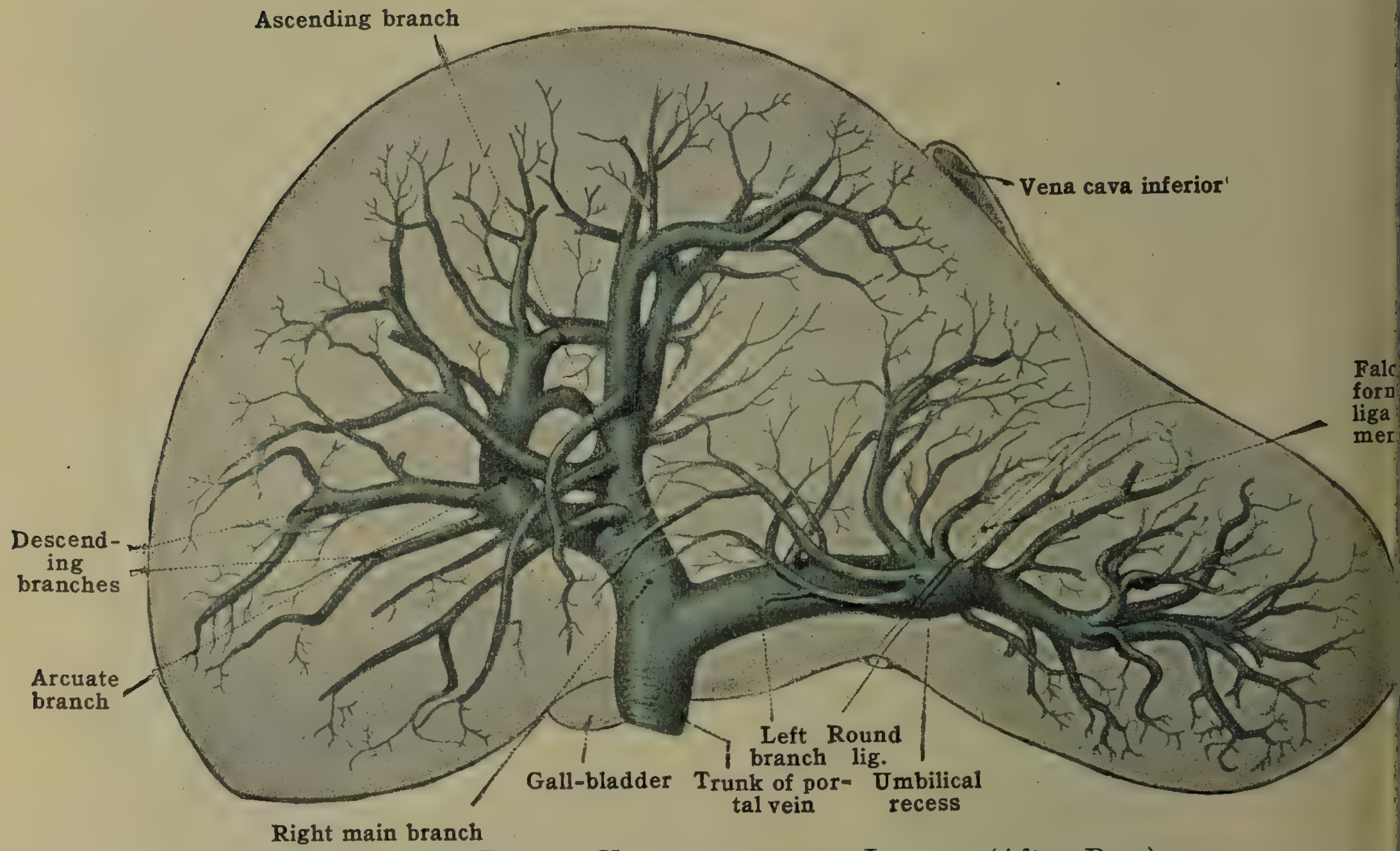


FIG. 609.—THE PORTAL VEIN WITHIN THE LIVER. (After Rex.)

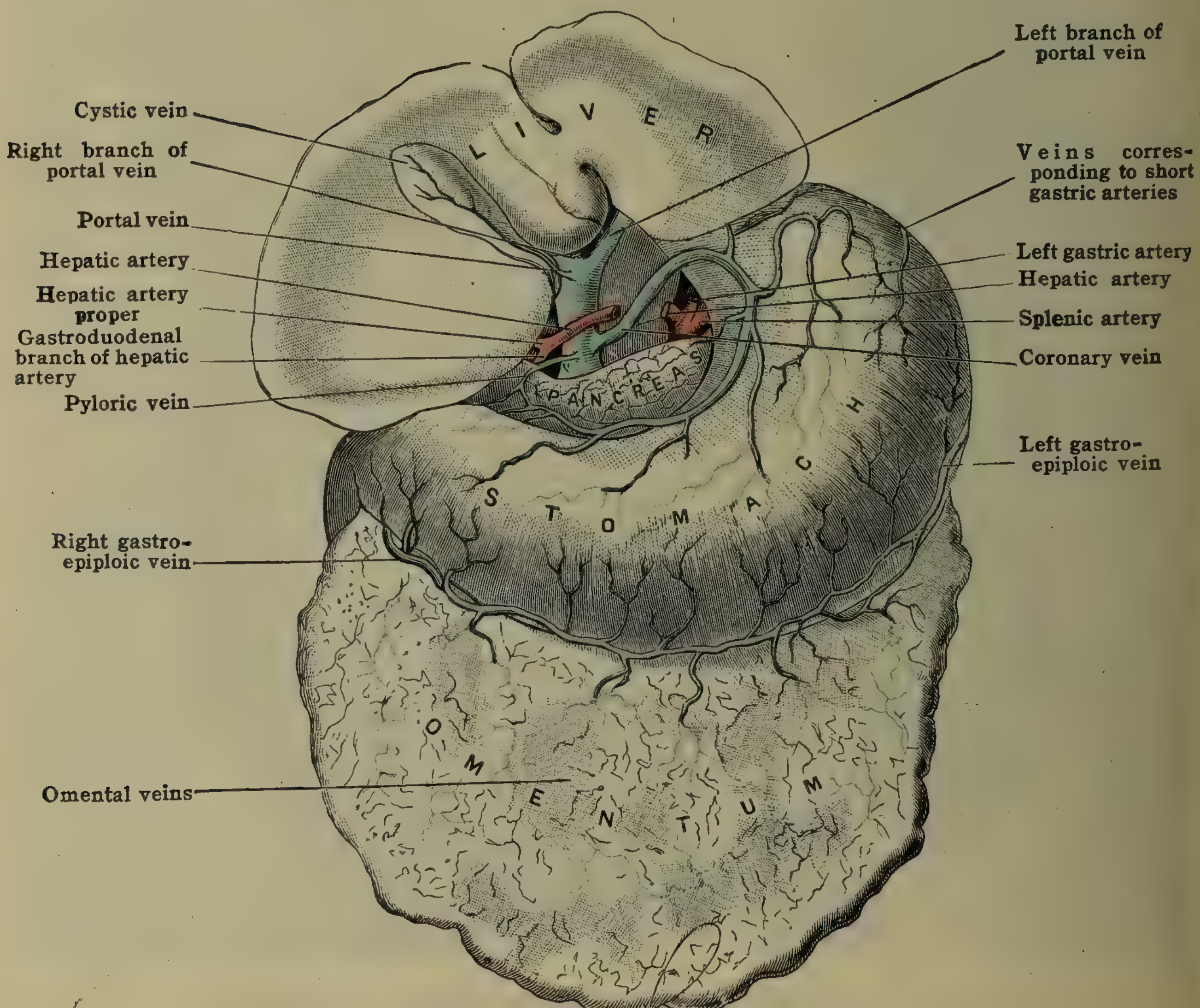


FIG. 610.—THE VEINS OF THE STOMACH AND THE PORTAL VEIN. (From a dissection by W. J. Walsham.)

rior directly, but unite to form a common trunk—the **portal vein.** This vein enters the liver, and breaks up in its substance into **sinusoids** from which the blood is again ultimately collected by the hepatic veins, and carried by them into the vena cava inferior. The portal vein and its larger tributaries have no valves in the adult.

A few valves are found at birth in the tributaries of the gastroepiploic and the coronary vein and in the veins from the colon, but practically all of these are lost before maturity.

The **portal** vein [v. portæ] (fig. 608), is a thick trunk 7 or 8 cm. (3 in.) in length. It is formed behind the neck of the pancreas, opposite the right side of the body of the second lumbar vertebra, by the union of the superior mesenteric with the splenic vein. It passes upward and to the right behind the superior part of the

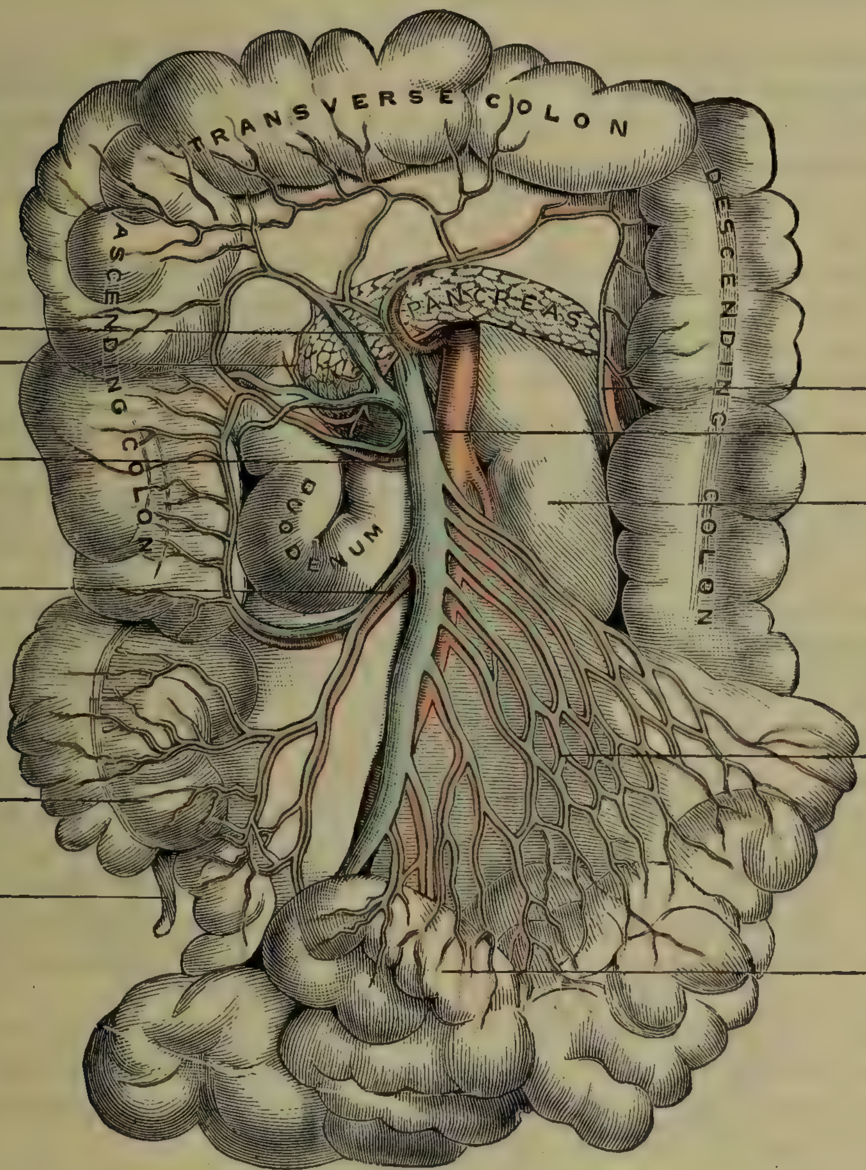


Fig. 611.—The Superior Mesenteric Vein.
(The colon is turned up, and the small intestines are drawn over to the left side.)

duodenum, and then between the layers of the lesser omentum. In the latter situation it passes in front of the foramen epiploicum and is accompanied by the hepatic artery and the bile-duct. Finally it enters the porta of the liver, and there divides into a right and a left branch.

In this course the hepatic artery and the common bile-duct are in front the, former to the left, the latter to the right. It is surrounded by branches of the hepatic plexus of the sympathetic nerve, and by numerous lymphatic vessels and some glands. The connective tissue sheath enclosing these structures is called the **fibrous capsule of Glisson** [capsula fibrosa, Glissoni]. Just before it divides it is somewhat dilated, the dilated portion being called the **sinus of the portal vein.** The division into right and left branches takes place toward the right end of the porta of the liver. The **right branch** is shorter and thicker than the left, and supplies the right lobe of the liver and a branch to the quadrate lobe. The **left branch** is longer and smaller than the right, and supplies the left lobe, and gives a branch to the caudate (Spigelian) and quadrate lobes. It is joined, as it crosses the left sagittal fossa, by a fibrous cord, known as the **ligamentum teres hepatis.** This represents the wall of the left *vena umbilicalis,* which throughout the greater part of embryonic life is the only channel through which arterial blood is transmitted from the placenta. Opposite this is a second fibrous cord, the **ligamentum venosum** (obliterated **ductus venosus**) which passes from the left portal branch to the hepatic part of the vena cava

inferior. The position of the original course of the umbilical vein across the left portal is marked, in adult life, by a dilation of the latter vein, called the **umbilical recess** (fig. 609).

Tributaries.—The portal vein receives (1) the pyloric; (2) the coronary (gastric); (3) the cystic; (4) the superior mesenteric; and (5) the splenic veins.

1. The **pyloric** vein (figs. 608, 610) begins near the pylorus in the lesser curve of the stomach, and, running from left to right with the right gastric artery, opens directly into the lower part of the portal vein. It receives branches from the pancreas and duodenum.

2. The **coronary** vein [v. coronaria ventriculi] (figs. 608, 610) runs with the left gastric artery, first from right to left, along the lesser curvature of the stomach, toward the cardiac end, and then, turning to the right, passes across the spine from left to right and downward to end in the portal trunk, a little higher than the pyloric vein. At the cardiac end of the stomach it receives small branches from the esophagus.

3. The **cystic** vein [v. cystica] (fig. 610) returns the blood from the gall-bladder. It usually opens into the right branch of the portal vein.

4. The **superior mesenteric** vein [v. mesenterica superior] (fig. 611) begins in tributaries which correspond to the branches of the superior mesenteric artery. It courses upward a little in front and to the right of the artery, between the layers of the mesentery. It passes in front of the inferior portion of the duodenum, and behind the neck of the pancreas, where it joins the splenic vein to form the portal trunk (fig. 608).

Tributaries.—In addition to the tributaries corresponding to the branches of the superior mesenteric artery—viz. the **ileocolic, right colic, middle colic** and **intestinal** veins (fig. 611)—it receives the **right gastroepiploic** vein and the **pancreaticoduodenal** vein just before its termination in the portal vein.

The **right gastroepiploic** vein [v. gastroepiploica dextra] (fig. 610) accompanies the artery of that name. It runs from left to right along the greater curvature of the stomach, receiving branches from the anterior and posterior surfaces of that viscus, and from the greater omentum, and, passing behind the superior portion of the duodenum, ends in the superior mesenteric vein just before that vessel joins the portal trunk. In fig. 608, it apparently joins with the middle colic vein.

The **pancreatioduodenal** veins [vv. pancreaticoduodenales] (fig. 608) run with the superior and inferior pancreaticoduodenal arteries between the head of the pancreas and the second portion of the duodenum. They receive **pancreatic** and **duodenal** veins [vv. pancreaticæ et duodenales] and are collected into a single stem which follows the inferior pancreaticoduodenal artery and ends in the superior mesenteric vein a little below the right gastroepiploic vein.

5. The **splenic** vein [v. lienalis] (fig. 608) issues as several large veins from the hilus of the spleen. These soon unite to form a trunk, which passes across the left kidney and suprarenal and their veins in company with the splenic artery, below which it lies, to join the superior mesenteric vein at nearly a right angle. In this course it lies behind the pancreas; and at its union with the superior mesenteric to form the vena porta it is in front of the left margin of the vena cava inferior.

Tributaries.—The splenic vein receives the **short gastric** veins [vv. gastricæ breves], from the fundus of the stomach, the **left gastroepiploic** vein, and the **inferior mesenteric** vein. As it lies in contact with the pancreas it receives also some small **pancreatic** veins [vv. pancreaticæ].

The **left gastroepiploic** vein [v. gastroepiploica sinistra] (fig. 610) accompanies the left gastroepiploic artery. It runs from right to left along the greater curvature of the stomach, receives branches from the stomach and omentum, and opens into the commencement of the splenic vein.

The **inferior mesenteric** vein [v. mesenterica inferior] (fig. 612) begins at the rectum as the superior hemorrhoidal vein (v. rectalis cranialis NK). This emerges from the hemorrhoidal plexus (plexus rectalis NK) in which it communicates freely with the middle and inferior hemorrhoidal veins. It passes out of the pelvis with the inferior mesenteric artery; but, after receiving the **sigmoid** and **left colic** veins [vv. sigmoideæ et v. colica sinistra] which accompany the arteries of the same names, it leaves the artery and runs upward on the psoas to the left of the aorta and behind the peritoneum. On approaching the pancreas it turns medially, and passes obliquely behind that gland to join the splenic vein just before the latter unites with the superior mesenteric to form the vena porta.

The absence of valves adversely affects the circulation of blood within the portal system. The liability to excessive pressure in the most dependent part of it, is evidenced by the great frequency of the condition known as piles (hemorrhoids), due to dilation of the veins of the internal hemorrhoidal plexus.

The accessory portal veins.—Since the blood returning from the abdominal portion of the digestive tract and spleen must pass through the hepatic capillaries before returning to the heart, extensive obliteration of these capillaries, such as occurs in certain diseases of the liver, would prevent the return of the portal blood to the heart were it not for anastomoses between tributaries of the portal vein and those of the caval systems, constituting what have been termed accessory portal veins. Some of the more important of these are—(1) between the branches of the coronary vein of the stomach and the esophageal veins which open into the vena azygos; (2) between the **parumbilical** veins [vv. parumbilicales], which communicate with the portal vein above and descend upon the ligamentum teres to the anterior abdominal wall to anastomose with the superior and inferior epigastric and superior vesical veins; (3) between the superior hemorrhoidal veins with the middle and inferior hemorrhoidal veins, which are drained directly or indirectly into the hypogastric, and (4) between a wide-meshed retroperitoneal plexus of veins which communicates with the portal vessels over the posterior surface of the liver and the veins of the pancreas, duodenum and ascending and descending colon on the portal side, and with the phrenic and azygos veins on the systemic.

THE COMMON ILIAC VEINS

The **common iliac** veins [vv. iliacæ communes], (fig. 613) are formed opposite the sacroiliac articulation by the confluence of the external iliac and hypogastric (internal iliac) veins. They converge as they ascend, and unite oppo-

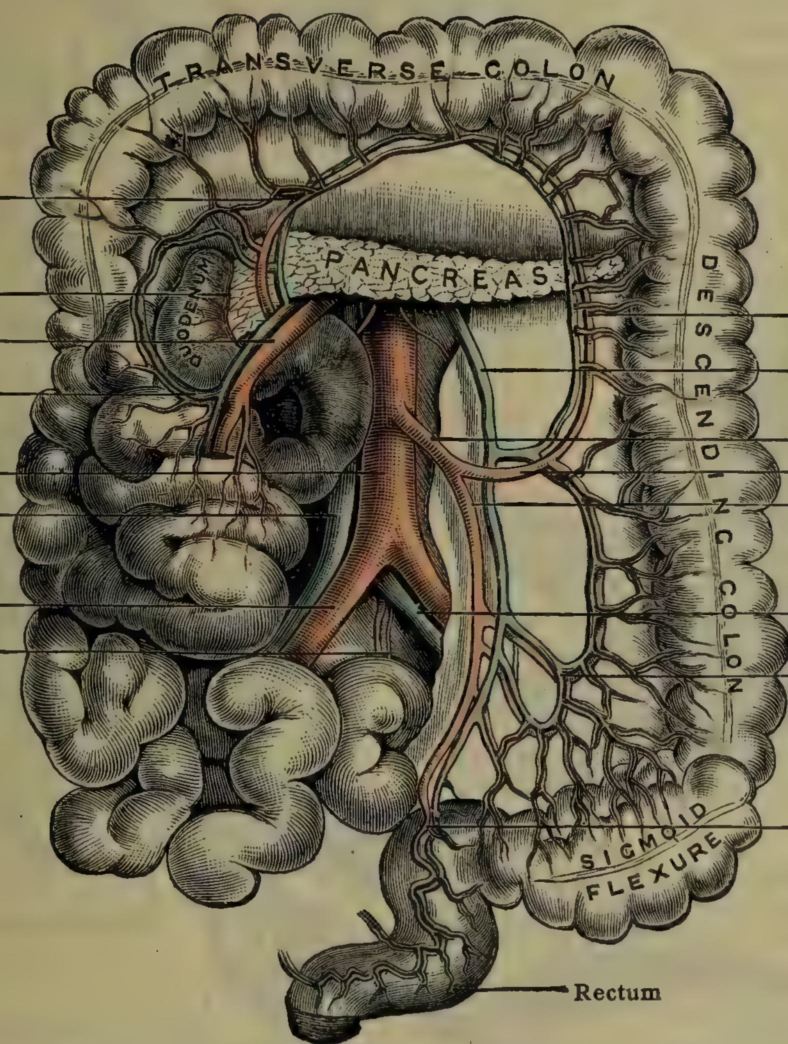


FIG. 612.—THE INFERIOR MESENTERIC VEIN.
(The colon is turned up, and the small intestines are drawn to the right side.)

site the upper border of the fifth lumbar vertebra and a little to the right of the median line to form the vena cava inferior.

The **right** vein, shorter and more vertical in direction than the left, passes obliquely behind the right common iliac artery to its lateral side, where it is joined by the left common iliac vein.

The **left** vein lies to the medial side of the left common iliac artery, and, after crossing in front of the promontory of the sacrum and the fifth lumbar vertebra below the bifurcation of the aorta, passes beneath the right common iliac artery to join the right vein and form the vena cava inferior. Valves may occur but are usually not present.

Tributary.—The iliolumbar veins may enter the lower part of the common iliac, or open into the hypogastric vein. The left vein receives the middle sacral vein.

The **middle sacral** vein [v. sacralis media] opens usually as a single trunk into the left common iliac vein. The venæ comitantes which form it ascend on either side of the middle sacral artery in front of the sacrum. They communicate with the lateral sacral veins, forming the **anterior sacral plexus** [plexus sacralis anterior] which receives the sacral intervertebral veins, and anastomoses freely with the neighboring lumbar and pelvic veins. Below, the middle sacral veins communicate with the hemorrhoidal veins.

THE VEINS OF THE PELVIS

The veins of the pelvis consist of the hypogastric vein, the spermatic or ovarian veins (according to sex) and the middle sacral vein. The spermatic and ovarian veins (p. 745) and the middle sacral vein have already been described.

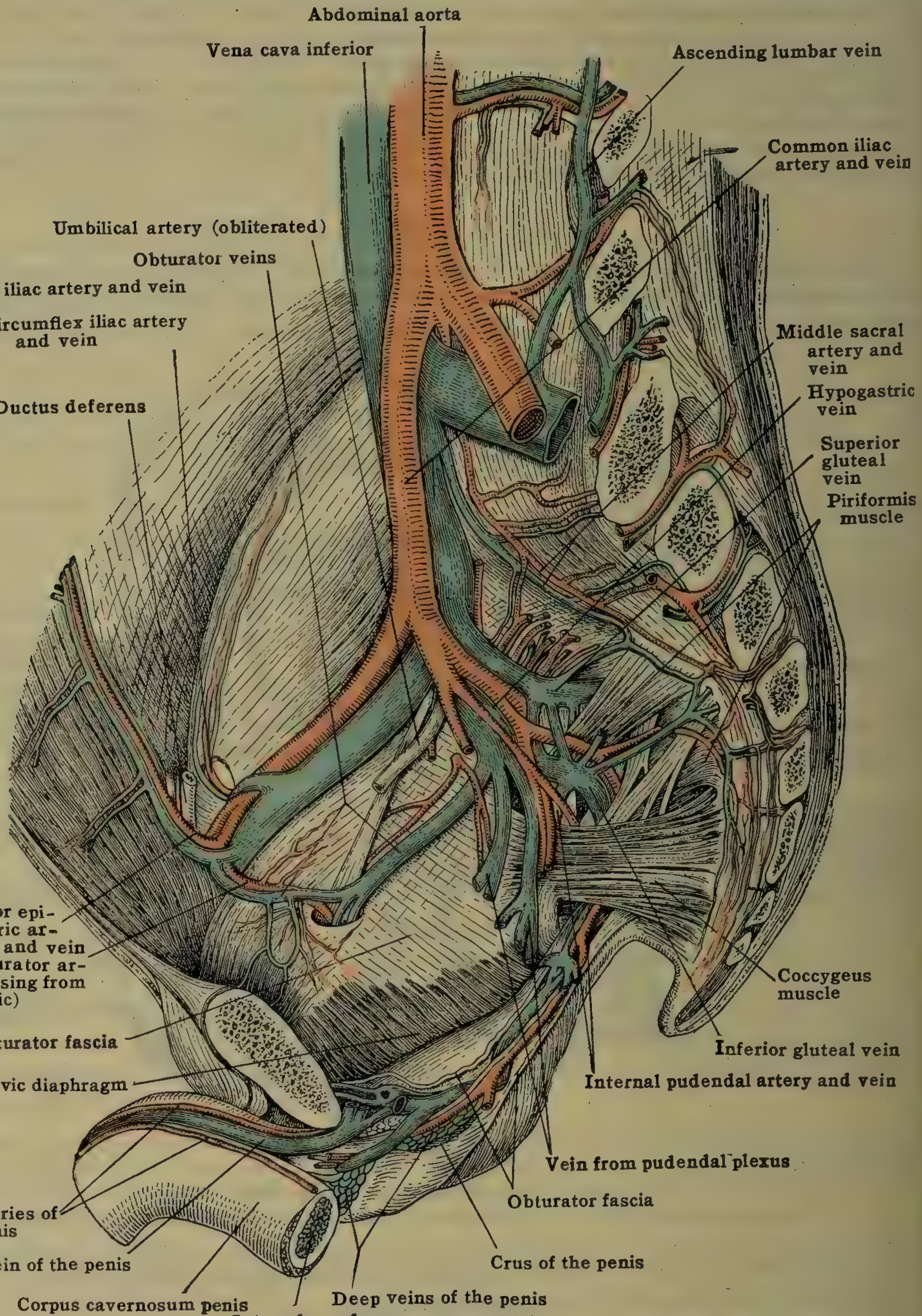


FIG. 613.—THE VEINS OF THE PELVIS, MALE. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

THE HYPOGASTRIC VEIN

The **hypogastric (internal iliac)** vein [v. hypogastrica] (or v. ilica interna NK) (fig. 613) is formed by the confluence of the veins (except the umbilical) corresponding to the branches of the hypogastric artery on each side. It varies considerably in length, but is usually quite a short trunk, extending from the upper part of the great sciatic foramen to the sacroiliac articulation, where it joins the external iliac to form the common iliac vein. It lies behind and a little medially to the hypogastric artery. It contains no valves.

Tributaries.—The hypogastric vein receives directly or indirectly the following vessels on each side:—the superior gluteal, iliolumbar, lateral sacral, obturator, inferior gluteal (sciatic), internal pudendal, and (in the female) the uterine veins; also branches from the pudendal, vesical, and hemorrhoidal plexuses. The **single umbilical vein**—corresponding to the right and left umbilical arteries—does not enter the pelvis, but, leaving the umbilical arteries at the navel, passes along the falciform ligament to the liver. After birth it is converted into the ligamentum teres hepatis. (See PORTAL VEIN, p. 749.)

The **superior gluteal** veins [vv. gluteæ superiores] (fig. 613) accompany the superior gluteal artery and, passing through the upper part of the great sciatic foramen, open into the hypogastric vein near its termination, either separately or as a single trunk.

The **iliolumbar** veins [vv. iliolumbales] open into the hypogastric a little higher than the superior gluteal. At times they join the common iliac vein.

The **lateral sacral** veins [vv. sacrales laterales] (fig. 613) join the superior gluteal or the hypogastric at or about the same situation as the gluteal. They form with the middle sacral veins a plexus in front of the sacrum, which receives tributaries from the sacral canal.

The **obturator** vein [v. obturatoria] (fig. 613), which lies below the obturator artery as it crosses the side of the pelvis, opens into the front of the hypogastric vein or into the inferior epigastric vein, or into both. Its branches correspond to those of the artery.

The **inferior gluteal** vein [vv. gluteæ inferiores] accompany the inferior gluteal (sciatic) artery, and, as a rule, unite to form a single trunk before joining the hypogastric a little below the obturator vein.

All the above veins so closely follow the ramifications of their respective arteries that no further special description is required. They all contain valves.

The **internal pudendal** vein [v. pudenda interna] (fig. 613) begins at the termination of the deep veins of the penis [vv. profundæ penis] which issue from the corpus cavernosum penis with the artery of that body. These veins communicate with the dorsal vein at the root of the penis. In its course the internal pudendal vein runs with the internal pudendal artery, receiving tributaries corresponding to the branches of that vessel. It terminates in the lower part of the hypogastric vein.

The **dorsal vein of the penis** [v. dorsalis penis] (fig. 613) begins in a plexus around the corona glandis, then runs along the mid-dorsal line of the penis between the two dorsal arteries. In this course it receives large tributaries from the interior of the organ, the *deep veins of the penis* [vv. profundæ penis]. These emerge for the most part between the corpus cavernosum urethrae and corpus cavernosum penis, wind obliquely over the lateral surface of the latter structure to the dorsum of the penis and end in the dorsal vein. At the root of the penis the dorsal vein communicates with the subcutaneous veins of the dorsum of the penis and, leaving the arteries, passes straight backward between the two layers of the suspensory ligament. It then goes between the arcuate ligament and the transverse ligament of the pelvis, formed by the upper part of the fascia of the urogenital diaphragm. Here it bifurcates, each branch passing backward and downward to the pudendal plexus of veins. At times the dorsal vein begins as two branches, which run between the dorsal arteries and only unite to form a single trunk about 3.7 cm. (1½ in.) from the symphysis. After dividing into a right and a left branch within the pelvis, each vessel generally communicates with the obturator vein by a branch passing over the back of the pubis to the obturator foramen.

The **pudendal plexus** [plexus pudendalis] surrounds the prostate and the neck of the bladder. It receives in front the right and left divisions of the dorsal veins of the penis, and communicates with the posterior scrotal veins [vv. scrotales posteriores] and with the hemorrhoidal plexus. The prostatic veins and the vesical plexus open into it, and it also communicates with the internal pudendal vein. The veins forming the plexus are of large size, especially in old men, in whom they often become varicose, and contain phleboliths, or vein-stones. The plexus is surrounded by the *fascia prostatæ* (prostatic sheath); it terminates in a single stem on each side which opens into the hypogastric vein.

In the female the smaller pudendal plexus surrounds the urethra and the lower part of the vagina, and is contained in a fibrous sheath similar in structure to the prostatic sheath of the male. It receives the **dorsal and deep veins of the clitoris** [vv. dorsales et profundæ clitoridis], veins from the vestibule, and the **posterior labial** veins [vv. labiales posteriores]. It communicates freely with the uterovaginal plexus and is drained by the hypogastric veins.

The **vesical plexus** [plexus vesicalis] surrounds the apex, the sides, and the anterior and posterior surfaces of the bladder. It is situated between the muscular coat and the peritoneum, and where the bladder is uncovered by peritoneum external to the muscular coat in the pelvic cellular tissue. It opens into the pudendal plexus, with which it forms the plexus vesicopudendalis (NK).

The **uterovaginal plexus** [plexus uterovaginalis] connects with the hemorrhoidal, vesical, and uterine plexuses. Its lower part drains through the internal pudendal veins and the pudendal plexus, and its upper portion largely through the ovarian veins, and partly through the **uterine veins** [vv. uterinæ] to the hypogastric (fig. 607).

The **hemorrhoidal plexus** [plexus hemorrhoidalis] (plexus rectalis NK) surrounds the rectum, and is situated at the lower part of that tube. It consists of two portions, one of which, the internal hemorrhoidal plexus, is situated between the muscular and mucous coats, while the other, the external hemorrhoidal plexus, rests upon the outer surface of the muscular coat. The veins of this latter plexus terminate in the inferior, middle, and superior hemorrhoidal

veins. The **inferior** [vv. hemorrhoidales inferiores] (vv. anales NK) join the internal pudendal; the **middle** [v. hemorrhoidalis media] accompanies the middle hemorrhoidal artery and opens into the hypogastric and superior hemorrhoidal veins; the **superior** (p. 750) forms the com-

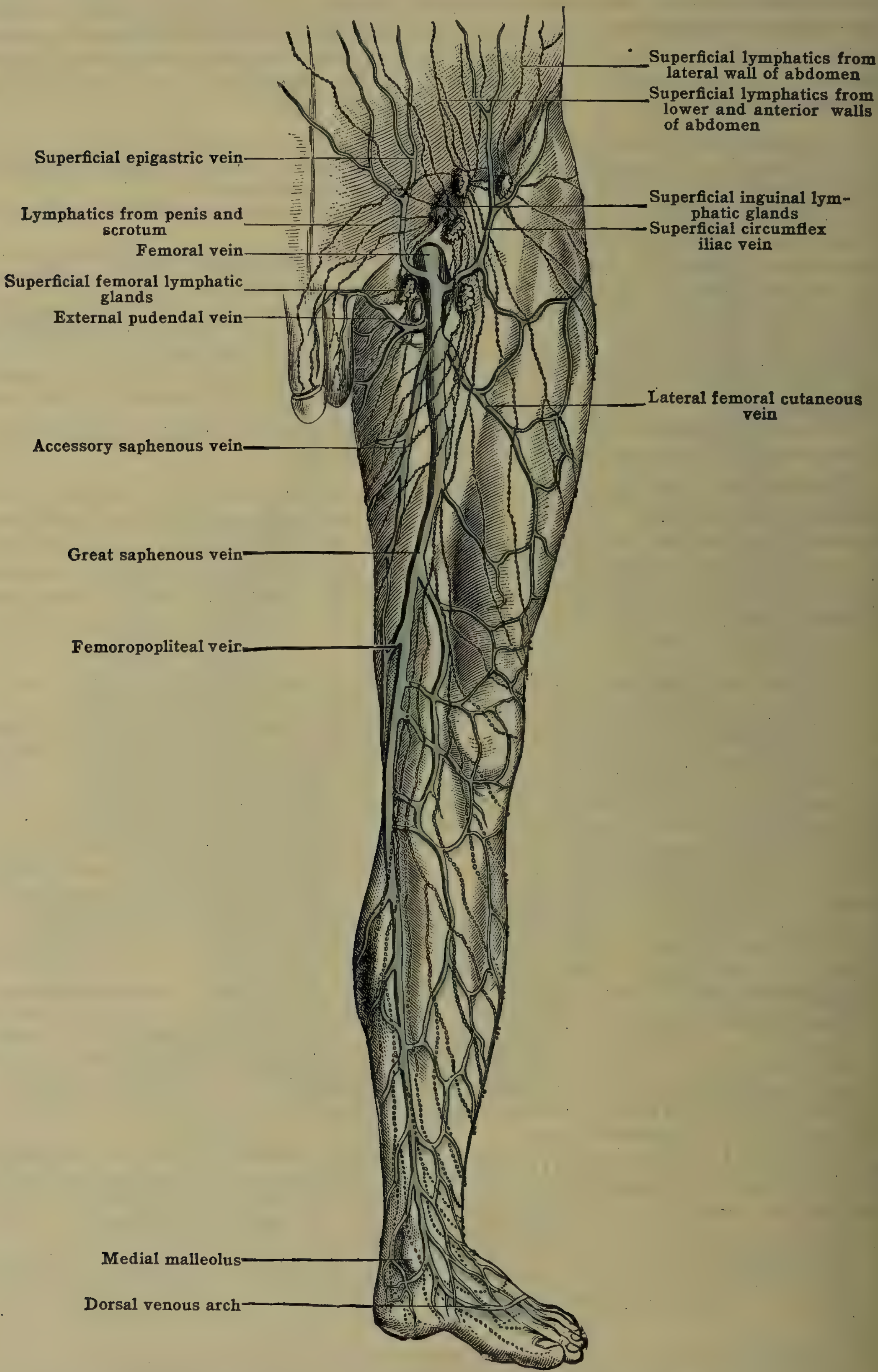


FIG. 614.—THE SUPERFICIAL VEINS AND LYMPHATICS OF THE LEFT LOWER LIMB. (Walsham.)

mencement of the inferior mesenteric vein, and through this the blood reaches the portal vein. None of these veins has any valves, hence the enlargement of the inferior hemorrhoidal veins, when the portal vein is obstructed, as in cirrhosis of the liver. Through the hemorrhoidal veins a free communication is established between the systemic and portal system of veins.

THE EXTERNAL ILIAC VEIN

The **external iliac** vein [v. iliaca externa] (fig. 613), is the upward continuation of the femoral. Beginning at the distal border of the inguinal ligament, it accompanies the external iliac artery along the brim of the minor pelvis, lying at first on the superior ramus of the pubis, and then on the psoas major muscle. It terminates by joining the hypogastric vein behind the hypogastric artery, opposite the sacroiliac articulation, to form the common iliac vein. It lies at first medially to the external iliac artery, and on the left side remains medial to the artery throughout its course. On the right side, however, as it ascends, it gradually gets behind the artery. It contains one or two valves.

In addition to the femoral, the external iliac receives the **inferior epigastric** vein [v. epigastrica inferior] (fig. 613) and the **deep circumflex iliac** vein [v. circumflexa ilium profunda] (fig. 618), which accompany the arteries of the same name. They anastomose with the superior epigastric, lumbar, iliolumbar, and superior gluteal veins, and with the superficial epigastric and superficial circumflex iliac veins.

THE VEINS OF THE LOWER EXTREMITY

The **veins of the lower extremity** are divided into (1) the superficial and (2) the deep. The **superficial** veins lie in the subcutaneous tissue superficial to the deep fascia, through which they receive numerous communicating branches from the deep veins. They are collected chiefly into two main trunks, which, beginning on the foot, extend upward, one, the great saphenous, lying anteromedially, and the other, the small saphenous, posterolaterally. The former finally joins the femoral vein by passing through the deep fascia at the groin; the latter reaches the popliteal by perforating the fascia at the ham. The **deep** veins, on the other hand, accompany their corresponding arteries. All the veins of the lower limb have valves which are more numerous than in the veins of the upper extremity and more numerous in the deep than in the superficial veins.

THE SUPERFICIAL VEINS OF THE LOWER EXTREMITY

The **superficial veins of the lower limb** begin in the plexuses of the foot. The **dorsal digital** veins [vv. digitales pedis dorsales] collect blood from the dorsal surfaces of the toes and unite in pairs, around each cleft, to form the **dorsal metatarsal** veins [vv. metatarseæ dorsales pedis]. The dorsal metatarsal veins, of which the first and fifth are larger than the others, join the **dorsal venous arch** [arcus venosus dorsalis pedis]. This arch is convex toward the toes and crosses near the bases of the metatarsal bones. From the medial and lateral ends of the arch the great and small saphenous veins, respectively, take origin. The area of the dorsum of the foot contained between the arch and the two saphenous veins is covered by the **dorsal venous rete** (rete venosum dorsale pedis] which extends as high as the ankle-joint (figs. 614, 615).

On the plantar surface the **plantar digital** veins [vv. digitales plantares] return the venous blood to the clefts of the toes and unite to form the **common digital** veins [vv. digitales communes pedis]. The common digital veins join freely with one another on the sole to form the **plantar venous rete** [rete venosum plantare]. There are numerous communications between the superficial veins of the dorsum and sole. These occur both in the clefts of the toes, by means of the **intercapitular** veins [vv. intercapitulares], and around the margins of the foot. Communications between the superficial and deep veins of the foot are very free (fig. 616).

The **great** (or internal) **saphenous** vein (v. saphena magna] (fig. 614) commences at the medial end of the dorsal venous arch, and, after receiving branches from the sole which join it by turning over the medial border of the foot, it turns proximally in front of the medial malleolus. It passes about a finger's breadth behind the medial border of the tibia in company with the saphenous nerve, which becomes superficial just below the knee. It then passes behind the medial epicondyle, and then runs up on the medial side of the front of the thigh to about 3.7 cm. (1¼ in.) below the inguinal ligament, where it dips through the fossa ovalis (saphenous opening) in the fascia lata, and ends in the femoral vein.

Tributaries.—In its course through the leg and thigh the great saphenous receives numerous unnamed cutaneous tributaries. In the thigh it often receives a large vein, the femoropopliteal which communicates with the small saphenous, and several of the cutaneous veins on the lateral part of the thigh, and a second vein, the **accessory saphenous** [v. saphena accessoria], formed by the union of the cutaneous veins from the medial and back part of the thigh (fig. 614). The great saphenous vein contains from six to twenty valves.

Immediately before entering the fossa ovalis the great saphenous vein receives the superficial epigastric, superficial circumflex iliac, and external pudendal veins, though any of these veins—or all of them—may pierce the fascia separately and enter the femoral vein.

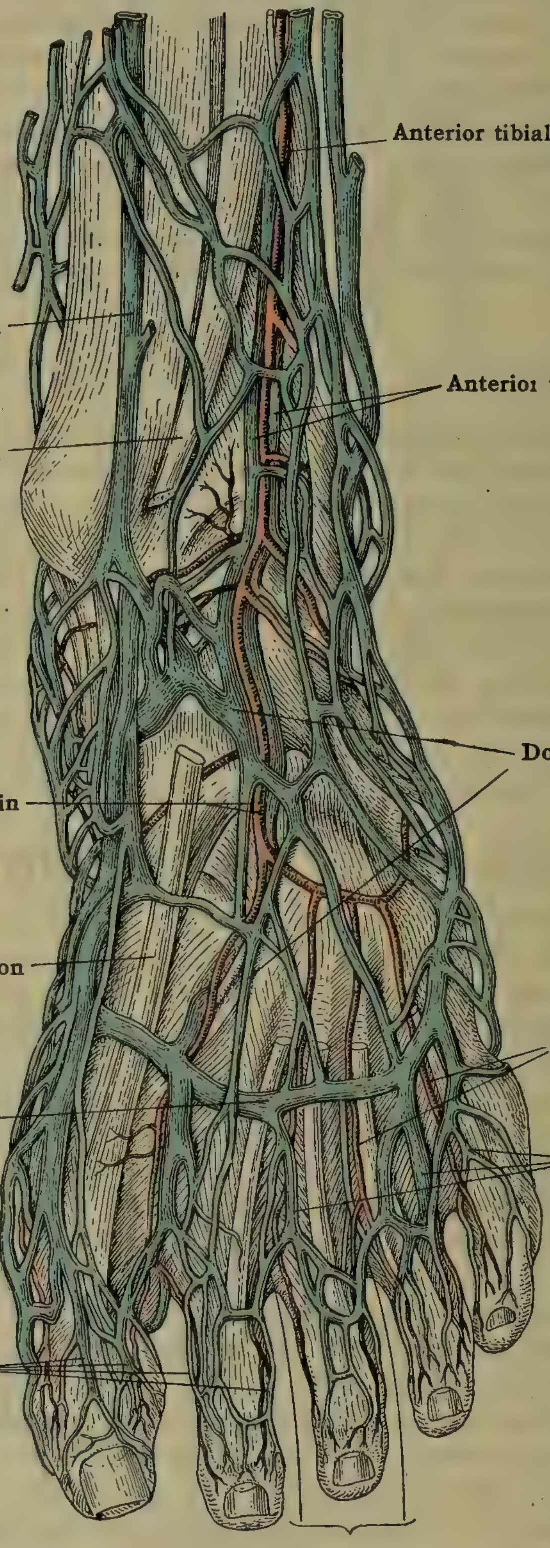


FIG. 615.—THE VEINS OF THE DORSUM OF THE FOOT. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

The **superficial epigastric** vein [v. epigastrica superficialis] anastomoses with the superficial abdominal, and parumbilical veins.

The **superficial circumflex iliac** vein [v. circumflex ilium superficialis] anastomoses with the thoraco-epigastric and the superficial circumflex iliac veins.

The **external pudendal** veins [vv. pudendæ externæ] collect venous blood from the **anterior scrotal or labial veins**, which anastomose with the posterior scrotal or labial veins, and from the **subcutaneous veins of the dorsum of the penis** [vv. dorsales penis subcutaneæ].

The **small saphenous vein** [v. saphena parva] (fig. 617) begins at the lateral end of the venous arch on the dorsum of the foot. After receiving branches from

the sole, which turn over the lateral border of the foot, it passes behind the lateral malleolus, and turns proximally, passing at first along the lateral side of the tendo calcaneus (Achillis), afterward along the back of the calf, in company with the sural (short saphenous) nerve, to about the lower part of the popliteal fossa, where it perforates the deep fascia, and, sinking between the two heads of the gastrocnemius, opens into the popliteal vein.

Tributaries.—As it passes along the calf between the superficial and deep fascia, it receives numerous cutaneous veins from the heel, and the lateral side and back part of the leg, and communicates at intervals, through transverse or intermuscular branches, with the deep veins

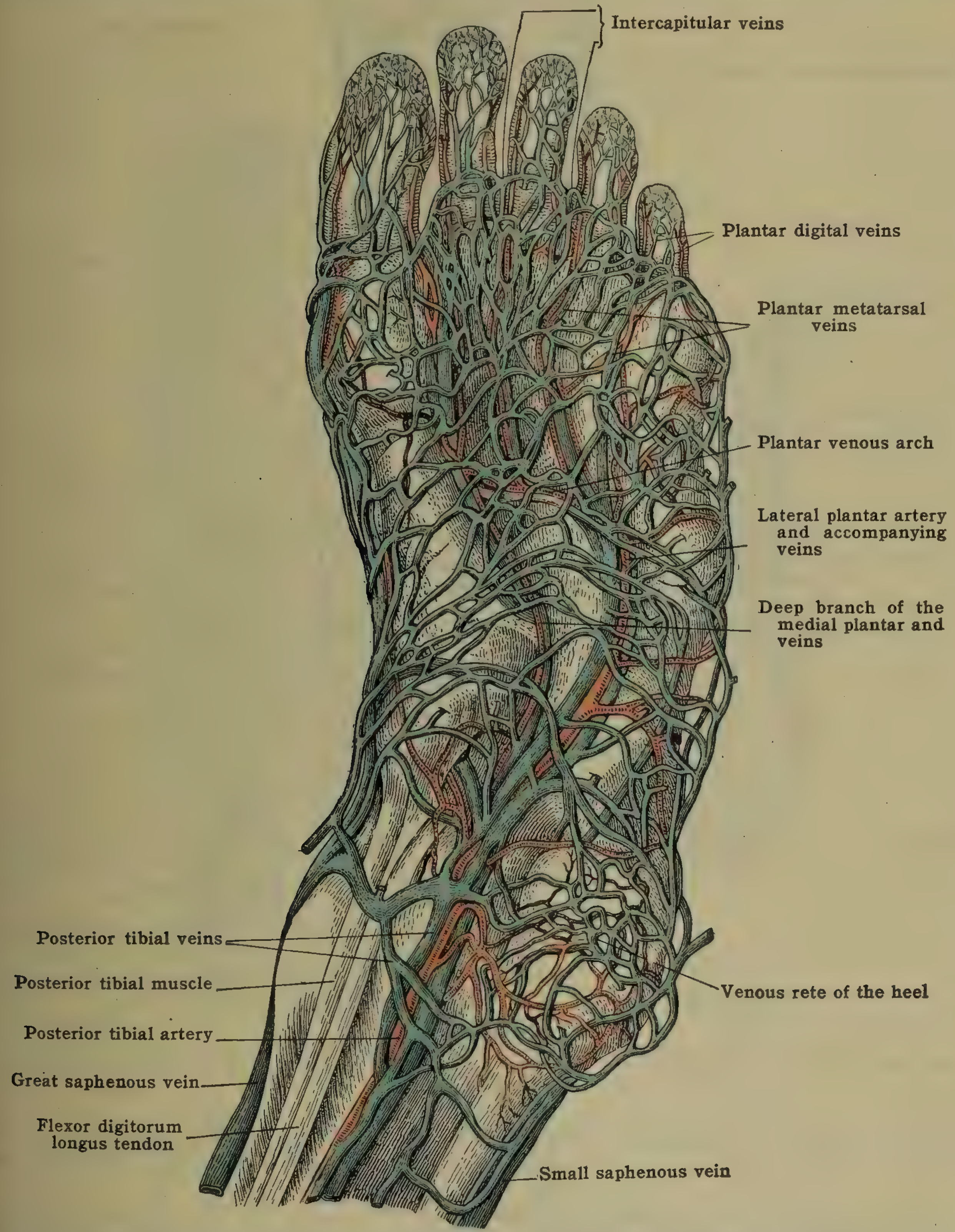


Fig. 616.—The Veins of the Sole of the Foot. (After Toldt, 'Atlas of Human Anatomy', The Macmillan Company.)

accompanying the peroneal artery. Just before perforating the deep fascia, it receives a large descending branch, the **vena femoropoplitea** (fig. 614), from the lower and back part of the thigh. This communicates with a plexus of veins upon the posterior and lateral regions of the thigh and with the great saphenous. In many cases the small saphenous vein is entirely drained, by means of the femoropopliteal, into the great saphenous. Under these circumstances the usual place of termination of the small saphenous is marked by a small vein opening into the popliteal. A small offshoot from the inferior sural branch of the popliteal artery accompanies this vein for a short distance along the back of the calf. The small saphenous vein contains from nine to twelve valves.

Clinical aspects of the saphenous veins are important, owing to the tendency of these and their branches to become varicose. The **great saphenous vein**, having passed from the arch on the dorsum over the medial malleolus, runs up close to the medial border of the tibia, where it is to be avoided in ligature of the posterior tibial, to the back of the medial condyle; here this vessel is to be remembered in operations on the knee-joint; then upward along the thigh, over the roof of the adductor (Hunter's) canal, to the fossa ovalis (saphenous opening) where it joins the femoral by perforating the cribriform fascia and the femoral sheath.

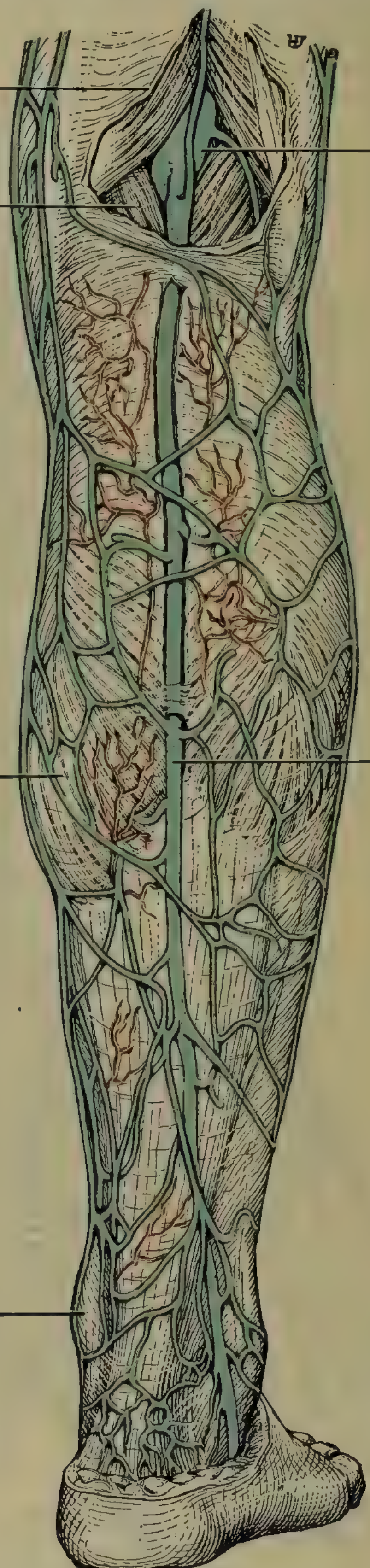


Fig. 617.—Small Saphenous Vein. (After Bonamy, Broca and Beau.)

The 'dangerous area,' or that in which thrombosis is most likely to occur, reaches from the center of the thigh to the middle of the leg (Bennett). The saphenous nerve joins the vein below the knee, having been under the sartorius above this point. The surface-marking of the upper part of the vein is a line drawn from the posterior border of the sartorius or the adductor tubercle to the lower part of the fossa ovalis.

THE DEEP VEINS OF THE LOWER EXTREMITY

The **deep veins of the lower extremity** [venæ comitantes] accompany the arteries, and have received corresponding names. From the foot to the knee

there are two veins to each artery. These veins run on either side of the corresponding artery, and communicate at frequent intervals with each other across it. From the knee upward there is a single main vein to each artery, except at the back of the thigh and in the gluteal region, where there are commonly two.

The veins of the foot and leg.—The deep veins of the foot become separated from the superficial where the **plantar metatarsal** veins [vv. metatarseæ plantares] leave the plantar digital and intercapitular veins to accompany the plantar metatarsal arteries. The plantar metatarsal veins empty into the **plantar venous arch** [arcus venosus plantaris] which accompanies the arterial plantar arch in the depth of the sole (fig. 616).

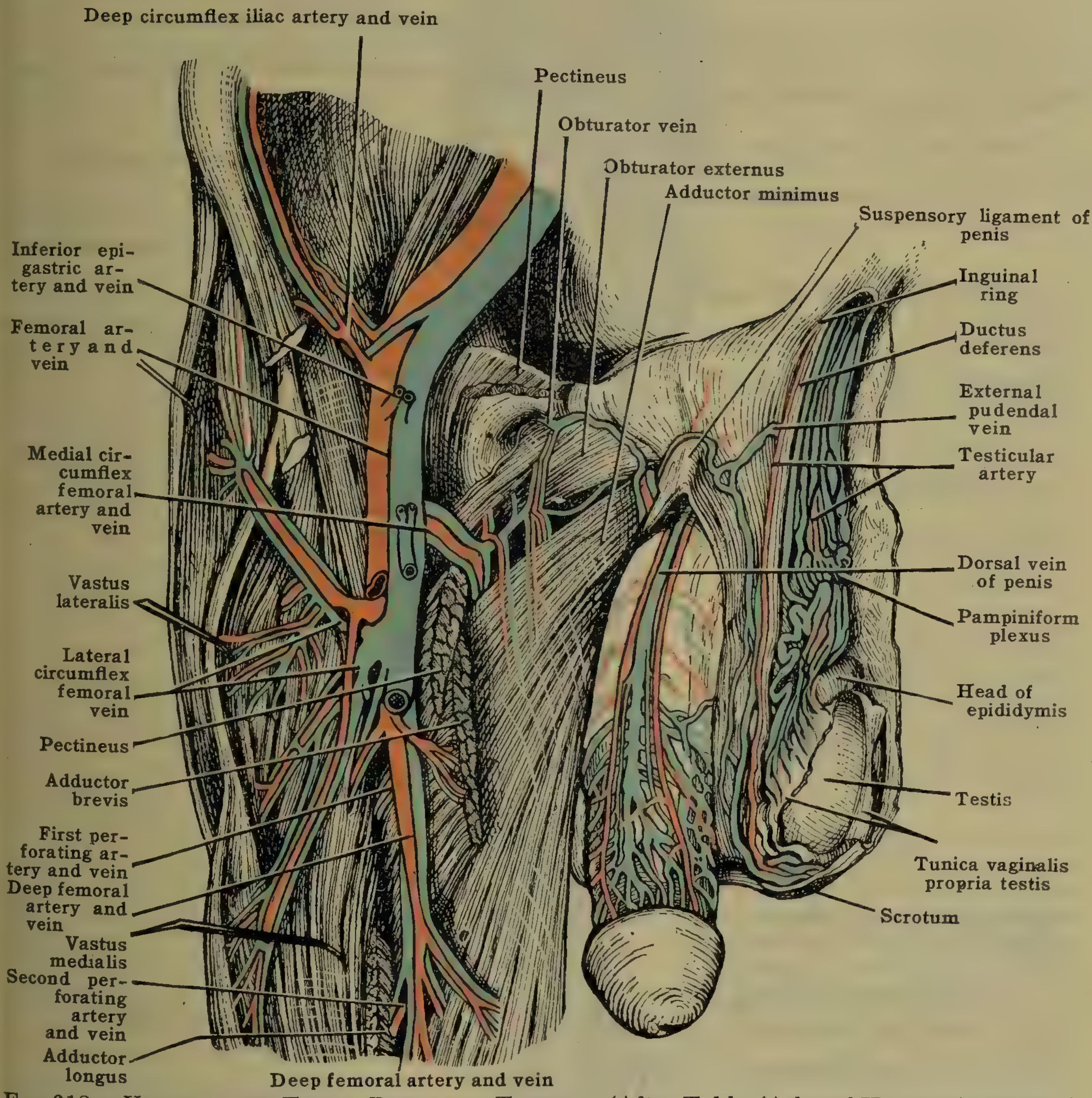


Fig. 618.—Veins of the Thigh, Penis and Testis. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The **posterior tibial** veins [vv. tibiales posteriores] drain the plantar venous arch and the superficial rete (fig. 619).

They follow the posterior tibial artery through the leg, receiving tributaries corresponding to its branches, the largest of which are the **peroneal veins** [vv. peroneæ]. They unite with the anterior tibial venæ comitantes at the lower border of the popliteus muscle.

The **anterior tibial** veins [vv. tibiales anteriores] begin in the dorsal venous rete and accompany the anterior tibial artery through the leg receiving tributaries corresponding to branches of the artery.

They pass backward between the interosseous membrane and the tibia and fibula to unite with the posterior tibial veins. The posterior and anterior tibial veins unite at the distal border of the popliteus muscle to form the popliteal vein.

All these veins contain numerous valves, and communicate, by means of intermuscular branches, with the superficial veins.

The **popliteal** vein [v. poplitea] (fig. 619), is formed by the confluence of the venæ comitantes of the anterior and posterior tibial arteries at the distal border of the popliteus, and extends proximally to the opening in the adductor magnus at the junction of the middle and distal third of the thigh, where it changes its name to femoral.

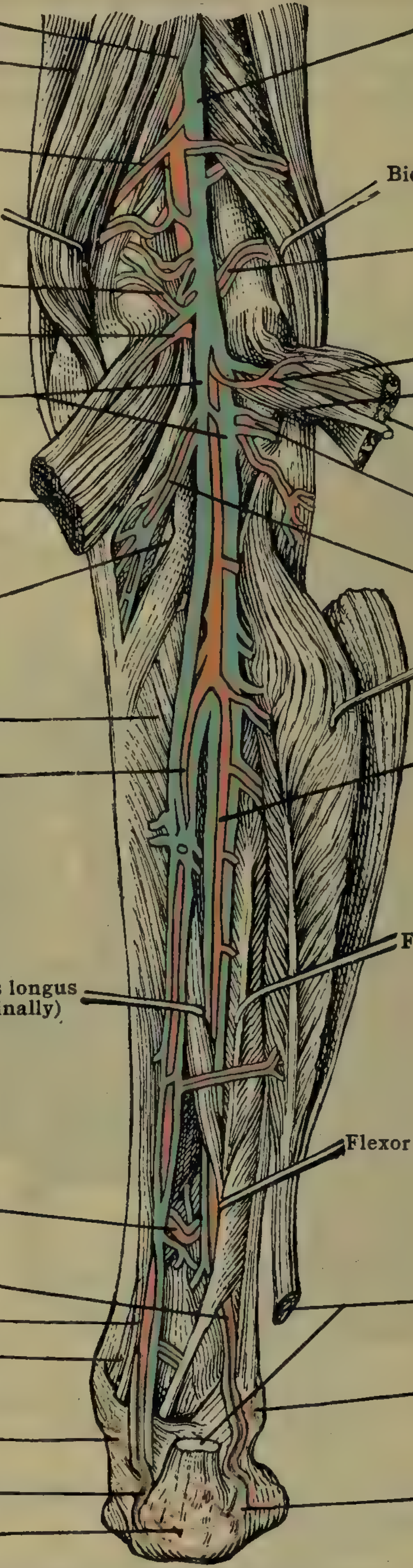


Fig. 619.—The Deep Veins of the Leg. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The popliteal vein accompanies the popliteal artery, lying superficial to it in the whole of its course, and tightly bound down to it by its fascial sheath. At the lower part of the fossa it is a little medial to the artery, but, crossing the vessel obliquely as it ascends, lies a little lateral to it at the proximal part of the fossa. The tibial (internal popliteal) nerve lies superficial to the vein, being lateral to it above, then posterior to it, and then a little to its medial side. The close relation of the vein and nerve explains the early stiffness of the knee, the pains below (often called 'rheumatic') and the edema in popliteal aneurism. The popliteal vein contains two or three valves.

The popliteal receives the small saphenous vein. It is also joined on its lateral and medial sides by the *accessory popliteal* veins [vv. popliteæ accessoriæ] which form common trunks of

termination of the sural and articular veins of the respective sides. The medial vein receives in addition, through a plexus extending as high as the opening in the adductor magnus, the veins accompanying the a. genu suprema.

The **femoral** vein [v. femoralis], the continuation of the popliteal extends from the tendinous opening in the adductor magnus to the inguinal ligament. In this course its relations are similar to those of the femoral artery. As the vein passes through the adductor canal, it lies behind and a little lateral to the artery. At the apex of the femoral trigone (Scarpa's triangle) it is still posterior to the artery, but gradually passes to the medial side as it passes through the trigone (fig. 618).

In the neighborhood of the inguinal ligament the femoral vein lies on the same plane as the artery from which it is separated by a delicate prolongation of the fascia stretching between the front and back layers of the femoral sheath. On the medial side the vein is separated by a similar septum from the femoral canal. For relations of the femoral sheath and canal to femoral hernia, see p. 1275. The femoral vein contains five pairs of valves.

Tributaries.—The femoral vein receives (in addition to the great saphenous vein, and, in some cases the superficial veins of the epigastrium and groin) the profunda femoris and circumflex femoral veins and a variable number of small femoral venæ comitantes.

The **profunda femoris** veins [vv. profundæ femoris] arise from the venæ comitantes corresponding to the perforating branches of the profunda artery [vv. perforantes]. The **perforating** veins accompany the perforating arteries and anastomose with femoropopliteal and other veins of the posterior femoral region, and with the circumflex and accessory popliteal veins. They return blood from the femur and the adductor, hamstring and vasti muscles. Proximally the profunda femoris veins generally unite to form a vein which lies anterior to the artery.

The **medial** and **lateral femoral circumflex** veins [vv. circumflexæ femoralis mediales et laterales] accompany the femoral circumflex arteries and anastomose freely with each other and with the gluteal and genicular veins. They open either into the femoral or the profunda femoris veins (fig. 618).

MORPHOGENESIS AND VARIATIONS OF THE VEINS

The developing heart, as soon as it has assumed the simple tubular form, is found to receive two pairs of veins, the vitelline and umbilical (fig. 39). The right and left vitelline veins return blood from the yolk-sac and reach the heart by transversing the splanchnic mesoderm. The single umbilical vein, which returns blood from the placental part of the chorion. reaches the embryo by way of the body-stalk. Before entering the body-wall it divides into two branches, each of which transverses the somatopleure of its own side to unite with the corresponding vitelline vein near the venous end of the heart. The heart thus receives two short common vitelloumbilical trunks which join the parts of the sinus venosus known as the right and left sinus-horns.

During the further course of development two pairs of veins appear which are entirely intraembryonic; they are the right and left precardinals and postcardinals. The precardinal veins drain the head and neck, while the postcardinals drain the trunk and developing extremities. Each precardinal vein joins the postcardinal vein of its own side to form a medially directed vessel called the common cardinal. Each common cardinal unites with the common vitelloumbilical stem of its own side. The two common cardinal veins, although they undergo a considerable amount of shifting, are recognizable until a relatively late stage of development, while the proximal parts of the vitelline and umbilical veins, on the other hand, are partially destroyed. The *duct of Cuvier*, the venous trunk which leads into either horn of the sinus venosus, probably includes the entire common cardinal vein together with a portion of the original vitelloumbilical trunk. The efferent components of the embryonic capillary plexus supplied at first from the aortic sac and later from the sixth pair of aortic arches by the pulmonary arteries converge to form a single *pulmonary vein*, which opens into the left atrium. That these components occasionally form abnormal connections with systemic veins is indicated by some of the anomalies which may occur. One or other of the pulmonary veins has been found to open into the vena cava superior, into the left innominate, or into the vena azygos.

THE VENA CAVA SUPERIOR AND ITS TRIBUTARIES

1. MORPHOGENESIS

(*a*) **Vena cava superior.**—The *precardinal veins* at first return blood from the head and neck only (fig. 39). As the heart gradually migrates toward the thorax, however, relative positions become altered and the precardinal veins soon receive, through the subclavian veins, the blood returning from the upper extremities also. By the time the venous end of the heart has entered the thoracic region the Cuverian ducts no longer preserve their original transversely dorsoventral position. They begin to assume a longitudinal direction and become the proximal portions of the symmetrically placed venæ cavæ superiores.

At a stage of about 16 mm. the thymicothyroid veins, which open into the right and left precardinals, become connected and form a transverse venous channel between the two precardinal veins. This soon becomes a large vessel, and its presence allows of a revision of the

nomenclature of the neighboring venous channels. The cross-branch itself becomes the major part of the *left innominate vein.* The part of the right precardinal which extends from the right extremity of the cross-branch to the proximal end of the right subclavian vein, becomes the *right innominate vein,* while the part extending from the cross-branch to the right duct of Cuvier becomes the distal portion of the right *superior cava.* On the left side the parts immediately above and below the cross-branch, become the left end of the left innominate and the distal

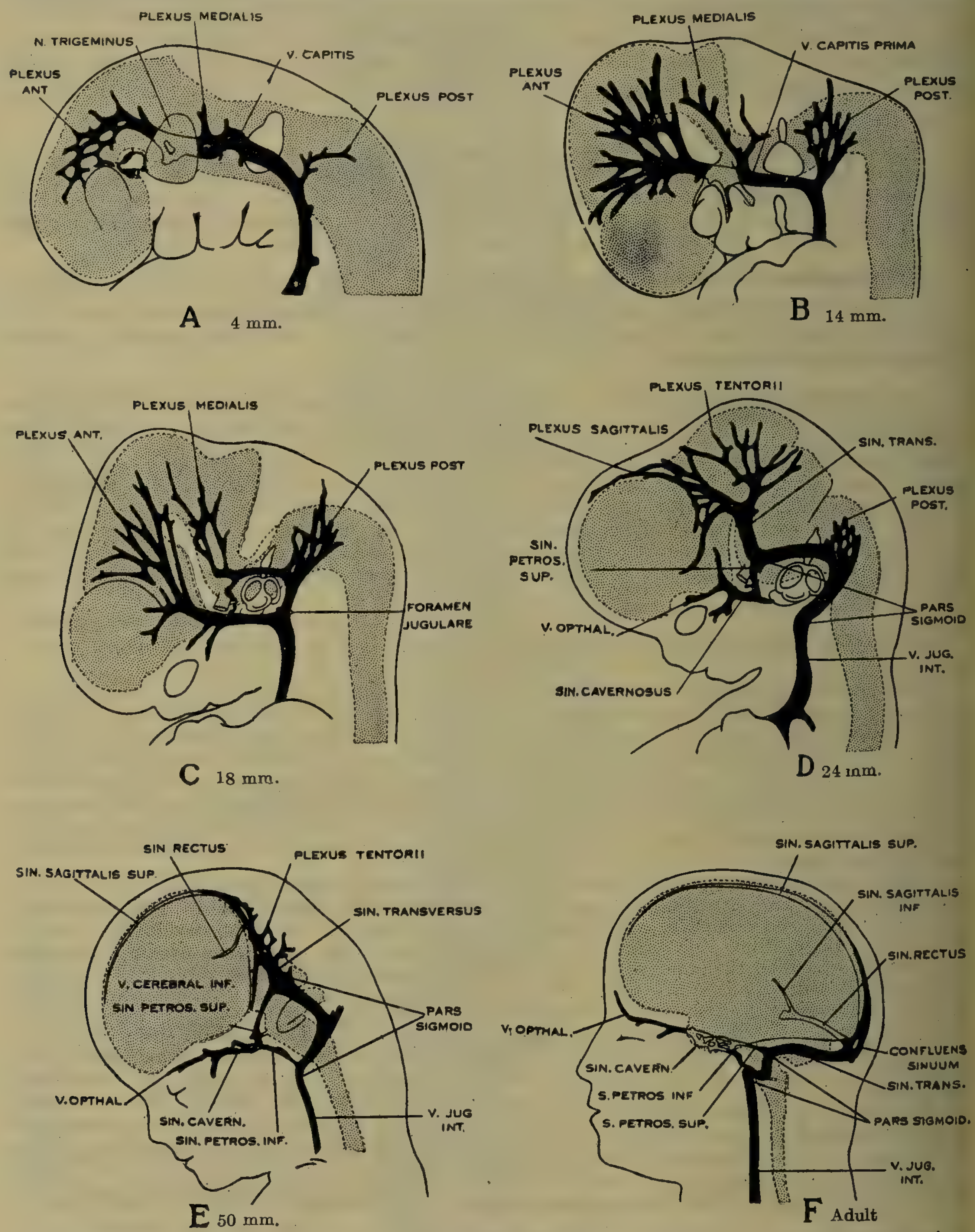


Fig. 620.—Development of the Dural Venous Sinsuses. (Streeter, Carnegie Contributions to Embryology, 1918.)

portion of the left superior cava respectively. The left innominate vein rapidly increases in size and the right superior cava gradually usurps the function of the corresponding vessel of the left side. The left vena cava superior eventually disappears but evidences of its former presence are recognizable in the adult as the *oblique vein of Marshall* (p. 599).

(*b*) **The veins of the neck and upper extremity.**—The portion of the precardinal vein extending from the innominate vein to the base of the skull on either side appears to become divided longitudinally to produce the *internal jugular* and *vertebral* veins (Thyng). The former drains the dural sinuses, while the latter receives the segmental veins which drain the vertebral plexuses. The embryonic *linguofacial vein* drains the submental and anterior and posterior facial regions into the internal jugular veins (F. T. Lewis), and becomes the *common facial vein.* The *external and anterior jugular veins,* which appear relatively late in development, may take over parts of the original linguofacial area of drainage.

The veins of the *upper extremity* at first form part of the general superficial venous plexus of the neck and thorax, which is drained by the umbilical vein and by the cardinals. A marginal vein soon becomes apparent upon the free border of the developing limb, the preaxial and postaxial limbs of which are known as the radial and ulnar vein respectively. The drainage of the upper extremity and the chest is now taken over by a large channel which connects the ulnar vein with the precardinal. The ulnar vein receives the largest vein of the chest, the thoracoepigastric, while the radial vein becomes reduced to a plexus. The ulnar vein becomes the *basilic* and the *axillary vein*, the thoracoepigastric becomes the *lateral thoracic*. The *subclavian* vein replaces the original channel of connection between the ulnar vein and the precardinal. The *venæ comitantes* of the deep arteries of the limb, and the *cephalic vein* appear later in development; the latter at first opens into the external jugular.

(*c*) **The venous sinuses of the dura mater** (fig. 620).—The forebrain and midbrain are closely invested, at an early stage of development, by a plexus of capillaries which eventually becomes converted into the circulus arteriosus and the cerebral and choroidal arteries and veins. This plexus is drained on either side by a vein which courses along the ventrolateral aspect of the hindbrain and is connected by an occipital intersegmental vein with the corresponding precardinal. The longitudinal vein which forms the first part of the drainage line of the forebrain and midbrain has long been known as the *v. capitis medialis*, for it lies upon the medial side of the cranial ganglia. It was formerly thought to pass, by a form of anastomotic migration, to the lateral side of the ganglia, and thus become converted into the *v. capitis lateralis*. Sabin, however, finds that these vessels are formed independently and substitutes for them the terms *vasa primitiva rhombencephali* and *vena capitis prima*, respectively.

The plexus formed from the vasa primitiva rhombencephali is fed by arterial offshoots of the aortic arch system. It is subsequently converted into the arteries and veins of the hindbrain. In addition to receiving the venous stem of the forebrain and midbrain plexus, the vena capitis prima receives two other branches from the plexuses of the anterior and posterior parts of the hindbrain, respectively. By the time the three main tributaries of the *v. capitis prima* are fully formed, the forebrain and midbrain plexus consists of a superficial part, which drains the dura, and of the original deeper part in which cerebral arteries and veins are undergoing differentiation. The blood entering the three tributaries is derived very largely from the dural layer of the head. On this account the terms *anterior*, *middle*, and *posterior dural plexus* have been substituted by Streeter for the terms anterior, middle and posterior cerebral veins (of Mall).

The main dural venous channels present in embryos of the stage of 4 mm., and the alterations in their arrangements which lead to the production of the adult arrangement, are indicated in fig. 620. It will be seen that at the stage of 18 mm. (C), a new connection has arisen between the middle and posterior plexuses; this, together with the stem of the posterior plexus, will become the sigmoid part of the *sinus transversus*. At the stage of 21 mm. (D), the anterior and middle dural plexus have coalesced to form the sagittal and tentorial plexuses. The part of the *v. capitis prima* upon the medial side of the trigeminal ganglion, now the *sinus cavernosus*, receives the *ophthalmic* and *middle cerebral* veins. The remainder of the v. capitis prima having been lost, the blood from the cavernous sinus drains into the transverse sinus through the *sinus petrosus superior*, originally the lower part of the stem of the middle plexus. The drainage of the entire venous system of the dura mater is now effected through the sinus transversus. During the succeeding stages of development (E and F) the *inferior petrosal sinus* appears and the sagittal plexus becomes differentiated into the *sagittal sinuses* and *sinus rectus*. The tentorial plexus becomes the *confluens sinuum* and the horizontal part of the s. transversus, its connections with the posterior dural plexus form the *sinus occipitalis*, and the plexus itself persists, in part, as the *marginal sinuses*.

(*d*) **The azygos system of veins.**—The asygos, hemiazygos, accessory hemiazygos and superior intercostal veins are the adult representatives of the thoracic portion of a pair of embryonic veins to which Huntington and McClure have applied the term *supracardinal*. The supracardinal veins pursue a longitudinal course through the abdomen and thorax lying dorsolaterally to the aorta. They take over the drainage of the lumbar and intercostal veins from the postcardinals which eventually disappear almost entirely. The right and left supracardinal veins intercommunicate in several places, the persistence of one or two communications, at about the level of the eighth thoracic segment, usually determines the eventual drainage of the larger part of the left supracardinal vein into the right. The latter vein is connected superiorly, through a small persisting portion of the postcardinal, with the right duct of Cuvier (vena cava superior); its intrathoracic part becomes the vena azygos. The part of the left supracardinal above the fourth thoracic segment becomes the *left superior intercostal* vein. The part of the supracardinal which now drains downward, and across into the azygos becomes the *accessory hemiazygos*, while the remainder of the intrathoracic portion of the left supracardinal becomes the *hemiazygos* vein.

2. VARIATIONS

(*a*) **Vena cava superior.** The connection between the embryonic thymicothyroid veins of the two sides may fail to persist. In this case both embryonic venæ cavæ will persist and each receive the subclavian and internal jugular vein of its own side, the left innominate vein being absent and the right not marked off from the remainder of the right superior cava. The left vena cava superior may coexist with the right even when the embryonic connection between them has appeared in the usual way. The innominate veins are present in such cases, but the left is commonly small. A left vena cava superior may altogether replace the right of the adult in association with *situs inversus* or as an independent variation. The left superior cava is formed from the left duct of Cuvier and the adjacent part of the left precardinal vein and joins the coronary sinus. The abnormal termination of the vena cava inferior in the vena cava superior is mentioned below under the azygos system.

(*b*) **Veins of the neck and upper extremity.** The comparative size of the two internal jugular veins depends upon the manner of drainage of the dural sinuses. Either *the anterior* or *the external* jugular vein may be absent. In such cases the *common facial* vein resembles more closely than usual the embryonic linguofacial from which it is derived. The external or the anterior jugular vein may, on the other hand, almost entirely replace the common facial; variations in the relative extent of the areas drained by these three veins are extremely common.

The *cephalic* vein may be absent, or it may cross the clavicle to enter the external jugular. The *lateral thoracic* (embryonic thoracoepigastric) may be very large. The *subclavian* vein occasionally passes between the subclavius muscle and the clavicle.

(*c*) **Venous sinuses of the dura mater.** The *superior sagittal sinus* may be partially reduplicated, or it may bifurcate at the lambda and follow the limbs of the lambdoid suture to join the lateral ends of the transverse sinuses (Malacarne). It may be small, or altogether absent. In either case the s. rectus and s. sagittalis inferior are large and receive the superior cerebral veins through dilated channels in the falx.

An accessory sinus or series of sinuses in the falx may drain both the s. sagittalis inferior and the v. magna cerebri in cases in which the *s. rectus* is absent. The s. rectus may drain only the v. magna cerebri in cases in which the *s. sagittalis inferior* is absent, or, being present, is drained into the superior sagittal sinus by large veins of the falx.

The *transverse sinuses* may be equal in size when the confluens sinuum is large, or the horizontal part may be absent from one side. Both ss. transversi may be small in cases in which the *s. occipitalis* is large enough to carry most of the blood from the confluens to the *marginal sinuses* and so to the jugular veins. The occipital and marginal sinuses may be absent.

The variations mentioned above seem to afford instances of lack of uniformity in the selection of channels from amongst the many alternative routes afforded by a plexiform system. The appearance of the *s. petrosquamosus* depends, in all probability, upon the occasional persistence of an anterior tributary to the stem of the middle dural plexus.

(*d*) **The azygos system of veins.** Variations in the details of the drainage of the intercostal veins are very common. They are referable either to an increase in the number of transverse connections between the two embryonic supracardinal veins or to the absence of some or all of them. In extreme cases, all of the left intercostal veins may terminate in the v. azygos, the hemiazygos vein and accessory hemiazygos being absent. In such cases the single azygos vein usually opens into the vena cava superior; it may, however, open through a persistent left duct of Cuvier into the coronary sinus (Gruber). In the absence of the part of the vena cava inferior normally derived from the right subcardinal connecting with the hepatic vein, the lower part of the vena cava may be continued into the azygos (Winslow, etc.), or into the hemiazygos and so into the azygos (Quain), or into a left-sided azygos vein which opens into the coronary sinus.

B. THE VENA CAVA INFERIOR AND ITS TRIBUTARIES

1. MORPHOGENESIS

The vena cava inferior is a vessel of a composite origin. The upper part of it receives the hepatic veins, which contain the venous blood returning from the alimentary viscera; its development is described in connection with that of the portal system of veins. The lower part of the vena cava inferior receives venous blood from the remainder of the abdominal viscera, and from the abdominal walls and lower extremities; its development is described with that of its tributaries.

(*a*) The **portal system** of veins arises by means of a series of transformations which take place in the vitelline and umbilical veins of the embryo. The proximal ends of the vitelline veins, where they lie between the umbilicals, are early enveloped in, and invaded by, the growing liver. The columns of liver cells, while not penetrating the endothelium, subject the vitelline veins to a process of fenestration by which the original channels are subdivided into innumerable smaller vessels or sinusoids. The *sinusoids* arising from the two vitelline veins intercommunicate to form a continuous network within the liver in which the vessels are larger in the afferent (portal) and efferent (hepatic) areas than in the intermediate zone.

The two umbilical veins now form communications with the portal area of the sinusoidal network and eventually lose their original connection with the sinus venosus (fig. 621). The fate of the umbilical veins differs on the two sides; the right degenerates, from the sinus venosus to the common umbilical vein, while the left persists to receive all the blood flowing from the placenta. The left umbilical vein, having lost its connection with the sinus venosus, discharges its blood partly into the portal sinusoidal zone, and partly, by means of a direct channel of new formation, the *ductus venosus*, into the right vitelline (fig. 621).

The hepatic portion of the left vitelline vein eventually loses its connection with the sinus venosus and becomes reduced to sinusoidal channels, while that of the right increases very considerably in caliber. The hepatic portion of the right vitelline now forms the only means of transit between the hepatic sinusoids and the sinus venosus of the heart, and is called the *common hepatic* vein. The main venous channels of the lower abdomen, having undergone a series of changes meanwhile, acquire a connection with the common hepatic vein, which thus becomes the upper part of the *vena cava inferior*.

The single vitelline vein of the yolk-stalk separates into right and left veins before entering the liver. In a position intermediate between the proximal and distal anastomoses between the right and left vitelline veins, which occur (ventrally to the intestine) within the liver and upon the yolk-stalk, respectively, a third connection appears on the dorsal aspect of the duodenum. The formation of the *portal vein* is effected by the disappearance of the portion of the right vitelline vein on the distal side of the dorsal connection and of the portion of the left vitelline upon the proximal side. The portal vein is joined by the *superior mesenteric* vein upon the left side of the duodenum and by the *splenic vein* behind it; the portion of the common vitelline vein beyond the junction of the superior mesenteric with the left vitelline subsequently disappears.

(*b*) **The lower part of the vena cava inferior.** At an early stage of development the postcardinal veins are invaded by the growing Wolffian bodies and here become transformed into in intercommunicating system of sinusoids, which is drained by three longitudinal venous channels. One of these traverses the dorsal region of the organ, and retains the name postcardinal; one traverses the medial region and is called the *subcardinal* vein (F. T. Lewis). The third vein traverses the ventral region and does not share in the development of the vena cava inferior or its tributaries. The subcardinals are united across the median line, on a level subsequently occupied by the kidneys, by what is commonly known as the *renal anastomosis*, and each subcardinal receives a vein from the suprarenal gland and from the gonad of its own side. The postcardinal veins for a long time remain the chief drainage channels for the Wolffian bodies and for the iliac veins; they later, however, relinquish the drainage of the veins of the body-wall to a pair of veins of later formation, the *supracardinals* (Huntington and McClure, Am. Jour. Anat., vol. 6, 1907).

Each supracardinal vein pursues a longitudinal course near the dorso-lateral aspect of the aorta; it is connected with the postcardinal near the place of entry of the iliac veins, and, extends to the anterior end of the postcardinal vein of its own side, into which it opens a short distance below the duct of Cuvier. The supracardinal veins intercommunicate at frequent intervals and eventually replace the thoracic portion of the postcardinal veins. A large communication between the supracardinal and the subcardinal vein occurs, at the level of the renal anastomosis, so that the aorta is surrounded by a venous ring, the renal collar.

The drainage of the left common iliac vein is now transferred by means of a cross anastomosis, to the right supracardinal, which becomes the part of the vena cava inferior below the renal anastomosis. The remainder of the vena cava inferior is formed from the right half of the renal collar, part of the right subcardinal vein above the renal anastomosis and a venous communication between this and the common hepatic vein. The embryonic components of the vena cava inferior become enormously enlarged and the left supracardinal vein diminishes in size.

As soon as the kidneys have attained their permanent position, the ureter is found to pass between the supracardinal vein and the postcardinal; the dorsal loop of the periureteral ring

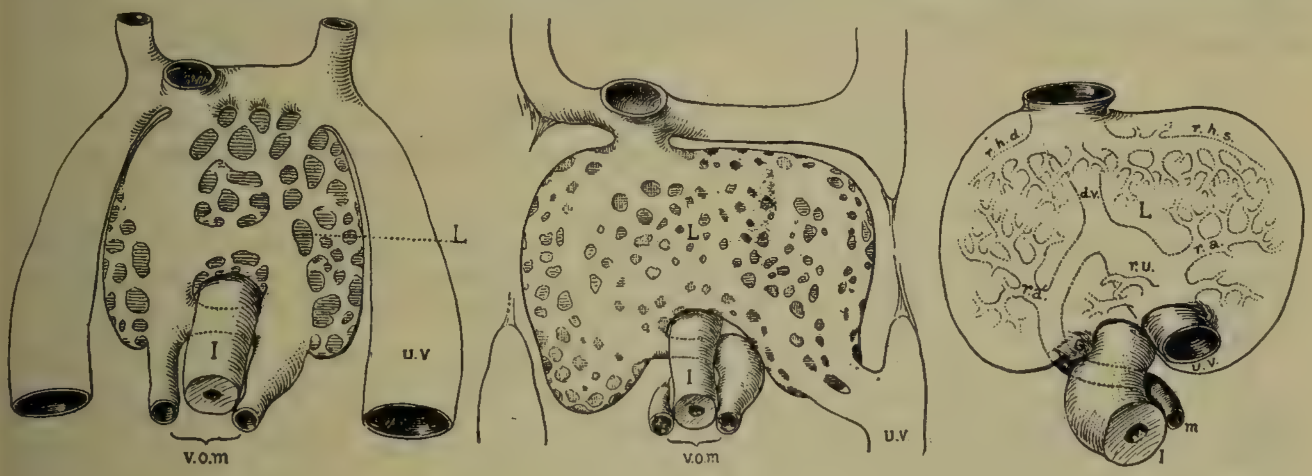


Fig. 621.—Semidiagrammatic Reconstructions of the Veins of the Liver, Ventral Aspect (Mall). A, Embryo of 4.5 mm. Long; B, 4 mm. (more advanced than A); C, 7 mm. d.v., ductus venosus; I., intestine; L., liver; m., superior mesenteric (continued as portal) vein; r.a., ramus angularis; r.a'., right branch of portal vein; r.h.d., right hepatic vein; r.h.s., left hepatic vein; r.u., recessus umbilicalis; u.v., left umbilical vein (the right umbilical vein is not labelled); v.o.m., vitelline veins.

described by Hochstetter in 1893 is, therefore, a part of the supracardinal vein. Two veins (dorsal and ventral) leave each kidney to open into the corresponding side of the renal collar. The left ventral kidney-vein retains its connection with the renal anastomoss, forming the left renal vein of the adult. The ventral kidney-vein of the right side persists as the right renal vein of the adult, which opens into the vena cava inferior. The portion of the left subcardinal vein above the renal anastomosis becomes the left suprarenal vein. The corresponding portion of the right subcardinal vein forms a part of the vena cava inferior and the entire right suprarenal vein. The part of the postcardinal vein contained within the Wolffian body diminishes in size and forms a connection between the gonadic vein of each side and the corresponding subcardinal. Some part of the postcardinal vein persists, therefore, as the spermatic (or ovarian), the right opening into the vena cava inferior and the left into the left renal vein.

(*c*) **The veins of the lower extremity.** The superficial plexus of the developing limb is at first drained by the postcardinal and umbilical veins. It soon becomes condensed into a marginal vein, the fibular limb of which enters the pelvis as the hypogastric vein and continuing as the common iliac vein, joins the postcardinal. The external iliac vein grows from the common iliac, and forms a connection with the plexiform tibial limb of the marginal vein. This connecting branch receives the venous drainage of the thigh and lower abdomen and subsequently forms the proximal part of the femoral and great saphenous veins. The deep veins of the limb appear somewhat later. The popliteal takes over the distal part of the fibular marginal vein, which then becomes the small saphenous. The proximal part of the fibular vein is transformed into a plexus upon the back of the thigh, which is drained by the great saphenous vein and the hypogastric veins. The drainage of the common iliac veins is later transferred from the postcardinal to the supracardinal veins, and the upper part of the left common iliac vein is formed by an inter-supracardinal anastomosis.

2. VARIATIONS

(*a*) **The portal system of veins.** Major variations of the *portal system* of veins are practically unknown. In cases in which the lower part of the vena cava inferior is continued into the vena azygos, or into the v. hemiazygos in postnatal life, the common hepatic vein is smaller than usual and transmits blood from the portal system only.

(*b*) **The lower part of the vena cava inferior.** The left renal vein not uncommonly passes on the dorsal (instead of the ventral) side of the aorta. This condition is due to the persistence of the dorsal, and not the ventral, of the two embryonic kidney-veins which open into the left side of the 'renal collar.' The left suprarenal, and the left spermatic vein open, in such cases, into the vena cava inferior and not into the left renal vein.

The *vena cava inferior* lies upon the left side of the aorta in cases of *situs inversus*, and in some cases without situs inversus. In the latter case the left supracardinal vein, instead of the right, has persisted below the level of the renal veins; the left inferior vena cava is continued across the front of the aorta and, receiving the left spermatic and the left suprarenal vein, passes to the right atrium in the usual way. There are occasionally two venæ cavæ, one on each side of the aorta; the two persisting supracardinal veins are united, in such cases, by the embryonic renal anastomosis. In all cases in which the left vena cava is present, with or without a right, the part which crosses the aorta is derived from the embryonic renal anastomosis and, therefore, corresponds in origin to the proximal part of the left renal vein.

Cases of dissociation of the embryonic antecedents of the vena cava inferior have already been mentioned (see azygos system). The venous blood from the lower part of the vena cava inferior in such cases finds an outlet through the thoracic portion of one of the supracardinal veins.

The renal vein of either side may open into the common iliac, particularly in cases in which the organ is lower than usual. The vein of a pelvic kidney may open into the middle sacral vein. Many interesting anomalies of a less striking character may occur.

(*c*) **The veins of the lower extremity.** Major variations of the veins of the lower extremity are not common. The small saphenous vein is frequently continued upon the back of the thigh, with or without communication with the popliteal. It is drained in such cases into the great saphenous, either by means of a plexus or through a definite femoropopliteal vein.

FETAL CIRCULATION

For a discussion of the fetal circulation and of the postnatal changes, see Section I, p. 37.

References for blood-vascular system—A. Heart: *Early development*, Davis, C. L., Contrib. Embryol., 19: 247. *Later development and adult*, Tandler, J., Bardeleben's Handb. der Anatomie des Menschen, Bd. 3, 1te Abth., Jena 1931. *Fetal circulation*, Kellogg, H. B., Am. J. Anat., 42: 443. *Foramen ovale*, Patten, B. M., Am. J. Anat., 48: 7.

B. Blood vessels: *Development*, Evans, H. M., in Keibel and Mall, Manual of Human Embryology; Sabin, F. R., Carnegie Contrib. Embryol., 6: 61, 9: 213; Congdon, L. D. (*aortic arches*), Carnegie Contrib. Embryol., 14: 47; Streeter, G. L. (*dural sinuses*), Carnegie Contrib. Embryol., 8: 7; Reagan, F. P. (*vena cava inferior*), Quart. Rev. Biol., 4: 179. *Development and variations*, Göppert, E., Ergeb. der Anat. u. Entw., 15: 1; Bremer, J. L. (*renal arteries*), Anat. Rec., 9: 59; Muller, E. (*upper extremity arteries*), Anat. Hefte, 22: 377, 27: 73; Senior, H. D. (*lower extremity arteries*), Am. J. Anat., 33: 243, 36: 1, 44: 111. McClure and Huntington (*vena cava inferior*), Am. Anat. Memoirs, no. 15. Variations, Adachi, B., Das Arteriensystem der Japaner, Kyoto, 1928; Dubrueil-Chambardel, L. Variations des artères du membre supérieur, Paris, 1925 and Variations des artères du pelvis et du membre inférieur, Paris, 1926.

SECTION VII

THE LYMPHATIC SYSTEM

By ELIOT R. CLARK, A.B., M.D.

PROFESSOR OF ANATOMY, UNIVERSITY OF PENNSYLVANIA

GENERAL ANATOMY OF THE LYMPHATIC SYSTEM

THE blood-vascular system has, as a part of its function, the collection of substances from the various tissues of the body which are to be conducted to the other tissues. In carrying on this function it is assisted by a second system of collecting vessels, the lymphatics. The lymphatic system consists of a set of closed vessels which start as closed capillaries in the various organs and tissues, continue as closed vessels, pass through lymph-nodes in which the vessels break up into capillaries and spaces separated from the outside fluid by endothelium, and again collect into closed vessels, which eventually terminate in the veins of the neck.

This second system resembles the blood-vascular system in many ways, but differs markedly in others. Like the blood-vascular system, it is made up of minute endothelial-lined capillaries, where the absorption of substances occurs, and of larger conducting vessels. It differs from the blood-vascular system in two important particulars. While the blood-vascular system is provided with a pumping mechanism by which its fluid content is driven through a complete circuit from the heart, through artery, capillary, vein and back to the heart, the lymphatics merely conduct fluid *from* the capillaries to the larger vessels, which eventually empty their contents into the large veins of the neck. The second important difference between the two systems is found in the presence, along the course of the lymphatic vessels, of glands or nodes (fig. 625) [lymphoglandulæ] in which the vessels branch out into lymph-capillaries. These are lined, as are the absorbing capillaries, with a single layer of endothelial cells, thus permitting an interchange of substances between the contents of the lymph-capillaries and the lymphoid tissue around them.

Our present knowledge does not permit an exact statement of the complete extent of the lymphatic system. While, in a general way, the lymphatics may be said to be present whereever blood-capillaries occur, there are certain tissues where lymphatics have not been definitely demonstrated. The *tissue-spaces* outside the lymphatic endothelium, which are filled with a fluid or semifluid material, which has often been termed 'lymph' but which would better be termed 'tissue-fluid, are not part of the lymphatic system. Similarly, the various serous cavities —pleural, percardial, synovial, cerebrospinal, etc.—while they may serve, as in the case of the cerebrospinal spaces and the intraocular spaces, a somewhat similar function, are not considered as parts of the lymphatic system.

The general constitution of the lymphatic system will be considered under three heads—(1) the capillaries, (2) the collecting vessels and (3) the lymphoid organs.

1. *THE LYMPHATIC CAPILLARIES*

The lymphatic capillary, like the blood-capillary, is the portion of the lymphatic system which is chiefly concerned in the specific function of this system. In the blood-capillaries, where the blood is separated from the outside tissues by a single layer of flat endothelial cells, there occurs the interchange of fluid substances and of cells, while the heart, arteries and veins serve to transport the blood, modified in the capillaries, to other parts of the body. Similarly in the lymphatic system, it is in the capillaries, both those most peripheral and those in the lymph nodes, where the absorption and interchange of fluid substances and of cells takes place. Consequently it becomes of prime importance to obtain a clear understanding of the structure of the lymphatic capillaries, their relation to the other tissues, and their mode of functioning. At the outset, however, it must be admitted that our knowledge on this subject is far from complete.

Historical.—Previous to the development of microscopic anatomy, in the middle third of the 19th century, there was no accurate knowledge of such small structures as the lymphatic capillary. In order to explain the absorption of substances by the lymphatics, as well as the passage of substances from the blood-vessels through the tissues, various theories were invented. Prominent among such theories was that of the 'vasa serosa,' of H. Boerhaave and other 18th century anatomists and physiologists, which was perhaps most elaborately developed by Bichat, 1801-03. According to this theory there are two sets of minute vessels. The one set leads from the blood-capillaries onto the various surfaces and into the loose spaces in the tissues—the 'exhalants.' The other set leads from the body surfaces (including the serous cavities) and the loose spaces in the tissues to the lymphatics—the inhalants or 'absorbents.' This theory was somewhat shaken by the criticism of early 19th century anatomists who developed the technic of injection of lymphatics to a high point.

Our present conception of the lymphatic capillaries may be said to have started with Kölliker who, in 1846, saw, with the aid of the microscope, the lymphatic capillaries in the transparent tails of living frog larvæ. Like Schwann who, in 1837, had studied the blood-capillaries in the tail of the frog larva, he erroneously supposed that the fine processes of the lymphatic capillaries were continuous with similar processes of the surrounding connective tissue cells. Since, according to the conception current at the time, cells were thought to be hollow structures, it was concluded that the mode of transmission of fluid from blood to lymphatic capillary took place through canaliculi inside these cells. This conception was elaborated by Virchow, in his

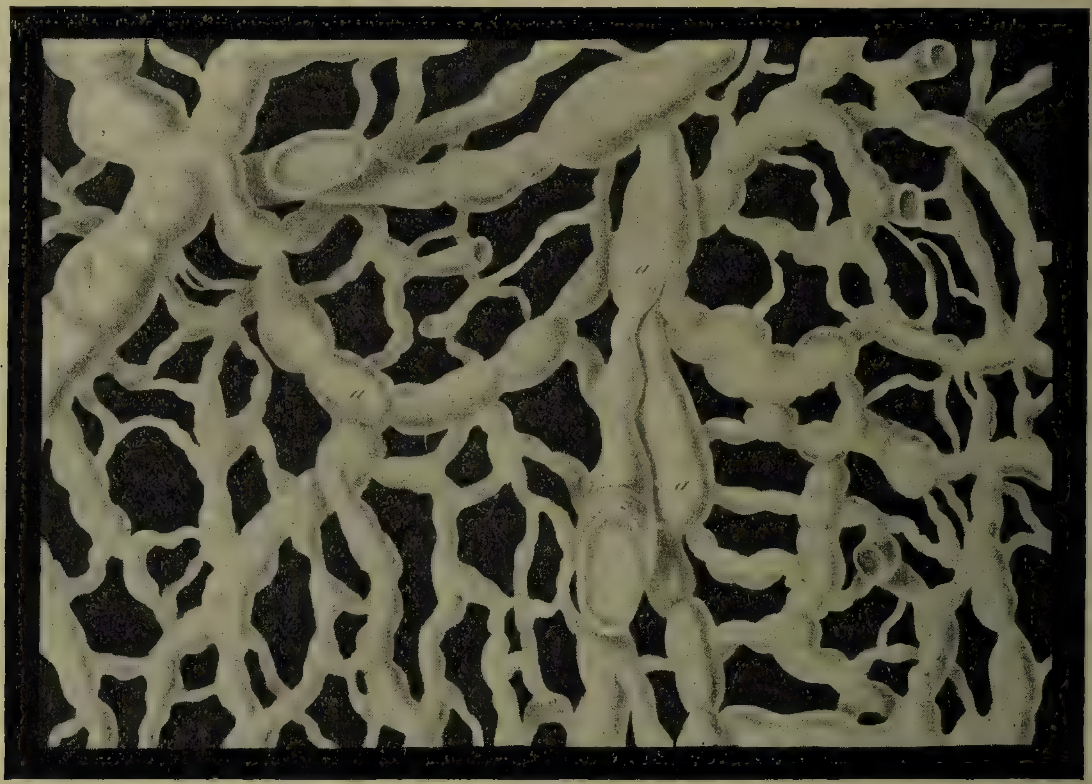


FIG. 622.—THE LYMPHATICS OF THE SCROTUM. (AFTER TEICHMANN.) SHOWING the transition of the capillaries to the vessels with valves (a, a, a).

Cellular-Pathologie. In 1862 von Recklinghausen by means of the silver nitrate staining method discovered that the lymphatic vessels are lined with an endothelium made up of flattened cells. He also described open communications ('stomata') between the lymphatics and the peritoneal cavity. Cohnheim described similar though smaller openings in blood-capillaries, and His described them in other lymphatic capillaries. Arnold termed the openings in the vessels 'stigmata,' as distinguished from the openings into the peritoneal cavity, or 'stomata.' More recent investigators (Kolossow, A. W. Meyer, W. G. MacCallum) have failed to find these 'stomata.' Careful studies of the lymphatic capillaries in the transparent tails of living frog larvæ, which may be clearly seen with the higher magnifications of the microscope, show that the endothelial lining of these capillaries is complete, with no trace of an opening into the spaces in the tissue outside (E. R. Clark). In microscopic studies made on lymphatics which have grown into a thin space left in a double-walled transparent chamber introduced in the rabbit's ear, the lymphatics have been found to be closed, normally. However, when, under abnormal conditions, a lymphatic capillary is broken open at the tip at a place where free fluid is present outside the lymphatic, the opening may persist for several days, permitting the direct passage of cells, fluids or debris from the outside into the lymphatic. (Clark and Clark.)

Form.—The shape of the lymphatic capillaries has been found to vary enormously in the different parts of the body where they have been studied. In general they form richly anastomosing plexuses, from which may extend cul-de-sacs, which end blindly. Such cul-de-sacs are especially noticeable in the dermal papillæ, in the filiform papillæ of the tongue, and in the intestinal villi. The plexuses are often present in two layers—a superficial and a deep. The vessels of the superficial plexus are of smaller caliber than those of the deep. These two sets of plexuses are particularly well seen in the skin and the gastrointestinal tract. In relation to the blood-capillaries, the lymphatic capillaries are generally the more deeply placed. In caliber, unlike the comparatively uniform diameter of blood-capillaries, the lymphatics vary enormously. In the same capillary a very narrow part may be succeeded by a very wide

ne (figs. 622–624). Teichmann found lymphatic capillaries varying in diameter from a few nicra to one millimeter or more. The capillaries are without valves.

Activity.—That the lymphatic endothelium is not exclusively a passive membrane has been hown by Clark in studies on the lymphatics in the transparent tails of living frog larvæ. The ymphatics here are seen to send out protoplasmic processes which, somewhat like an ameba, ctively take into the interior of the lymphatic red blood-cells accidentally forced from the lood-capillaries into the tissue-spaces. The mode of passage of leucocytes into or out of the ymphatics offers no such difficulties as that of the fluids, for they are able, by ameboid movenent, to pass independently through the endothelium—a process first directly observed by Cohnheim.

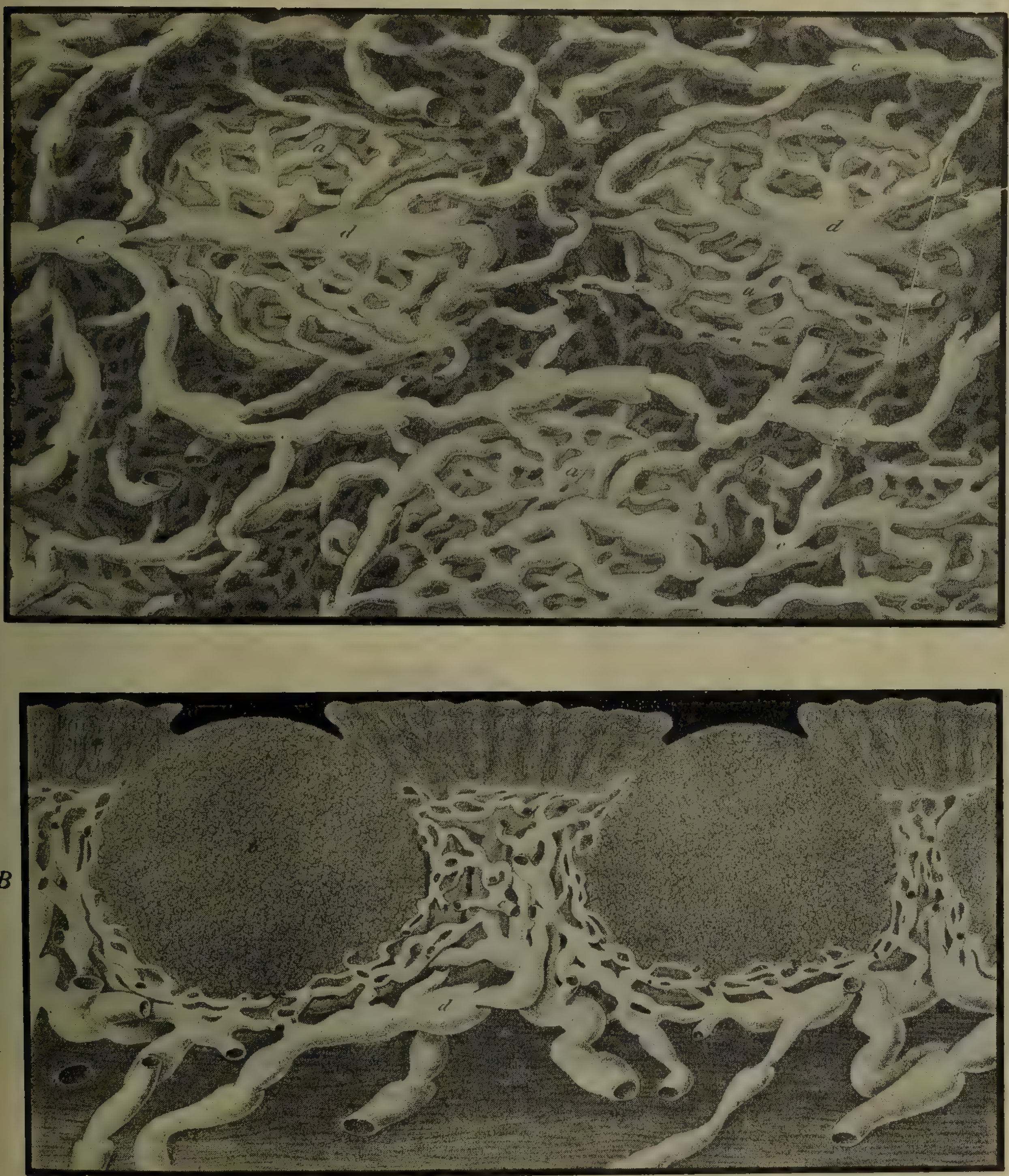


FIG. 623.—SURFACE VIEW AND SECTION OF LYMPH-NODES OF THE INTESTINE. A. Solitary follicle. B. Peyer's patch. (After Teichmann.)

THE EXTENT AND CHARACTER OF LYMPHATIC CAPILLARIES

The *skin* over the entire surface of the body is richly provided with lymphatic capillaries. They form two sets of plexuses in the dermis, a superficial and a deep. The superficial set sends out blind cul-de-sacs into the dermal papillæ. The richest skin plexuses are found in the scrotum, the palms of the hand and palmer side of the fingers and in the soles of the feet and plantar side of the toes. In the loose *subcutaneous* fascia, according to Teichmann, there are present only the larger collecting vessels, with no lymphatic capillaries. Lymphatic capillaries of the *scrotum* are shown in fig. 622.

The *conjunctiva*, both the sclerotic and corneal, is supplied with a rich plexus of capillaries, which are narrower in the corneal than in the sclerotic portion. At the corneal border the capillaries form a fairly regular ring which has been called by Teichmann a circulus lymphaticus (fig. 636).

At the various *orifices* of the body, the skin plexuses go over into the mucous plexuses forming anastomoses with them. Throughout the entire *alimentary tract*, the lymphatic capillaries form extensive plexuses which are in many places divided into a superficial plexus in the mucosa and a deeper plexus in the submucosa. In portions provided with a peritoneal covering, there is a third rich subserous plexus. In the tongue and the small intestine the plexus in the mucosa sends out blind cul-de-sacs; in the tongue into the filiform papillæ; in the small intestine into the villi. Where muscle is present along the alimentary tract, the lymphatics pass between the muscle bundles, but form no plexuses around them. Lymphatics have been demonstrated in the pulp of the tooth (Schweitzer).

The lining of the *nasal*, *tracheal* and *bronchial passages* is supplied with a double plexus of lymphatic capillaries, a mucous and a submucous set, which vary in richness according to the looseness of the tissue. In the smaller bronchi but a single layer of capillaries is present, and no capillaries are present around the air cells (Miller). Plexuses surround the pulmonary arteries and veins. Under the *pleura* lie rich plexuses which connect with deeper lymphatics around the veins only in places where the veins reach the surface of the lung.

Concerning the arrangement of the lymphatic capillaries in the *glands* derived from the alimentary tract much remains to be learned. The *salivary glands* have been studied by Aagaard, who has found lymphatic capillaries accompanying the blood-vessels into the interior of the lobules, and forming here irregular plexuses.

FIG. 624.—LYMPHATIC PLEXUS AROUND THE PORTAL VEIN IN AN ADULT MAN. (After Teichmann.)

The *thyroid gland* contains lymphatic plexuses which lie in relation to the colloid-containing alveoli. Direct connection between the lymphatics and the alveoli has been described by Matzunaga, but this observation needs verification. The lymphatics are apparently concerned in the absorption of the colloidal secretion, for traces of it have been found in the lymphatics draining the gland.

Concerning the lymphatics of the *parathyroids* nothing is known.

The course of the lymphatics draining the *thymus* has been described, but the nature of the capillaries in this gland is unknown. In the *spleen* lymphatics have been definitely found only in the capsule and the larger trabeculæ; not in spleen pulp.

The lymphatic capillaries of the *liver* are of great importance, for the lymph which flows from this organ forms a very considerable part of the total lymph which is collected into the thoracic duct. And yet very little is definitely known about the nature and distribution of the lymphatic capillaries in the interior of the organ. In the capsule there is a rich plexus, lying under the peritoneum, in which very large widenings have been described (called by Teichmann 'Lymphbehälter'). In the interior rich plexuses surround the branches of the hepatic artery and portal vein (fig. 624), and plexuses have been described accompanying the branches of the portal vein into the lobules. The path from blood-capillary to lymphatic in the perilobular spaces is more open than has been found in other organs, for Mall has found that if very finely

anular masses are used, and are injected through portal vein or hepatic artery under mild essure, the granules pass over into the lymphatics. Moreover, the lymph from the liver is her in proteins—more like the blood serum—than is the lymph from other organs.

The linings of the large *bile-ducts* and the *gall-bladder* are provided with a submucous network lymphatics (Sudler and Clermont). The gall-bladder has also a rich subserous plexus.

Concerning the lymphatic capillaries of the *pancreas* Bartels notes briefly that they form hly branched plexuses in the interlobular connective tissues, which surround larger or smaller rts of whole lobules, not the single gland elements.

The mucous lining of the *genitourinary tract*, wherever it has been carefully studied, has en found provided with plexuses of lymphatics. In the *bladder* they form a rich plexus of egular capillaries which lie immediately under the almost intraepithelial blood-capillaries. ey connect, through the muscular layer, with a subserous plexus. The lymphatic plexus of e *urethra* anastomoses with the capillaries of the base of the bladder, and in the male with those the glans penis. In the *prostate* (Camineti) the lymphatics form rich plexuses surrounding e glands, which connect with a very wide meshed subcapsular plexus, surrounding the entire and.

In the *testis* there is a rich superficial plexus, lying directly beneath the tunica albuginea. ncerning the deep lymphatics of the testis there has been much dispute. Ludwig and omsa found the lymphatic capillaries going over into lacunæ, without endothelium. This s been disputed by Tommasi and Gerster, who find, in the septa, capillaries with endothelial ll, which they consider the beginnings of the lymphatics.

In the female, lymphatic plexuses have been found in the mucosa of *vagina* and *hymen*, astomosing with those of the vulva. In the *uterus*, capillaries in the mucosa are very difficult demonstrate. Definite lymphatics, however, have been found passing through the mus-laris, and under the peritoneum a rich subserous plexus of capillaries is present. In the preg-nt uterus these subserous capillaries are much distended (Schick). The *Fallopian tubes* are ovided with lymphatics, but they have not been carefully described.

The *ovary* has a rich superficial lymphatic plexus. In the interior of the gland, according His, the capillaries form networks in the connective tissue framework. In the tunica externa the follicles there is a rich plexus.

The *kidney* has two sets of lymphatics, a superficial, capsular set, and a deep set. The cap-lar set is divided into two layers, one lying directly beneath the peritoneum made up of a wide eshed plexus, and the other in the fibrous capsule of the kidney, with finer capillaries and arrower meshes, which anastomose with the deeper capillaries. The lymphatic capillaries of e kidney parenchyma have been described by Kumita. He found rich plexuses in both rtex and medulla, surrounding the straight and convoluted tubules, the loops of Henle and e collecting tubules. He also found a plexus surrounding and accompanying the blood-ssels into the interior of the glomeruli.

The lymphatic capillaries of the *suprarenal* have also been described by Kumita. His sults agree with those of Stilling, who studied the lymphatics of the suprarenal of horse, cow d calf. Like the kidney, the suprarenal possesses a superficial and a deep set. The superficial t is in two layers, as in the kidney, the outer lying in the looser tissue around the suprarenal d the inner lying within and just under the capsule. The latter is made up of a rich lymphatic lexus, which anastomoses with the capillaries of the parenchyma. The parenchymatous mphatics are present in the form of plexuses which surround the groups of cells.

In spite of numerous investigations, endothelial-lined lymphatics have not been definitely und in the central nervous system, or in the peripheral nerves. The subarachnoid and similar aces, including the perineural spaces, do not form parts of the lymphatic system.

Rich plexuses of lymphatic capillaries are present in the *tendons* of *muscles* (Schweigger-eidel and Ludwig). In muscles, themselves, the question of the presence of lymphatics has ng been disputed, sometimes answered in the affirmative, more often in the negative. A tudy by Aagaard, however, would seem to place beyond doubt the presence of lymphatic capil-ries in *striated muscles*. By long continued injection, he was able to find lymphatics in the tramuscular portions of the tendons, which extended out among the muscle-fibers themselves. Ie also found capillaries in the tongue musculature.

The *heart* is provided with a subpericardial plexus of lymphatic capillaries. A subendo-ardial plexus has also been described (Sappey, Rainer). Bock has found an extremely rich ymphatic network throughout the substance of the heart. According to his description, the ymphatic capillaries are more numerous than the blood-capillaries.

The *periosteum of bones* is provided with a rich plexus of lymphatic capillaries. They are resent in several layers, of which the outermost form the richest plexus. Lymphatic capillaries ave also been described accompanying the blood-vessels in the Haversian canals in bones Rauber, Schwalbe, Budge). Nothing is known concerning the lymphatics of the bone-mar-ow. *Cartilage* lacks both blood- and lymphatic capillaries.

The capsular membranes of *joints* are richly provided with lymphatic capillaries (Tillmanns). They are arranged in two layers—an inner layer made up of a rich plexus of wide capillaries, ying just outside the subendothelial blood-capillaries, and an outer layer, consisting of a rich lexus in the subsynovial tissue. The lymphatic capillaries have no open connection with the oint-cavity.

The membranes surrounding the *pleural*, *pericardial* and *peritoneal cavities* are richly sup-lied with lymphatic capillaries, which form here thick plexuses under the mesothelium. These lexuses are usually described with the underlying organ, as the subserous lymphatic capillaries f the intestine, etc. In the central tendon of the diaphragm the subperitoneal lymphatics are xtremely rich. They widen out here to form very large endothelial-lined cavities which, in the paces between the connective tissue bundles, lie directly in contact with the peritoneal pithelium. The existence of open connections between these capillaries and the peritoneal and leural surfaces (the 'stomata' of von Recklinghausen) has been disproven. The capillaries n the two surfaces of the central tendon communicate freely with one another.

2. THE LYMPHATIC VESSELS

The lymph which enters the lymphatic capillaries passes over into collecting vessels [vasa lymphatica] which carry it through the lymph-glands (nodes) to the large veins at the base of the neck. The general course of the lymphatic drainage from any given region is usually very similar to that of the corresponding venous drainage. The lymph-vessels course in the loose subcutaneous tissues, in the connective tissues between muscles and organs, often accompanying the arteries and veins, sometimes forming networks around them. An idea of their arrangement can be best obtained by glancing at the illustrations of the lymphatics of special regions. In general they are made up of numerous long, narrow vessels, rarely more than half or three-fourths of a millimeter in diameter, which occasionally communicate with one another, and which converge toward groups of lymph-glands placed in certain definite regions. In the lymph-glands (fig. 625)

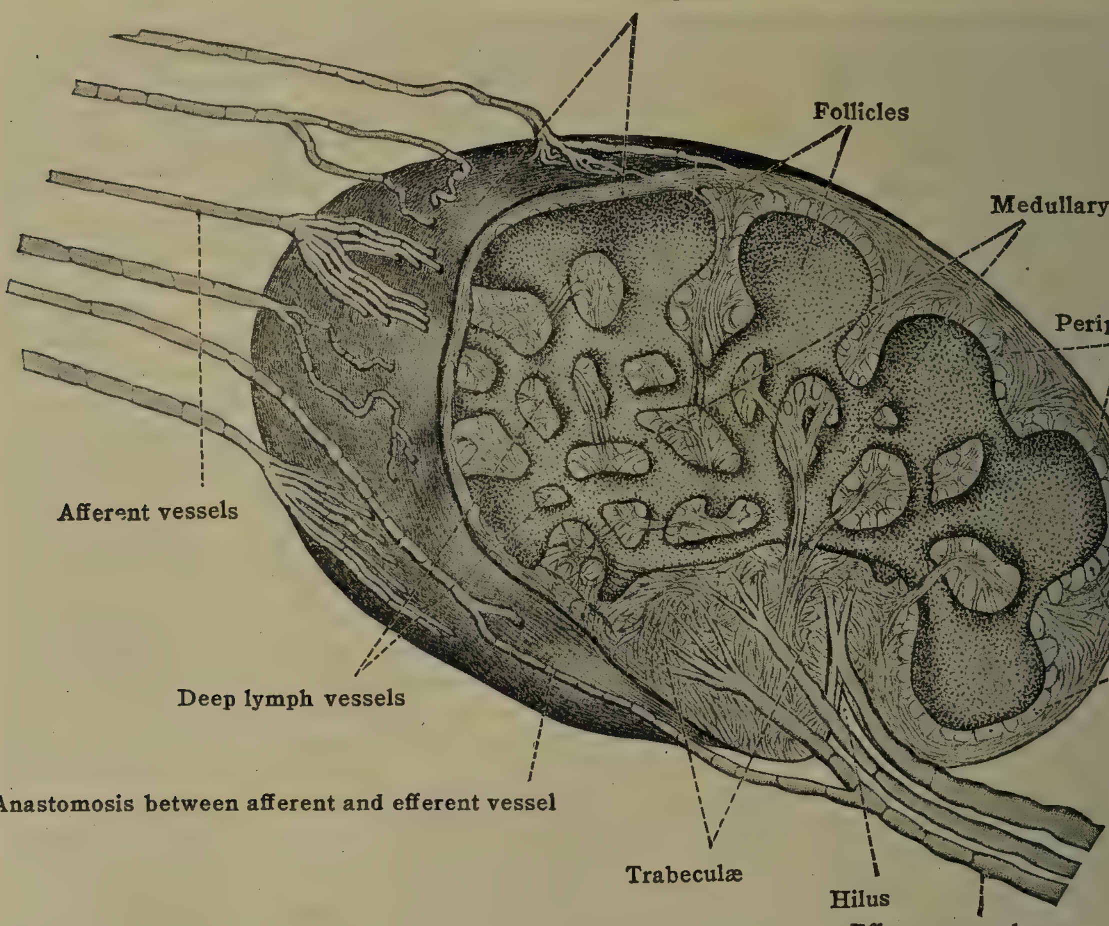


FIG. 625.—DIAGRAM OF A LYMPH-NODE. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

the afferent lymph-vessels break up into capillaries, which again collect into efferent vessels. Several of these efferents from each lymph-gland may pass to a second lymph-gland, where they undergo a second widening into capillaries. In this way the lymph, passing through one, two, three or more lymph-nodes in succession, eventually reaches the thoracic duct, or one of the short ducts, all of which empty into the large veins at the base of the neck. The thoracic duct which receives, at its lower end, the lymph from the lower half of the body, is the only lymphatic vessel which attains any considerable size (four to six mm. in diameter) and is usually the only one large enough to be seen readily without injection.

In *structure* the lymphatic vessels much resemble the veins. They possess an intima, a media and an adventitia, although the line of demarcation between the different layers is not sharp. In the thoracic duct, the endothelium of the intima is succeeded by a delicate layer of fibers, mainly elastic; outside of this is the media, made up mainly of circular smooth muscle-cells, interspersed with elastic and connective tissue fibers; then follows a layer of coarse elastic and connective tissue fibers, which is succeeded by the adventitia, containing longitudinal and transverse bundles of smooth muscle-cells, as well as blood-vessels and nerves. The other lymphatic vessels possess the three layers, which, however, toward the capillaries, grow thinner, and eventually reach a stage in which, outside the endothelium, there are found only single muscle-cells, or muscle-cells in groups of two or three.

The lymphatic vessels are characterized by their great richness in valves, which are present throughout their entire course, from their beginnings in the capillary region to their openings into the veins of the neck. The valves are bi- or tri-cuspid, and are always arranged so as to prevent the flow of lymph back to the capillaries. They thus aid indirectly in the *movement of the lymph*, in that any external pressure on the vessels must always force the lymph onward. The pressure of the surrounding organs and skeletal muscles, and the contraction of the smooth muscle in the walls of the lymph vessels, form important secondary factors in the movement of the lymph. The primary force, however, doubtless comes from the secretory or filtration phenomena of the lymphatic capillary walls.

Nerves of lymphatic vessels.—That the thoracic duct and the smaller lymphatic vessels are provided with nerves has been shown by several observers. According to Kytmanoff (in dogs) the nerves to the lymphatics are mainly non-medullated, and are both motor and sensory. They form four sets of plexuses—adventitial, supramuscular, intermuscular, and subendothelial. Sensory nerve-endings are found in adventitia and media, in the form of free-ending threads,

FIG. 626.—SURFACE VIEW AND SECTION OF A LYMPH-NODE SHOWING THE PERIPHERAL AND CENTRAL SINUSES. (After Teichmann.)

and bush-like endings. Motor endings are present in connection with the smooth muscle cells of the media. In the intima there is a plexus of extremely fine varicose threads. The physiological action of the nerves supplying the cisterna chyli has been tested by Camus and Gley who found in dogs a dilation of the cisterna as the result of electrical stimulation of the splanchnic nerve. Florey has observed spontaneous rhythmic contractions of mesenteric lymphatic vessels in guinea-pig and rat, but failed to find them in man and other mammals. In some animals they contracted as a result of stimulation of sympathetic nerves, and in all animals following direct mechanical stimulation.

3. *THE LYMPHOID ORGANS*

Closely associated with the lymphatic capillaries and vessels is a group of glandular structures known as lymphoid organs. They consist, essentially, of groups of round lymphoid cells, lying in a meshwork of reticulum fibers, and having often a definite relationship to the blood- or lymph-vessels. The group of lymphoid organs includes, in addition to the lymph-glands [lymphoglandulæ] or lymph-nodes (lymphonodi NK), which are particularly related to the lymphatic

vessels, the spleen, thymus and (in part) bone-marrow, which are also largely made up of lymphoid tissue. The thymus, however is considered separately with the Glands of Internal Secretion (Section XIII).

In their most simple form, the lymphoid organs form mere irregular accumulations or patches of lymphoid cells, which have been termed lymphoid infiltrations. Such patches are frequent in mucous membranes especially along the intestinal tract and the air-passages in the lungs.

Larger accumulations of lymphoid cells produce definite round nodules, which may occur singly, as *solitary follicles* or in groups, as *aggregated follicles* (Peyer's patches) (fig. 623). In the solitary follicle the lymphoid cells are arranged concentrically, with a region in the center where the cells are less closely packed together. This is called the germinal center, and contains numerous cells undergoing mitotic division. The solitary follicle contains blood-capillaries. Lymph-capillaries, however, do not enter the follicle but form a rich plexus about it.

The **lymph-glands** or nodes (fig. 625) are larger lymphoid structures, which are developed along the course of the lymph-vessels. They vary much in size, shape, and color, and may occur singly or in small or large groups. The *size* varies from the size of a pin-head to that of an olive, or larger. In *shape* they may be spherical, oval, or flattened on one or more sides, according to their relations to other organs. Each gland has an indentation or hilus, where the arteries enter, and where the veins and efferent ducts emerge. Their *color* depends upon position and state of function. The glands along the respiratory tract are black, due to the presence of carbon granules. The mesenteric glands are milk-white during digestion, and other nodes are pale and translucent when their sinuses are filled with fluid, and pink or even red when red-blood cells are present in the sinuses. The lymph-gland is made up of four distinct elements: lymphoid elements, lymphatic capillaries, supporting structures, and blood-vessels.

The *lymphoid elements* (fig. 625) are arranged as follicles and as cell-strings. The follicles lie around the circumference of the gland, and form the cortex [substantia corticalis]. The cell-string or medullary cords are irregular cords of cells which extend from the follicles through the central or medullary portion [substantia medullaris] of the gland. The follicles and medullary cords are made up, as are the solitary follicles, of round lymphoid cells.

The *lymphatic vessels* (figs. 625, 626) enter the lymph-gland as several vasa afferentia, and leave it, at the hilus, as the vasa efferentia. The vasa afferentia spread out in the cortical portion of the gland into an extremely rich plexus of wide capillaries which surround the follicles, forming the peripheral sinus. The capillaries do not enter the follicle. This plexus continues, around the follicles, into the medullary portion where it forms again a rich plexus, the medullary sinus, in the spaces around the medullary cords. The medullary sinuses are broken up by naked reticulum fibers and cells, which are thus exposed directly to the lymph passing through the gland. At the hilus medullary capillaries collect into larger vessels and emerge as the vasa efferentia.

The *supporting structures* consist of a fibrous capsule surrounding the gland, from which trabeculæ or septa pass in, around and between the follicles and cords. From the septa, a fine reticulum passes into the follicles and cords, where it forms a rich dense meshwork, in the interstices of which lie the lymphoid cells. The capsule and trabeculæ are made up of white fibers, elastic fibers and smooth muscle-fibers.

The *blood-vessels*, which enter and leave at the hilus, send branches into the follicles and into the medullary cords.

The enormous widening of the lymph-stream in the lymph-node from the vasa afferentia to the capillaries—like a brook widening out into a pond—causes a very great diminution in the rate of flow of the lymph. Thus there is present in the gland a very slowly moving stream of lymph, which is separated from the lymphoid tissue outside by a single layer of flattened endothelial cells. There is thus possible an easy interchange of substances, and an opportunity for the passage, through the endothelium, of wandering cells. While the entire mode of functioning of the lymph-gland is not clear, it is known that lymphocytes, formed here, enter the lymph-stream and probably also the blood-stream, and that substances such as, for instance, carbon granules, or leucocytes laden with bacteria, are checked in their course by the lymph-gland. It is also known that lymph-glands become swollen as a result of the presence, in the lymph reaching them, of the poisonous products of bacterial action. This swelling of the lymph gland is an inflammatory process, and is not necessarily to be regarded as protective.

Lymphoid tissue is markedly reduced in amount during starvation (Jolly) and increased by rich feeding (Settles). The number of lymphocytes in the blood stream is increased during digestion.

Variations in lymphoid tissue according to age.—Lymphoid tissue—including lymph-glands, palatine and pharyngeal tonsils, aggregated and solitary follicles, the lymphoid portion of spleen and thymus—is much larger in amount in the child than in the adult (cf. p. 39). In fact, after an early period of relatively rapid growth there is a steady reduction in size, or atrophy, of lymphoid tissue both relative and absolute, which commences before adult life is reached. Miller believes that an exception is furnished by the lymphoid tissue in the lungs, due to the continuous irritation produced by carbon particles inhaled, which are taken up mainly by macrophages, and deposited largely around lymphoid accumulations.

Arrangement.—The lymph-glands are so arranged throughout the body that all the lymph which enters the lymphatic capillaries must pass through one or more lymph-glands on its way to the veins.

It is possible that this rule may have exceptions, although none have yet been definitely proved. Thus, some of the small lymphatics which join the thoracic duct may enter it without having passed through a gland. Moreover, there is often found (fig. 625) a direct anastomosis between an afferent and an efferent lymphatic vessel.

Most of the glands are collected in certain regions, where they form centers toward which the lymphatic vessels radiate. Such groups are termed regional glands. The glands forming such a group are connected with one another by numerous anastomoses, which are termed lymphatic plexuses. In addition to the regional glands there are many isolated glands which lie along the course of the lymph-vessels, and through which pass the vessels draining a much more limited capillary area. Such glands are termed *intercalated* glands.

4. *THE DEVELOPMENT OF THE LYMPHATIC SYSTEM*

Our knowledge of the lymphatic system has been very greatly increased during the past thirty years by studies on its mode of development. Previous to 1902 nothing definite was known about the primary development or the mode of growth of the lymphatic system. It was concluded by some (Budge, Gulland and Saxer) that the lymphatics arise from undifferentiated

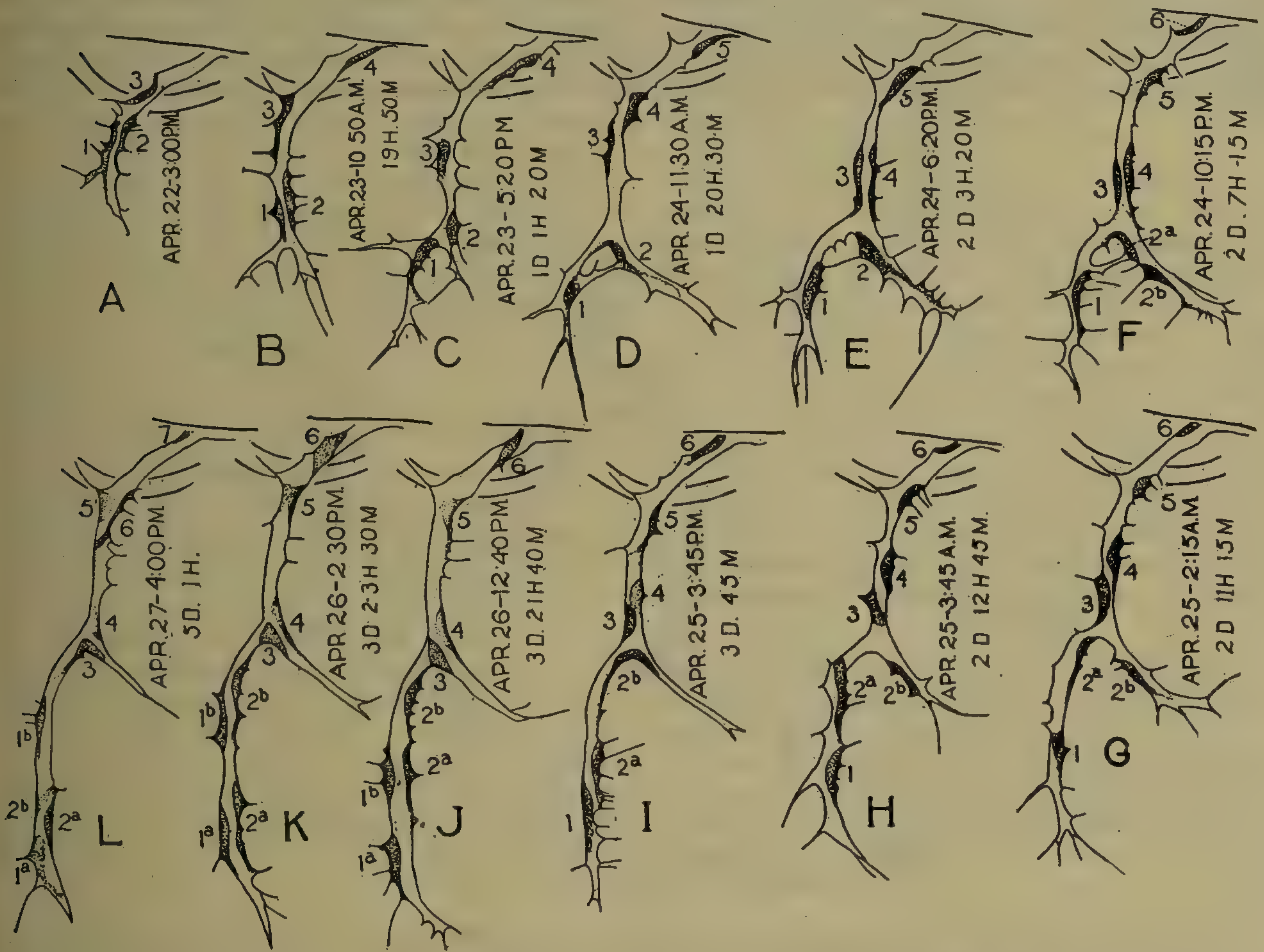


Fig. 627—The Growth of a Lymphatic Capillary, as seen in the Transparent Tail of a Living Frog-Larva. Nuclear areas are dotted, and corresponding areas are numbered. (After E. R. Clark.)

mesenchyme cells; Ranvier believed that they arise from veins by budding of the endothelium; while Sala described them as arising partly from the mesenchyme and partly from venous endothelium. Regarding the mode of growth and spreading of the lymphatics, various theories were likewise held. Kölliker, His, Goethe and, later, Sala held that growth takes place by the successive addition of mesenchyme cells; Langer, Rouget, and Ranvier maintained that growth takes place by sprouting of the endothelium. S. Mayer thought that new lymphatics are derived from transformed blood-capillaries.

Miss Sabin, in 1902, gave the first clear picture of the mode of origin and growth of the lymphatic system, and our present knowledge has grown largely out of her discoveries. She showed, by injections of pig-embryos, that the lymphatics of the skin appear first in four regions of the body—two on each side at the base of the neck, and two in the inguinal region—in the form of sacs which are connected with the veins and spread out step by step over the skin of the entire body in the form of a richly anastomosing capillary plexus. Numerous studies have since been made on the mode of development of lymphatics, in many different animals, including man. The results of these studies leave many points still matters of controversy, and several divergent views have been developed, particularly as to the primary source of lymphatic endothelium. Miss Sabin first made the obvious conclusion that it is derived from venous endothelium by a process of sprouting, a view maintained by Hoyer and his pupils. F. T. Lewis described the first lymphatics as forming by the actual transformation of veins into lymphatics—a view which Miss Sabin later concurred in. Huntington and McClure at first also agreed with this view, but later gave it up in favor of the view that all lymphatic endothelium is derived from mesenchyme cells. This view has been supported chiefly by their pupils—Stromsten, Miller and West. E. R. and E. L. Clark failed to find any evidence for the trans-

formation of blood-capillaries into lymphatics. There is pretty general agreement that the earliest endothelium differentiates in certain definite regions, in the neighborhood of the veins. A recent study of the early lymphatics in chick-embryos, however, casts doubt upon the validity of this view. It was found that, in chick-embryos, if regions such as the posterior body-wall and the base of the posterior limb-bud are experimentally isolated from their supposed source of lymphatic supply, lymphatics develop *in loco*—but whether from blood-vessels or mesenchyme cells the authors were unable to determine. However, it has been found by all investigators that lymphatics have numerous connections with the veins, at early stages, particularly in certain regions, and that the number of connections is rapidly reduced, as the separated lymphatics grow together and anastomose, until, in most higher vertebrates, the only connections which persist are those at the right and left jugulosubclavian angles. The exact mode of origin is still in dispute and uncertain, largely on account of difficulties in technique.

The method by which lymphatics extend after their primary differentiation is also a matter of dispute. According to Huntington and McClure, lymphatic endothelium spreads chiefly by the continued differentiation of the indifferent mesenchyme cell into lymphatic endothelium. S. Mayer thought that spreading occurred by the continuous transformation of blood-vessels into lymphatics, although E. R. Clark, working on the same material, showed conclusively that he was in error. A similar view has been tentatively proposed by F. T. Lewis. Another group including Ranvier, MacCallum, Sabin, Hoyer, Clark, etc., hold that the spreading takes place by sprouting—that after the primary differentiation new lymphatic endothelium is derived exclusively from old. This has been observed in the transparent tails of living frog-

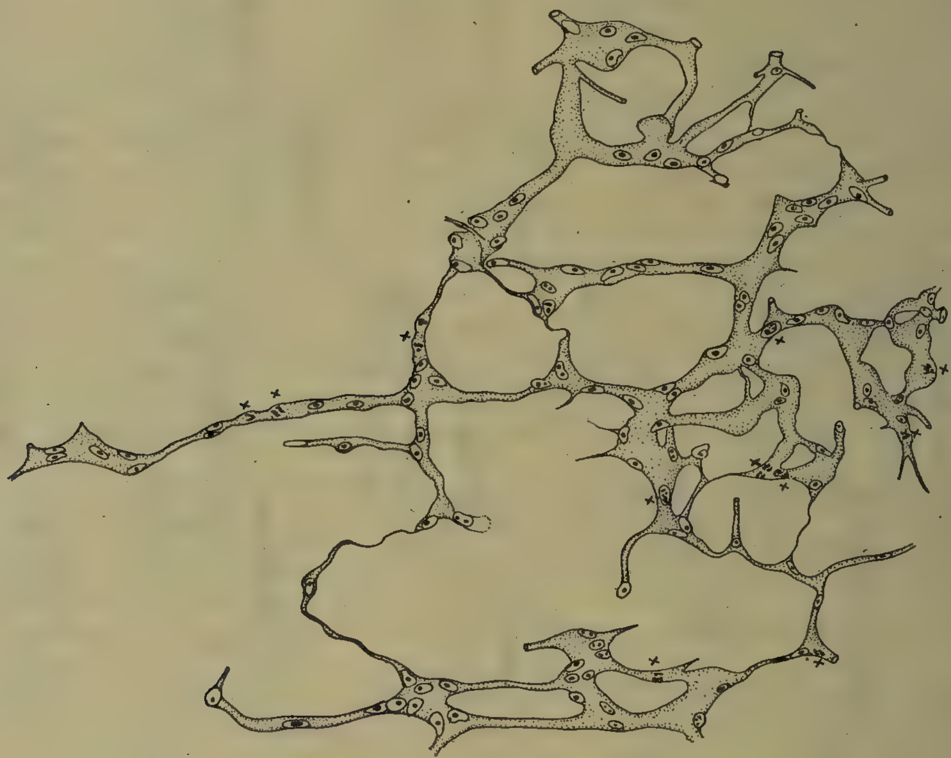


FIG. 628.—PORTION OF EARLY SUBCUTANEOUS LYMPHATIC PLEXUS. From the hip region of a chick embryo of 5 days, 7½ hrs. incubation, showing the character of the primitive plexus and the frequency of mitoses (marked X.) (After E. R. and E. L. Clark.)

larvæ (fig. 627). Studies of very early lymphatics in pig- and chick-embryos indicate clearly growth by sprouting (fig. 628). Growth by sprouting of mammalian lymphatics has been finally established by direct observation in the living, in artificial double-walled transparent chambers introduced into the rabbit's ear (Clark and Clark). There is therefore solid basis for the view that lymphatic endothelium, after its primary differentiation (the exact extent of which in time and place has not yet been entirely cleared up), becomes a specific, independent tissue, from which all lymphatic endothelium is derived.

The *lymphatic nodes* do not make their appearance until the system of vessels is well established. They are at first represented by masses of lymphoid tissue in the meshes of a lymphatic network. Later the lymphoid mass breaks up into smaller portions, into which the blood-vessels and branches from the surrounding network penetrate; and each mass, together with the portions of the network surrounding it, becomes enclosed in a connective tissue capsule. The original lymphoid tissue becomes transformed into the medullary cords and cortical nodules of the node, while the enclosing lymphatic capillaries form its peripheral lymph-sinus.

The earliest nodes appear in the places occupied by the primary lymphatic plexuses or sacs (Miss Sabin, F. T. Lewis, Jolly), and have been termed the 'primary nodes' (Miss Sabin). Secondary and tertiary sets of nodes develop later at places of confluence of many lymphatics (cf. A. H. Clark.)

Regeneration and new growth of lymphatic vessels and glands.—While blood-vessels are known to possess throughout life the capacity for regeneration and new growth, this process in lymph-vessels has been studied less fully. Coffin described newly-formed lymphatics in pleural adhesions, Evans in sarcomata, and E. R. and E. L. Clark have watched the process of regeneration and new growth in both the tail of the tadpole and the rabbit's ear. The process is similar to the new formation of blood-vessels, though appreciably slower.

The question as to whether lymph-glands may form anew is not yet entirely settled. The study of the problem is extremely difficult, because very small lymph-nodes may be normally present in a certain region, yet they may escape observation until they become hypertrophied under certain conditions. A. W. Meyer in a careful experimental study found no evidence of new-formation of lymph glands. On the other hand, there is considerable evidence for the new-formation of lymph-glands under pathological conditions.

The hemal nodes.—In addition to the lymph-nodes, there are present in certain animals (bovines, sheep and goats), and probably in man, a set of nodes somewhat similar to lymph-nodes in size, but related to the blood-vascular system, and without any connections with lymphatic vessels—the *hemal nodes* (hæmolymphonodi NK). Their structure resembles that of lymph-nodes, in that there are accumulations of lymphoid tissue, with peripheral and central sinuses, but the sinuses are filled with blood instead of lymph, thus giving them a red color. There is considerable resemblance, histologically, between hemal nodes and accessory spleens, and without doubt the two have frequently been confused. There is still some question as to the precise relationship between the sinuses and the arteries and veins. Some observers hold that arteries supply and veins drain the sinuses, others that the vascular connections of the sinuses are purely venous. Their function is unknown.

Their distribution is variable. In sheep (A. W. Meyer) they may be found anywhere near the viscera, from the base of the skull to the rectum, with a tendency to the following groupings: pararectal, lumbar or prevertebral, mediastinal, and cervical. The total number in sheep averages between thirty and forty. In bovines there is a variable number (2–36) of subcutaneous hemal glands, located mainly over the back in neck, shoulder and hip-regions. There are probably no hemal glands in cat, dog, pig, guinea-pig, rat and rabbit.

A much disputed point has been the question as to whether there is a type of gland, intermediate between the hemal gland and the lymph-gland. Several observers have described such glands. However, A. W. Meyer, who has made the most thorough studies of hemal glands, is very strongly of the opinion that there is no intermediary type—that the hemal glands are definite and distinct structures, and that the term 'hemolymph' gland should be discarded.

Comparative.—Lymphatics are present in all vertebrates, excepting possibly the lower fishes. In amphibia, there are several longitudinal vessels, two of which connect with a variable number of segmental veins. There is also an important connection at the junction of the anterior and posterior cardinal veins. At the points of connection of the lymph-vessels with the veins, lymph-hearts (in variable number, over 100 in Gymnophiona) are found, which pump the lymph into the veins. In reptiles, there is but a single pair of lymph-hearts (posterior). In certain birds, chiefly aquatic, a pair of posterior lymph-hearts persists throughout life, while in others, such as the chick, a pair is present and active until the time of hatching, after which it atrophies and disappears. No lymph-hearts are present in mammals. In the frog there are found large subcutaneous lymph-sacs, which are drained by lymphatic vessels.

The thoracic duct is double in lower vertebrates, and in early embryonic stages of mammals. In adult mammals it is normally single. The number of persistent connections of the lymph-vessels with the veins shows a reduction from lower to higher vertebrates. In reptiles, there are two pairs, in birds, one or two pairs, in mammals (typically) one pair.

No lymph-glands have been found in fishes, amphibia or reptiles. In birds (Jolly) lymph-glands are present in some of the lamellirosters—swan, duck and goose—but are absent in hen and pigeon. In mammals, all of which have more extensive sets of lymph-glands, the first to develop arise out of the primary lymph-sacs and correspond in location to the lymph-glands found in birds.

SPECIAL ANATOMY OF THE LYMPHATIC SYSTEM

The lymphatic system will be considered by regions as follows: A, head and neck; B, upper extremity; C, thorax; D, abdomen and pelvis; E, lower extremity.

A. THE LYMPHATICS OF THE HEAD AND NECK

The lymphatics of the head and neck may be divided into two sets. One set is superficial, draining the entire skin-surface, and has its nodes, for the most part, in the neck, the principal group lying along the external jugular vein. The other set is deeper and drains the mucous membrane of the upper part of the digestive and respiratory tracts, together with the deep organs, such as the thyroid gland, and the tendons of the muscles. The nodes of this set are deeply placed being situated along the carotid arteries, with outlying retropharyngeal nodes.

1. THE SUPERFICIAL NODES OF THE HEAD AND NECK

Lymph-nodes appear first in the neck in the process of development. In the pig the first node to appear develops from the lymph-sac, which is in the supraclavicular triangle behind the sternocleidomastoid muscle. From here vessels grow across the muscle and give rise to a chain of nodes along the external jugular vein. This chain is to be considered as the main chain of superficial nodes in the neck. From it lymphatic vessels grow over the back of the head, the side of the head, the face, and the front of the neck, and in their course groups of secondary

nodes develop. The nodes of the main chain are known as the superficial cervical nodes, and are from four to six in number. The secondary groups are—(1) the occipital; (2) the posterior auricular; (3) the anterior auricular; (4) the parotid; (5) the submaxillary, with the facial as a tertiary set, and (6) the submental

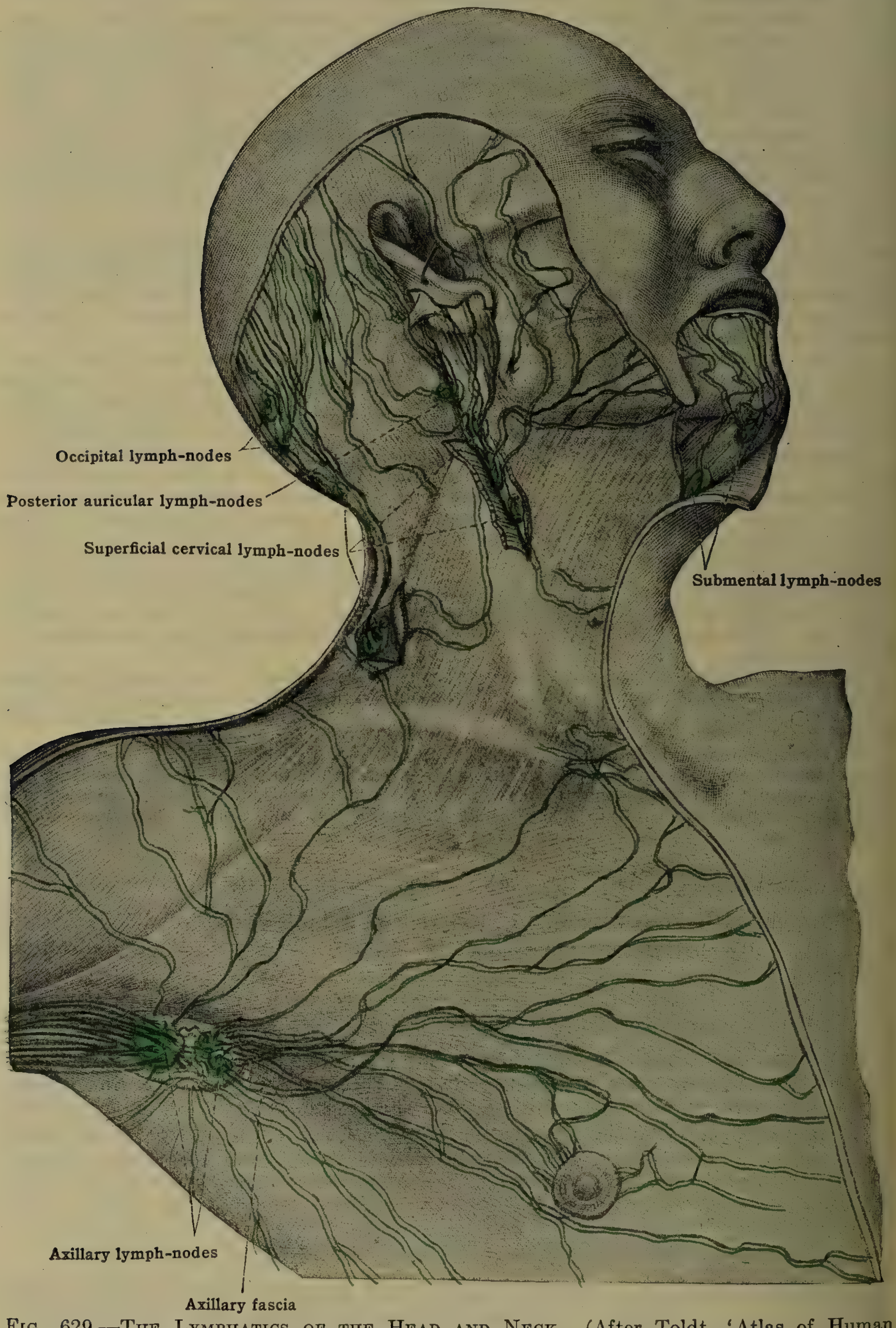


Fig. 629.—The Lymphatics of the Head and Neck. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

1. **The occipital nodes** [lymphoglandulæ occipitales].—The lymphatics of the scalp of the back of the head collect into a few trunks that either empty into from one to three small nodes near the occipital insertion of the semispinalis capitis

muscle, or pass by the secondary group and empty directly into the upper nodes of the main superficial cervical chain (figs. 629, 631).

2. The **posterior auricular nodes** [lgl. auriculares posteriores] (lymphonodi retroauriculares NK).—A portion of the temporal part of the scalp, together with the posterior surface of the auricle, except the lobule, and the posterior surface of the external auditory meatus, drain into two small nodes on the insertion of the sternocleidomastoid muscle. The efferent vessels of these nodes pass to the upper part of the superficial cervical chain (fig. 629).

3. The **anterior auricular nodes** [lgl. auriculares anteriores] are few in number—from one to three—and are situated immediately in front of the tragus. They receive vessels from the anterior surface of the auricle and the external auditory meatus, from the integument of the temporal region and the lateral

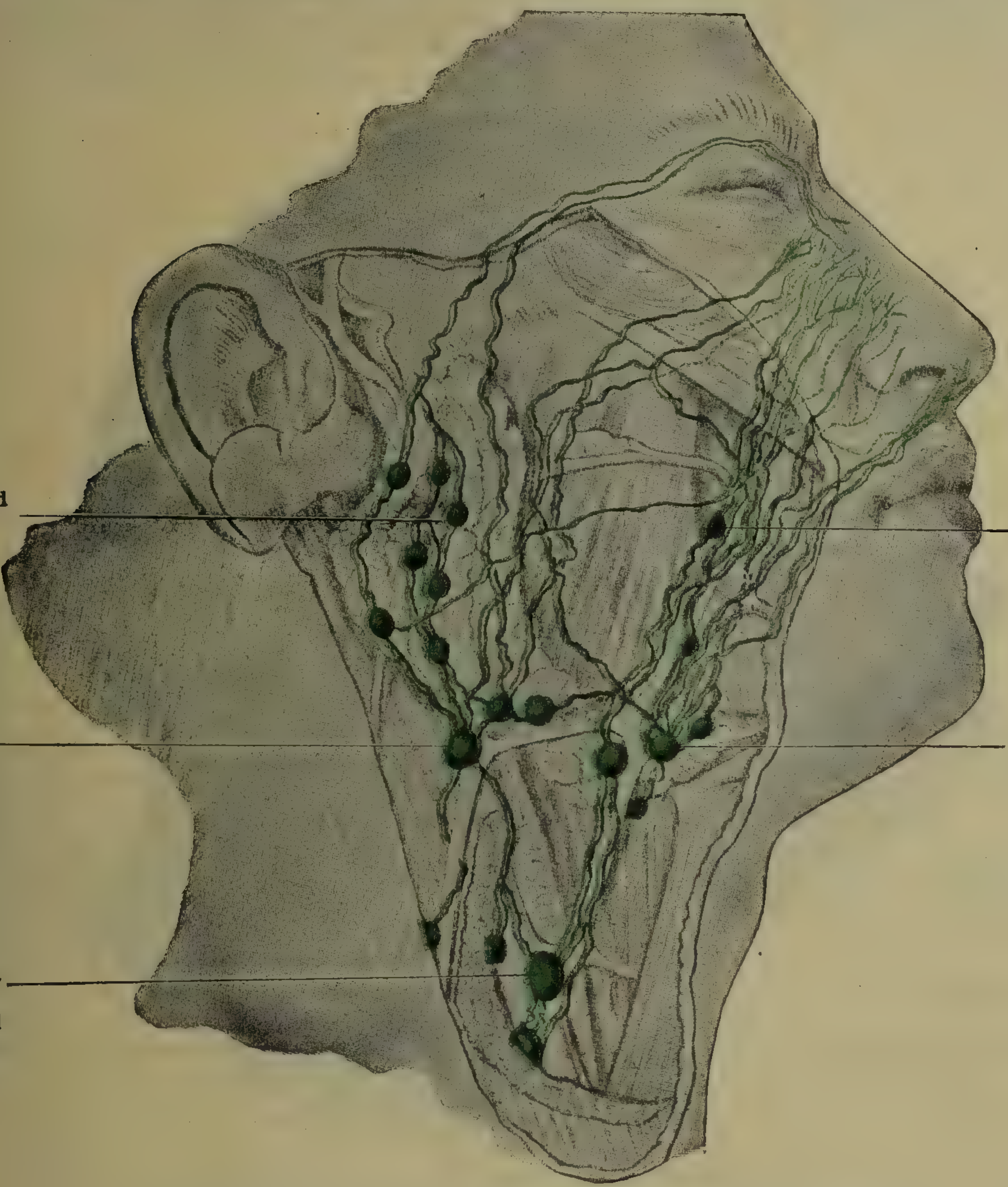


FIG. 630.—LYMPHATICS OF THE FACE. (After Küttner.)

portion of the eyelids. Their efferents pass to the parotid and superior deep cervical nodes (fig. 631).

4. The **parotid nodes** [lgl. parotideae].—The parotid group of nodes (figs. 630, 631, 635) is considerably larger than the two preceding, containing from ten to sixteen nodes, and the group drains a more complex area. It receives vessels from the adjacent surface of the external ear, the external auditory meatus, the skin of the temporal and frontal regions, and the eyelids and nose. The deeper nodes of this set receive vessels from the parotid gland.

In the embryo these nodes lie in the pathway of the lymph-vessels that grow to the scalp; many of these vessels, however, pass the parotid group and empty into the superficial cervical chain. The nodes of the parotid group lie embedded in the substance of the parotid gland, and their efferents pass to the submaxillary and the superior superficial and deep cervical nodes.

As 'inferior auricular nodes' (fig. 631), Bartels designates one or two small glands of the parotid group which lie below the ear, and receive afferent vessels from its lower part.

5. **The submaxillary and facial nodes.**—The submaxillary (lymphonodi submandibulares NK) group (figs. 630, 631, 635) consists of a chain of from three to six nodes, resting on the submaxillary (salivary) gland, along the inferior border of the mandible. They lie usually on the submaxillary gland, but may extend from the insertion of the anterior belly of the digastric to the angle of the jaw. They are about 5 mm. in diameter, and the largest is near the point where the external maxillary (facial) artery crosses the mandible. The submaxillary nodes, together with the next group, the facial, drain a complex area, including not only skin, but mucous membrane. They receive lymph-vessels from the nose, cheek, upper lip, the lateral part of the lower lip, together with almost all those from the gums and teeth and from the anterior third of the lateral portions of the tongue. In agreement with the fact that these nodes, though lying superficially and draining the skin, drain also the mucous membrane, their vessels empty not only into the superficial cervical chain, but also into the deep cervical chain.

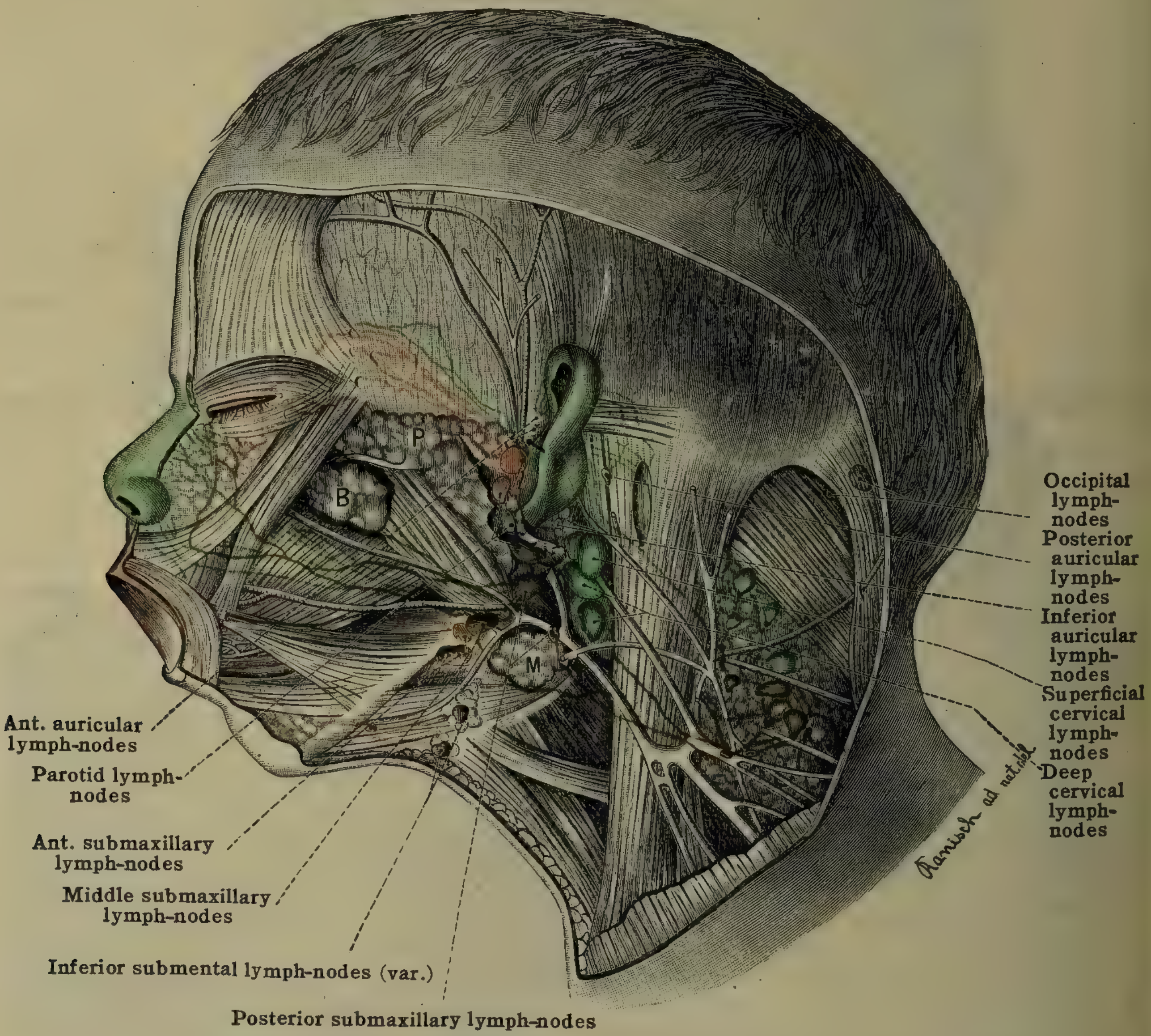


FIG. 631.—LYMPHATIC NODES AND VESSELS OF THE EAR, EYELIDS, NOSE AND LIPS. New-born child. P, parotid. M, submaxillary gland. B, buccal fat ('sucking pad'). The dorsal deep cervical lymph-nodes are not labelled. (After Bartels.)

The **facial nodes** (lymphonodi faciales profundi NK) (figs. 630, 632) are evidently outlying nodes of the submaxillary group. They are in two main sets—(1) the **supramaxillary set,** which consists of from one to thirteen nodes, resting on the mandible near the point where it is crossed by the external maxillary (facial) artery; (2) the **buccinator set,** lying on the line connecting the lower margin of the ear and the angle of the jaw.

Of these latter nodes, some lie near the point where the parotid duct perforates the buccinator muscle; the others are further forward, between the external maxillary artery and the anterior facial vein. Additional nodes belonging to the group may occur near the nose and in the suborbital region. These facial nodes receive afferents from the outer surface of the nose, the lips, eyelids, cheek, temporal part of the face, the mucosa of the mouth, the teeth of the upper jaw, the gums, the tonsils, and the parotid gland. Their efferents pass to the submaxillary and parotid nodes.

6. The **submental nodes,** usually two in number, lie in the triangle bounded by the anterior bellies of the two digastric muscles and the hyoid bone (figs. 629, 631, 637). They are usually near the median line, and drain the skin of the chin, the skin and corresponding mucous membrane of the central part of the lower lip and jaw, the floor of the mouth, and the tip of the tongue. The efferent vessels pass either to the submaxillary nodes or to the deep cervical chain.

2. THE LYMPHATIC VESSELS OF THE FACE

The different parts of the face and their lymphatic relation to these groups of superficial nodes will now be considered.

The lymphatics of the scalp (figs. 629, 635) form a rich network in the neighborhood of the vertex, from which vessels pass in various directions. From the frontal region a number of vessels pass downward and backward to the parotid nodes; those from the parietal and temporal regions pass to the anterior auricular, parotid, and posterior auricular nodes; and those from the occipital region pass

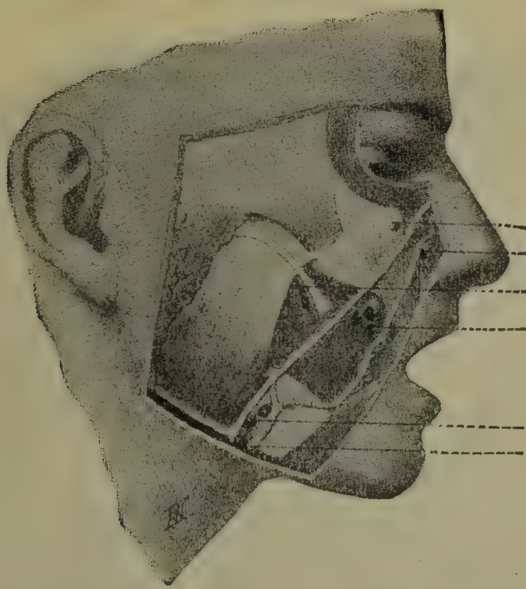


FIG. 632.—THE FACIAL NODES. (After Buchbinder.)

partly to the occipital nodes and partly to the superior deep cervical group, while a single large vessel descends along the posterior border of the sternomastoid muscle to terminate in one of the inferior deep cervical nodes.

The lymphatics of the eyelids and conjunctiva.—The capillary plexus of the eyelids and the conjunctiva is an abundant one, and at the free border of the eyelids becomes extremely close. The lymphatics from the lateral three-fourths of the lids pass to the anterior auricular and parotid groups of nodes, while those from the medial one-fourth pass obliquely across the cheek with the facial vein to terminate in the facial and submaxillary nodes (figs. 630, 631, 635).

The lymphatics of the nose.—The lymphatics of the nose (figs. 630, 631) form a network which is coarse at the root of the organ, but dense over the alar region. The vessels run in three sets—(1) one set passing over the eye to the parotid nodes; (2) a set passing under the eye to the same nodes; and (3) the most important group, consisting of from six to ten trunks, passing to the facial and submaxillary nodes. There are some anastomoses between the capillaries of the skin and those of the mucous membrane of the nose.

The lymphatics of the lips (figs. 633, 635).—The capillary plexuses of the skin and mucous membrane are continuous at the free border of the lips. The vessels of the upper lip, of which there are about four on each side, pass to the submaxillary nodes. From the lower lip the trunks from near the angle of the mouth pass to the submaxillary nodes, while those from the center of the lip pass to the submental nodes.

There are from two to four subcutaneous vessels and from two to three submucous vessels on either side. The collecting trunks passing to the submaxillary nodes do not anastomose, and the same is true of the submucous vessels of the lower lip. On the other hand, the subcutaneous vessels passing to the submental nodes anastomose freely, an important fact in connection with the extension of cancer of the lower lip.

The lymphatics of the auricle and external auditory meatus.—The lymphatic plexus in the auricle, external auditory meatus, and the outer side of the tympanic

membrane is an abundant one. An anastomosis has been described between a scanty plexus on the inner side of the tympanic membrane and the plexus on the outside. The collecting vessels pass to three sets of nodes:—(1) those from the external and internal surface of the auricle and the posterior part of the external auditory meatus pass to the posterior auricular nodes; (2) those from the lobule, the helix, a part of the concha and the outer portion of the external auditory meatus pass to the inferior auricular and superficial cervical chain; some of the vessels from the first and second areas also run to the deep cervical group; (3) an anterior group from the tragus and part of the external auditory meatus consisting of from four to six trunks, pass to the anterior auricular nodes, which are connected with the parotid nodes.

3. THE DEEP LYMPHATIC NODES OF THE HEAD AND NECK

The **deep cervical chain** (figs. 630, 631, 633–635) is the largest mass of nodes in the neck. It consists of from fifteen to thirty nodes, which lie along the entire

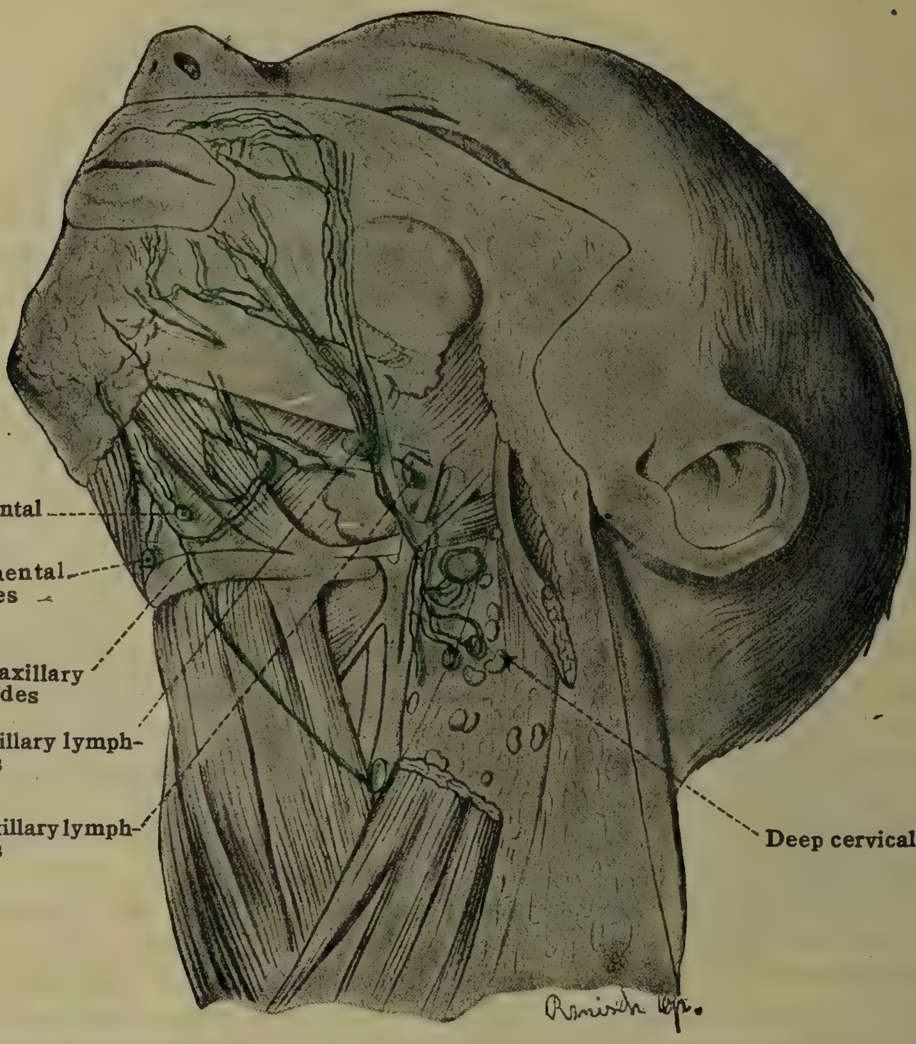


Fig. 633.—The Lymphatics of the Lips. Newborn child. (From Bartels after Dorendorf.)

course of the carotid artery and internal jugular vein. This chain receives vessels from all the superficial nodes, also directly from the skin, as well as from the entire mucous membrane of the respiratory and alimentary tracts in the head and neck. Thus it drains both the superficial and the deep structures.

For convenience of description this long chain, though usually continuous, is divided into two groups—(1) a superior group, lying above the level at which the omohyoid muscle crosses the carotid artery, and (2) an inferior or supraclavicular group, lying below that level.

(1) **The superior deep cervical nodes** [lgl. cervicales profundae superiores] extend from the tip of the mastoid process to the level at which the omohyoid muscle crosses the common carotid artery. The **dorsal** and smaller nodes of the chain lie on the splenius, levator scapulæ, and scalene muscles (fig. 631). They drain the skin of the back part of the head, both indirectly and directly, and receive (1) efferents from the occipital and posterior auricular nodes, (2) a large vessel from the skin of the occipital part of the scalp, (3) some trunks from the auricle, and (4) cutaneous and muscular vessels from the neck. The **ventral**

nodes of the chain lie on the internal jugular vein. They drain the face both directly and indirectly, as well as the deeper structures of the head and neck. They show especially well in fig. 637 in connection with the tongue. (See fig. 635.)

(2) The **inferior deep cervical** [lgl. cervicales profundae inferiores] or supraclavicular nodes lie in the subclavian triangle (fig. 635). In the upper part of the triangle the nodes rest on the splenius, the levator scapulæ, and the scalene muscles, while at the base of the triangle they are related to the subclavian artery and the nerves of the brachial plexus. They drain a wide area, receiving vessels from the head, neck, arm, and thoracic wall. They are connected with the superior deep cervical chain, and receive afferents from the axillary nodes, and, in addition, they receive vessels directly from the back of the scalp, from the skin of the arm, and from the pectoral region. Thus it will be seen that a large part of the lymph of the head and neck, as well as some from the arm and thorax, passes through these nodes. Their efferents unite to form the jugular trunk, which ends at the junction of the internal jugular and subclavian veins.

In the descriptions of the deep lymphatic vessels certain additional groups of nodes will be considered, which may be regarded as outlying groups from the deep cervical chain.

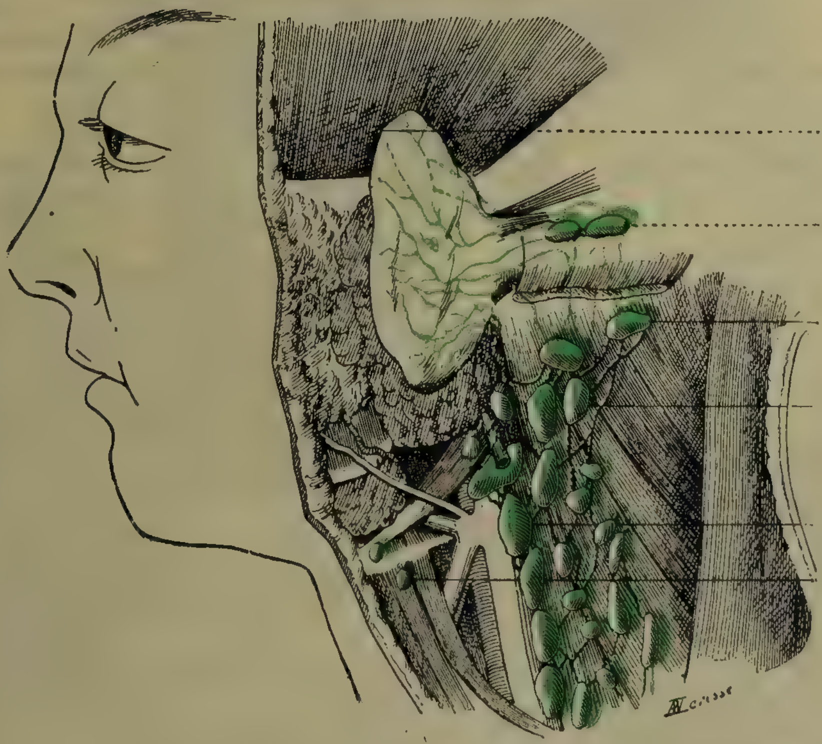


FIG. 634.—THE DEEP CERVICAL CHAIN. (After Poirier.)

4. THE DEEP LYMPHATIC VESSELS OF THE HEAD AND NECK

The lymphatics of the brain.—It is now recognized that there are no lymphatics in the brain and cord, so that the function of absorption must be accomplished by means of the veins. There is an abundant exudation of lymph around the nervous system into the subdural space, which is connected with the central canal of the nervous system, and which is to be considered as a zone in which the tissue-spaces are especially large. Along the arteries of the brain the adventitia is loose and open, possessing tissue-spaces which have received the confusing name of perivascular lymphatics. A better name would be perivascular tissue-spaces.

There is a continuous renewal of the fluid in the cerebral ventricle, chiefly derived from the choroid plexus. It passes into the subarachnoid spaces through the three foramina in the roof and at the sides of the fourth ventricle. Fluid is removed from the subarachnoid spaces chiefly by passing through the arachnoidal villi into the venous sinuses of the cranium.

The lymphatics of the eye.—No lymphatic vessels have as yet been discovered either in the eyeball or in the orbit. In both, however, there are abundant tissue-spaces, the most noteworthy of the orbit being the **interfascial space** (space of Tenon), which communicates by a space between the optic nerve and its sheath with the subarachnoid spaces of the cranial cavity.

In the eyeball the tissue-spaces are abundant, aside from the vitreous and aqueous chambers. Numerous spaces exist in the choroid coat, especially in the lamina suprachoroidea, and in the sclerotic, both sets communicating by perivascular spaces surrounding the venæ vorticosæ with

the interfascial space. In the cornea there are abundant lacunæ, united by their anastomosing canaliculi, to form a network of lymph-spaces which come into close relation with the conjunctival lymphatics at the corneal margin.

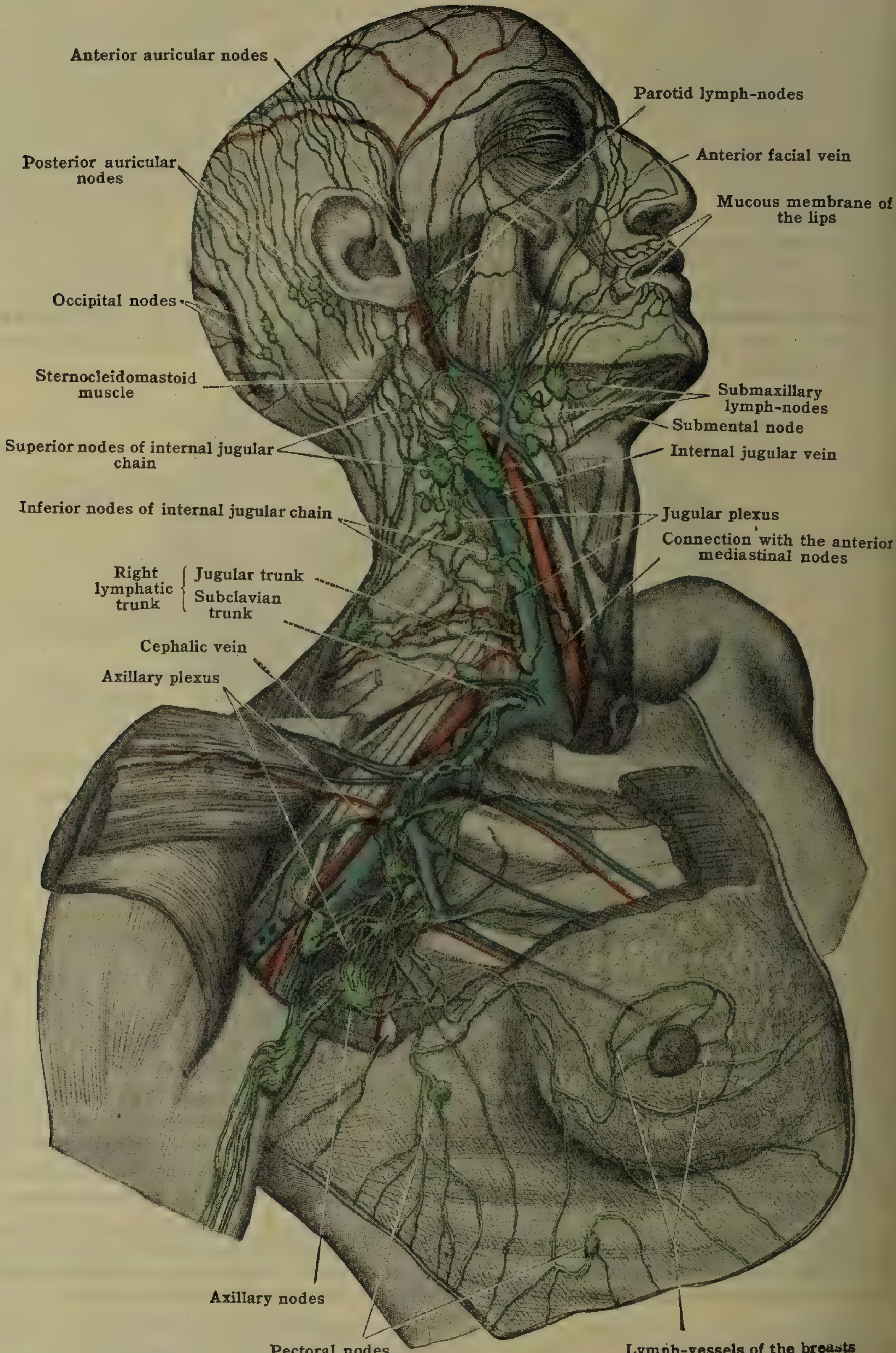


FIG. 635.—LYMPHATICS OF THE HEAD, NECK, AND AXILLA. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The **conjunctiva,** however, being a portion of the integument, does possess lymphatic vessels (fig. 636), arranged in a double network whose collecting vessels accompany those of the eyelids, and terminate with them in the submaxillary, anterior auricular, and parotid nodes.

THE LYMPHATICS OF THE DIGESTIVE TRACT IN THE HEAD AND NECK

The lymphatics of the gums and teeth.—The lymphatics from the mucous membrane of the gums pass to the submaxillary nodes. The capillary plexus is abundant; the collecting vessels arise from it on the inner surface of the gum, and pass between the teeth to reach a common semicircular collecting vessel on the outer surface. Lymphatics occur also in the pulp of the teeth (Schweitzer).

Both injections (Schweitzer) and clinical experience (Partsch and Ollendorff) indicate that the lymphatics which drain the pulp of the teeth of the upper jaw emerge through the infra-orbital foramen and pass chiefly to the middle and posterior submaxillary nodes, with exceptional drainage to the anterior submaxillary and parotid nodes. Those draining the teeth in the lower jaw pass along the mandibular canal to end chiefly in the middle submaxillary nodes, with occasional passage to the anterior or posterior nodes of this group.

FIG. 636.—THE LYMPHATICS OF THE CONJUNCTIVA, SURFACE VIEW. (After Teichmann.)

The lymphatics of the tongue (fig. 637).—There is a rich lymphatic plexus throughout the entire extent of the submucosa of the tongue, but that portion lying in the basal part of the tongue seems to be more or less independent of the rest. According to Aagaard the tongue muscles are provided with lymphatics which are drained by the vessels from the submucosal plexuses. There are four groups of collecting vessels—(1) apical, (2) marginal, (3) basal, and (4) central.

(1) The *apical vessels* are usually four in number, two on each side. One pair perforates the mylohyoid muscle and ends in a suprahyoid median node, while the other pair pass to the deep cervical chain. The latter are long, slender vessels, which run along the frenum of the tongue to the surface of the mylohyoid muscle, cross the hyoid bone just behind the pulley of the digastric and then run downward in the neck to a node of the deep cervical chain, just above the omohyoid. It will be noted in fig. 637 that the most anterior vessels end in the lowest nodes, while those from the back of the tongue end in higher nodes.

(2) The *marginal vessels* are from eight to twelve in number. They all pass to the superior deep cervical nodes, a part of them passing external to the sublingual gland, while the larger number pass internal to it. There is one large and constant node at the point where the digastric muscle crosses the jugular vein, to which a large number of the vessels converge.

(3) The *basal vessels* are seven or eight in number, and drain the basal portion of the tongue. Some end in the large node just mentioned, while others run backward close to the median line, where they anastomose, as far as the glossoepiglottidean fold, when they separate and join the tonsillar vessels to pass outward to the superior deep cervical nodes.

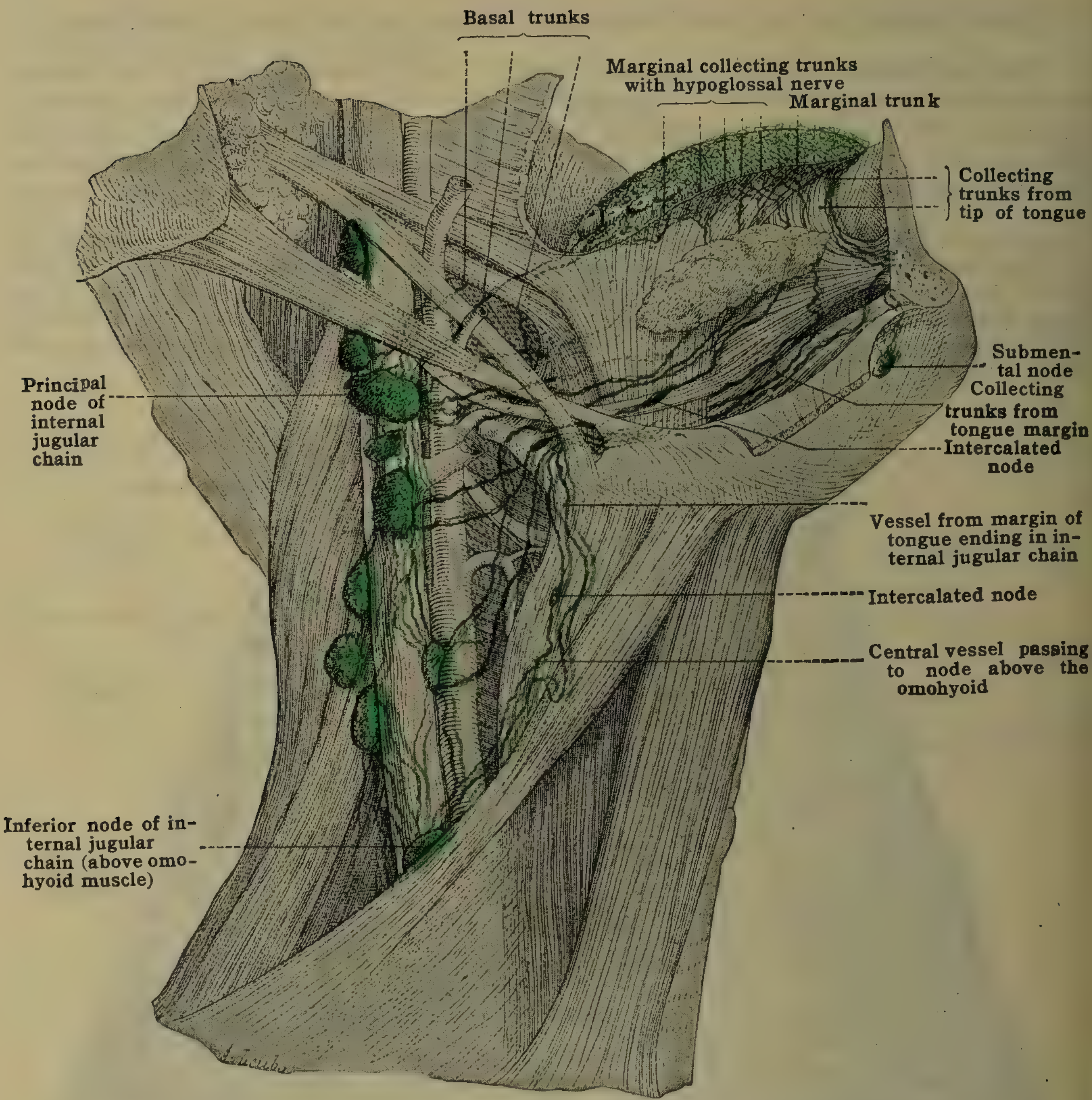


FIG. 637.—THE LYMPHATICS OF THE TONGUE. (Poirier and Charpy.)

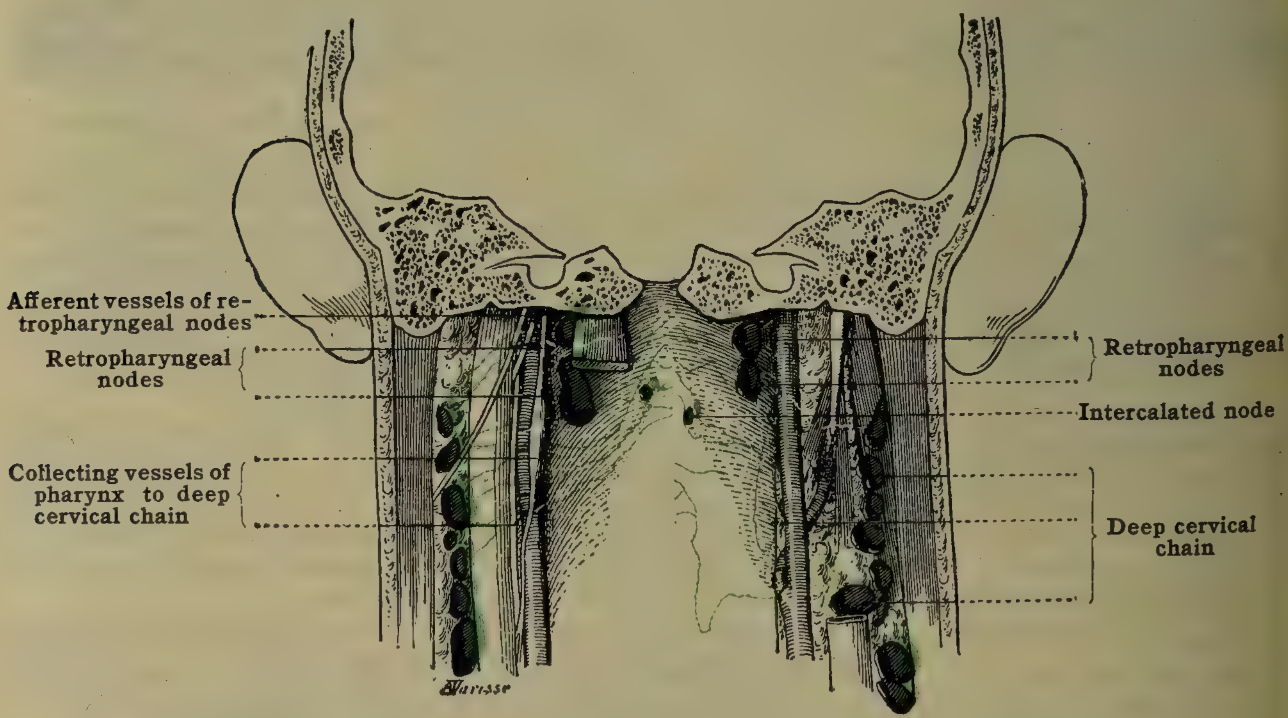


FIG. 638.—THE LYMPHATICS OF THE PHARYNX. (After Poirier and Cunéo.)

(4) The *central vessels*, arising from the central portion of the tongue, pass backward in the median line on the ventral surface of the tongue. They lie upon the mylohoyoid muscle, cross the hyoid bone, and end in the superior deep cervical chain.

The lymphatics of the palate.—The lymphatics from the palate pass to the deep cervical chain. The trunks from the hard palate run in the submucosa as far as the last molar tooth, where they pass in front of the anterior palatine arch (pillar) and end in the superior deep cervical nodes beneath the digastric muscle. In the soft palate the capillary plexus is very rich, reaching a maximum in the uvula. From the inferior surface of the soft palate and the palatine arches vessels pass directly to the superior deep cervical chain, but some of the vessels from the upper surface of the soft palate run forward with the pharyngeal vessels and end in the *retropharyngeal nodes*. It will be seen from fig. 638 that the retropharyngeal nodes are simply outlying nodes from the deep cervical chain.

The lymphatics of the pharynx.—As has just been stated, there are certain outlying nodes of the deep cervical chain which lie behind the pharynx. They receive some of the vessels from the submucosa of the roof of the pharynx, but many of the pharyngeal vessels pass by these nodes and end directly in the superior deep chain. The tonsil is especially rich in lymphatics, and its efferents, together with those from the middle and inferior portions of the pharynx, end in the superior deep cervical chain. The lymphatics of the Eustachian tube run to the lateral retropharyngeal lymph-nodes or, passing these, to the deep cervical nodes.

The lymphatics of the nasal cavities.—The mucous membrane of the nose contains a rich lymphatic plexus whose main trunks pass to the retropharyngeal nodes. An anterior set, however, anastomoses with the subcutaneous vessels, and through these their lymph is conveyed to the facial and submaxillary nodes. The posterior vessels run either to the deep cervical chain or to the retropharyngeal nodes. Key and Retzius have shown that an injection of the lymphatics of the nose may be made by injecting the subarachnoid spaces at the base of the brain, although there is presumably no direct connection between the spaces and the lymphatic vessels. The lymphatics of the nasal sinuses end in the retropharlyngeal nodes.

The lymphatics of the larynx.—The larynx is, for the most part, drained by the deep cervical nodes, although its lymph may also pass through certain outlying nodes situated upon its ventral surface. The mucous membrane is divided into two zones by the ventricular folds, the mucous membrane of these structures possessing but a scanty lymphatic plexus. The vessels from the upper part of the larynx, four or five in number, pass to the nodes of the superior deep cervical chain, situated near the digastric muscle; those from the lower part pass to the lower nodes of the same chain, some even descending as far as the supraclavicular nodes. The lymphatics of the trachea pass, on each side, to the paratracheal and inferior deep cervical nodes (see fig. 1149).

The lymphatics of the thyroid gland.—The lymphatics of the thyroid gland pass either to the small nodes situated in front of the larynx and trachea, or to nodes of the deep cervical chain, a part of them ascending and a part descending. The lymphatics of the thyroid region are shown in fig. 1149.

It will thus have been seen that the lymphatics of the mucous membrane of the head and neck all end in the deep cervical chain of nodes or in its outlying nodes. Some of the vessels pass by the outlying nodes, but since the nodes of the chain are so closely connected, the lymph must pass through several nodes before entering the veins. The palatine tonsils, the numerous lingual and pharyngeal tonsils, together with small lymph-follicles in the submucosa of the respiratory tract, represent lymph-nodes in the capillary zone.

B. THE LYMPHATICS OF THE UPPER EXTREMITY

1. THE LYMPHATIC NODES OF THE UPPER EXTREMITY

The lymph-nodes of the arm lie, for the most part, in the axilla, where there is a large group of nodes which receive almost the entire drainage of the arm and the thoracic wall. In addition, there is in the arm a set of outlying superficial nodes, the superficial cubital (supratrochlear), while small isolated nodes are often intercalated along the course of the deep lymphatic vessels which accompany the

radial, ulnar, anterior interosseus and brachial arteries, the cephalic vein, and the deep cubital vessels. The cubital nodes are shown in figs. 639 and 641.

(1) The **antibrachial nodes** are very small nodes (size of pin-head) intercalated along the deep lymphatics which accompany the radial, ulnar, anterior and posterior interosseus arteries.

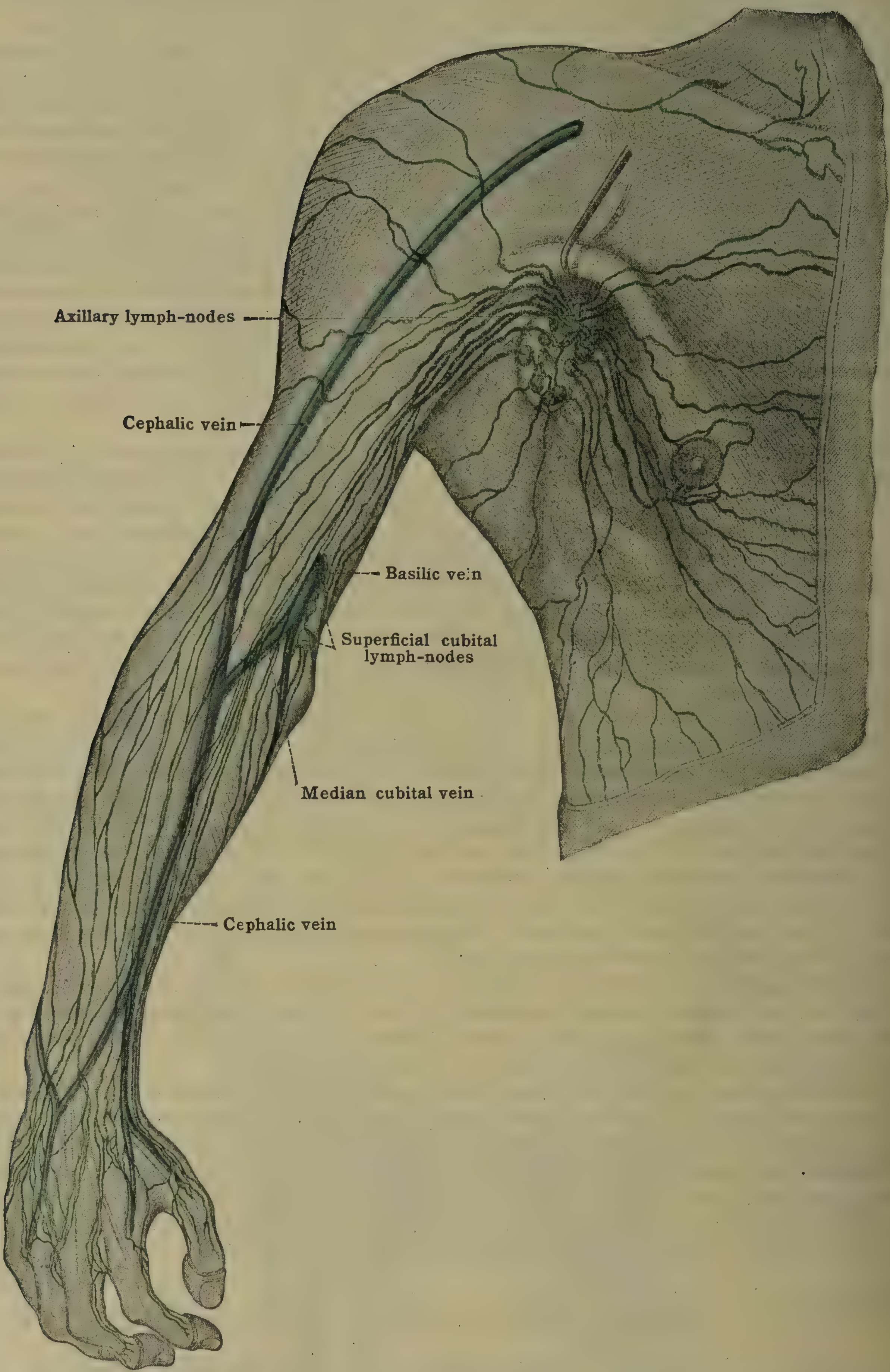


FIG. 639.—THE LYMPHATICS OF THE UPPER EXTREMITY. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

(2) The **deep cubital nodes** [lgl. cubitales profundæ] are also very small nodes, one or two in number, intercalated along the lymphatic vessels, near the deep vessels at the bend of the elbow.

(3) The **superficial cubital** (or supratrochlear) **node** [lgl. cubitalis superficialis] is situated three or four cm. above the medial epicondyle of the humerus. It lies in the superficial fascia on the medial side of the basilic vein near the place where it passes through the deep fascia. It is usually single, but may be absent or represented by a chain of from two to five nodes. Its efferents follow the basilic vein.

(4) The **deltopectoral nodes** are very small intercalated nodes, from one to three in number, and are situated in the groove between the deltoid and pectoral muscles. Their vessels follow the cephalic vein.

(5) The **axillary nodes** [lgl. axillares], from twelve to thirty-six in number, may be divided into groups according to the areas which they drain (figs. 639, 640). In addition to the upper extremity, they receive lymphatic drainage from the thoracic walls, including dorsal, lateral and ventral (mammary) regions.

(*a*) The *subclavian group* consists of four or five nodes, situated in the apex of the axillary fossa. They receive the efferent vessels of all the other groups, and their efferent vessels in turn unite to form a single trunk, the subclavian, which empties into the thoracic duct or subclavian vein on the left side and on the right side either into the vein directly or else after uniting with the jugular trunk. (See pp. 795, 796.)

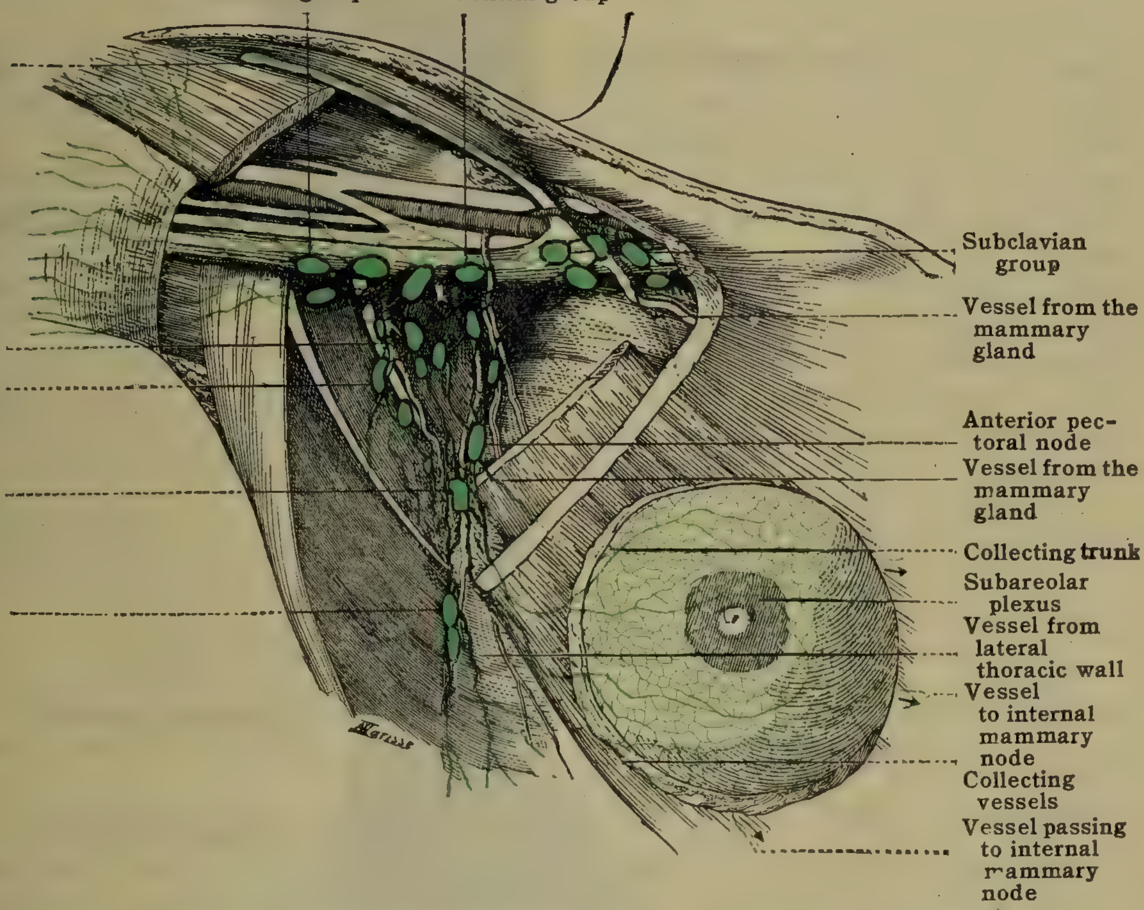


FIG. 640.—THE AXILLARY LYMPH-NODES. (After Poirier and Cunéo.)

(*b*) *The central group.*—A little lower along the axillary artery is a group of three to five nodes, which makes a second center for the vessels of the other groups, and sends its efferents to the subclavian group. It will be clear from fig. 640 that the separation of groups 1 and 2 is arbitrary.

(*c*) *The brachial group.*—This consists of four or five nodes, and, as its position toward the junction of the axillary and brachial arteries indicates, is the main station for the lymphatics of the arm proper. It receives almost all the superficial and deep lymphatics of the arm, and its efferents pass to the central and subclavian groups, although a few pass directly to the suprascapular group. Small, outlying nodes of this group may be intercalated along the vessels following the brachial artery throughout its course.

(*d*) *The subscapular group* [lgl. subscapulares].—In this group are six or seven nodes, which follow the subscapular artery and its branch, the circumflex (dorsal) scapular. Belonging to it there are usually two or three small nodes on the dorsal surface of the scapula, in the groove which separates the teres major and minor. This group receives vessels from the dorsal surface of the thorax, as well as from the arm, and its efferents pass to the brachial group.

(*e*) *The anterior pectoral group.*—This group consists of four or five nodes which lie along the lower border of the pectoralis major and drain the mammary gland and front of the chest. Their efferent vessels pass to the central and subclavian groups.

(*f*) The *posterior pectoral group* consists of small nodes situated on the inner wall of the axilla, along the course of the long thoracic artery. They receive afferents from the lateral integument of the thorax and drain into the nodes of the central group.

2. THE LYMPHATIC VESSELS OF THE UPPER EXTREMITY

The lymphatic vessels of the upper extremity are divided into two sets—a superficial and a deep set.

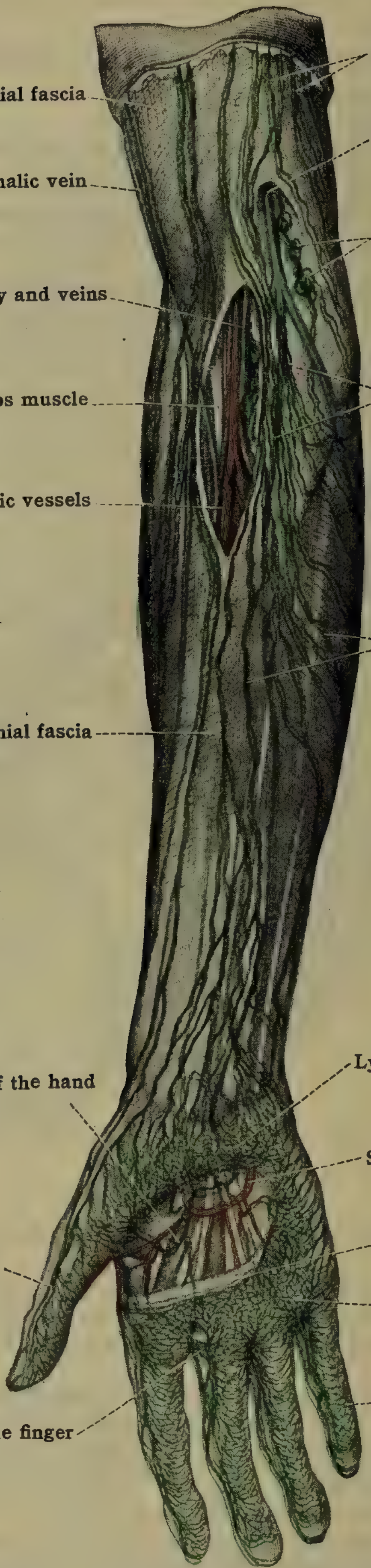


Fig. 641.—The Lymphatics of the Forearm. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The superficial vessels.—The superficial lymphatic vessels of the arm course in two layers, the one quite subcutaneous, the other next to the deep fascia, with frequent anastomoses between the two sets. The majority of these vessels remain superficial throughout the arm, but some of them pass through the deep fascia in the upper arm especially where the basilic vein pierces the deep fascia,

to join the deep lymphatics accompanying the brachial artery. The general distribution of the superficial lymphatics and their relations with the lymph-nodes are shown in figs. 639 and 641.

The capillary plexus is most dense in the volar surfaces of the fingers, where the meshes are so fine that they can only be seen with a lens. On the dorsal surface of the fingers and hand the plexus is less dense. From the plexus on the palmar side of the fingers vessels come together at the base of the fingers where they pass dorsally to be joined by the dorsal vessels of the finger. They now follow two rather distinct curves: (1) those from the thumb and index finger and a part of the middle finger pass upward along the radial side of the forearm, course medially over the lower part of the biceps muscle, and empty into the axillary lymph-nodes. One or two vessels follow the cephalic vein and, after traversing the deltopectoral node, pierce the coastocracoid membrane to enter the subclavian nodes, or pass over the clavicle into the inferior deep cervical nodes. (2) Those from the rest of the fingers course for a short stretch on the dorsum of the forearm, when they turn toward the ulnar side, wind around to the volar side and either continue superficially along the upper arm to the axillary nodes, or pass into the superficial cubital node, or, joining the efferents from these nodes, pass through the deep fascia to unite with the deep lymphatics. (3) A set of vessels from the palm of the hand passes upward along the volar side of the forearm. Anastomoses are frequent between these groups of lymphatic vessels, particularly in the cubital region.

It will thus be seen that the superficial cubital nodes receive lymph from the ulnar digits and from the palm of the hand, but not from the thumb and forefinger.

The superficial lymphatics from the rest of the arm join these three main groups at various levels.

The deep vessels.—The deep lymphatic vessels of the upper extremity drain the joint-capsules, periosteum, tendons, and (if the work of Aagaard is correct) the muscles. They collect into vessels which, in general, accompany the arteries; in the forearm, the radial, ulnar, anterior and posterior interosseous, and in the arm the brachial. Above the elbow they are joined by numerous superficial lymphatic vessels including efferents from the superficial cubital nodes. Along their course in the forearm are intercalated small nodes (pin-head size), radial, ulnar, anterior and posterior interosseous (Mouchet) and deep cubital; and, in the arm, small brachial intercalated nodes. The deep vessels in the main enter the brachial group of axillary lymph-glands which lie behind the large vessels and nerves, the efferents from which nodes pass either into the lower deep cervical lymph-nodes or directly into the subclavian trunk.

The lymphatics of the *shoulder-joint* have been described by Tananesco. He finds a ring of lymphatics in the joint capsule, whose efferents, in the main, following the arteries, run to the central and subclavian groups of axillary nodes.

C. THE LYMPHATICS OF THE THORAX

The lymphatics of the thorax will be considered under the following divisions: the superficial vessels, the deep nodes, and the deep vessels.

1. THE SUPERFICIAL LYMPHATIC VESSELS OF THE THORAX

The superficial lymphatics of the thorax pass almost exclusively to the axillary nodes, and may be regarded as forming three sets, a ventral, a lateral, and a dorsal. The **ventral set** drains the thoracic integument, which extends from the median line and the clavicle over to the lateral border of the chest, and includes the vessels of the mammary gland, which will, however, be described separately. The majority of the vessels from this area end in the anterior pectoral group of axillary nodes, a few, which arise beneath the clavicle, passing to the supraclavicular nodes, and a few perforating the intercostal spaces and ending in the chain of nodes along the internal mammary artery.

It has been shown that an injection into the subcutaneous plexus near the median line passes to the opposite side, and that, in addition to the anastomosis between the networks of the two sides of the thorax which this result manifests, there may also be a few collecting trunks crossing the median line, and, furthermore, anastomoses occur between the superficial networks of the anterior thoracic and abdominal walls. Thus while the main channel of lymphatic drainage is through the axilla, there are minor accessory channels (1) to the supraclavicular nodes, (2) to the axilla of the opposite side, (3) to the internal mammary chain, and (4) in isolated cases even to the inguinal nodes. These accessory channels may become more open in cases of obstruction to the main channels.

The **lateral set** of superficial thoracic lymphatics is much less extensive than the anterior, and its collecting vessels pass upward to open chiefly into the posterior pectoral group of axillary nodes.

The **dorsal set,** which occupies the subcutaneous tissue of the dorsal thoracic wall, sends its vessels to the subscapular group of axillary nodes.

The Lymphatics of the Mammary Gland (Figs. 640, 642)

The lymphatic network over the peripheral portions of the mammary gland is like that of the rest of the thoracic wall. In the areola, however, the capillaries are far more abundant, forming a double subareolar plexus. The superficial plexus is so dense that its meshes can be seen only with a lens. The deeper plexus not only drains the superficial plexus, but receives the vessels from the mammary gland itself, and from it arise usually two large trunks, one from the inferior and one from the superior part of the plexus. These two vessels pass to one or two of the nodes belonging to the anterior pectoral group of axillary nodes. In addition there may be—(1) one or two vessels passing to the nodes along the axillary artery; (2) in rare cases a vessel passing directly to the subclavian nodes. There is also a definite channel from the medial margin of the gland to the internal mammary nodes, the trunks following the perforating branches of the internal mammary

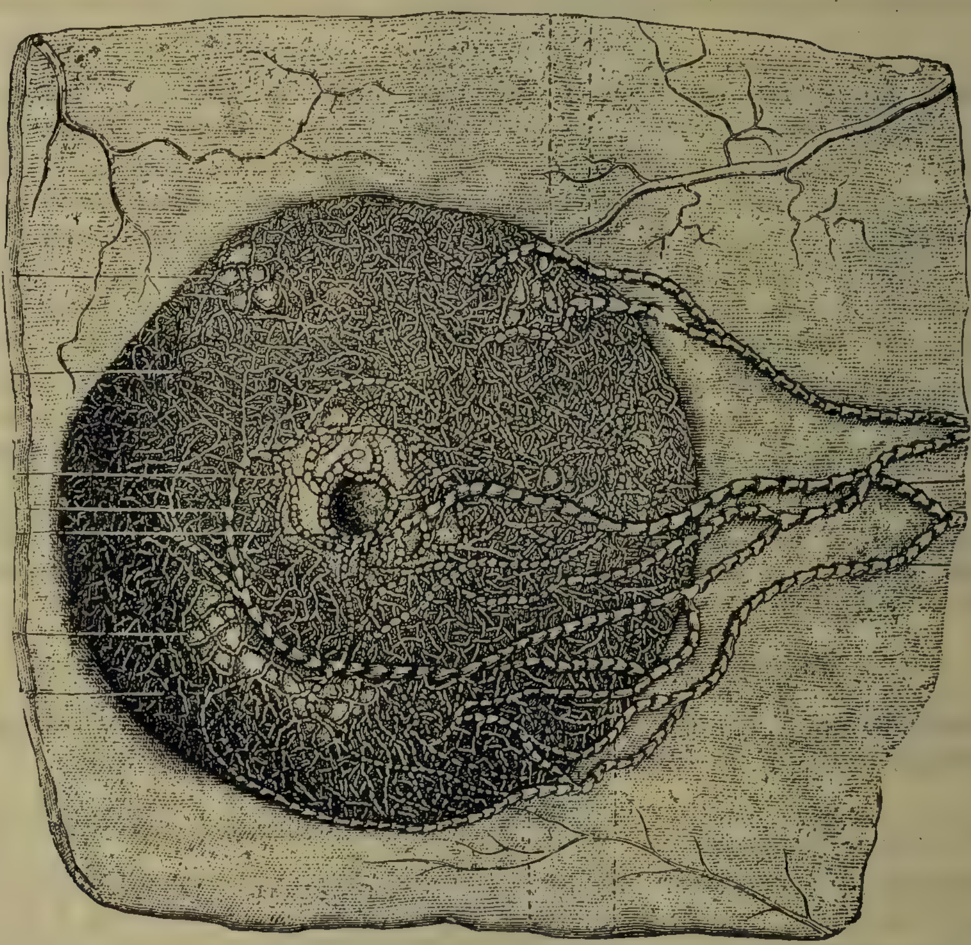


Fig. 642.—Lymphatics of the Subareolar Plexus of the Breast. (After Sappey.)

vessels. It may also be noted that the crossed anastomosis and that with the abdominal network, mentioned in connection with the superficial thoracic vessels, may occasionally serve as channels for the mammary drainage.

There is also clinical evidence indicating that lymphatic vessels from the lower and medial aspect of the mammary gland may pass through the abdominal wall in the angle between the xiphoid process and the costal cartilages, establishing a communication with the lymphatics of the abdomen in the diaphragmatic region.

Lymphatics of the thoracic muscles.—The studies of Aagaard make it probable that muscles are provided with lymphatics. It is unquestioned that lymphatic vessels course through the pectoral muscles—some passing to the axillary, others to the subclavian, and still others to the internal mammary chain of nodes. This would suffice to explain the fact that cancer of the breast may extend into and through the pectoral muscles.

2. THE DEEP LYMPHATIC NODES OF THE THORAX

The lymphatic nodes of the thoracic cavity may be divided into the parietal and the visceral. The **parietal nodes** are arranged in two sets, the sternal

and the intercostal nodes. Along the internal mammary artery are from four to six small **sternal nodes** [lgl. sternales] which receive trunks from the anterior thoracic and the upper part of the abdominal walls, from the anterior diaphragmatic nodes which drain the liver, and from the medial edge of the mammary gland. The efferent vessels usually unite with the vessels of the anterior mediastinal and bronchial nodes, to form the bronchomediastinal trunk, which may join the thoracic duct on the left and the jugular or subclavian trunk on the right or may empty separately into the subclavian vein on either side or both (fig. 1149).

The **intercostal nodes** [lgl. intercostales] (fig. 644) lie along the intercostal vessels, near the heads of the ribs. There are usually one or two in each space. They receive afferents from the deeper part of the thoracic wall and costal pleura. Their efferents enter the thoracic duct, those from the nodes of the lower four or

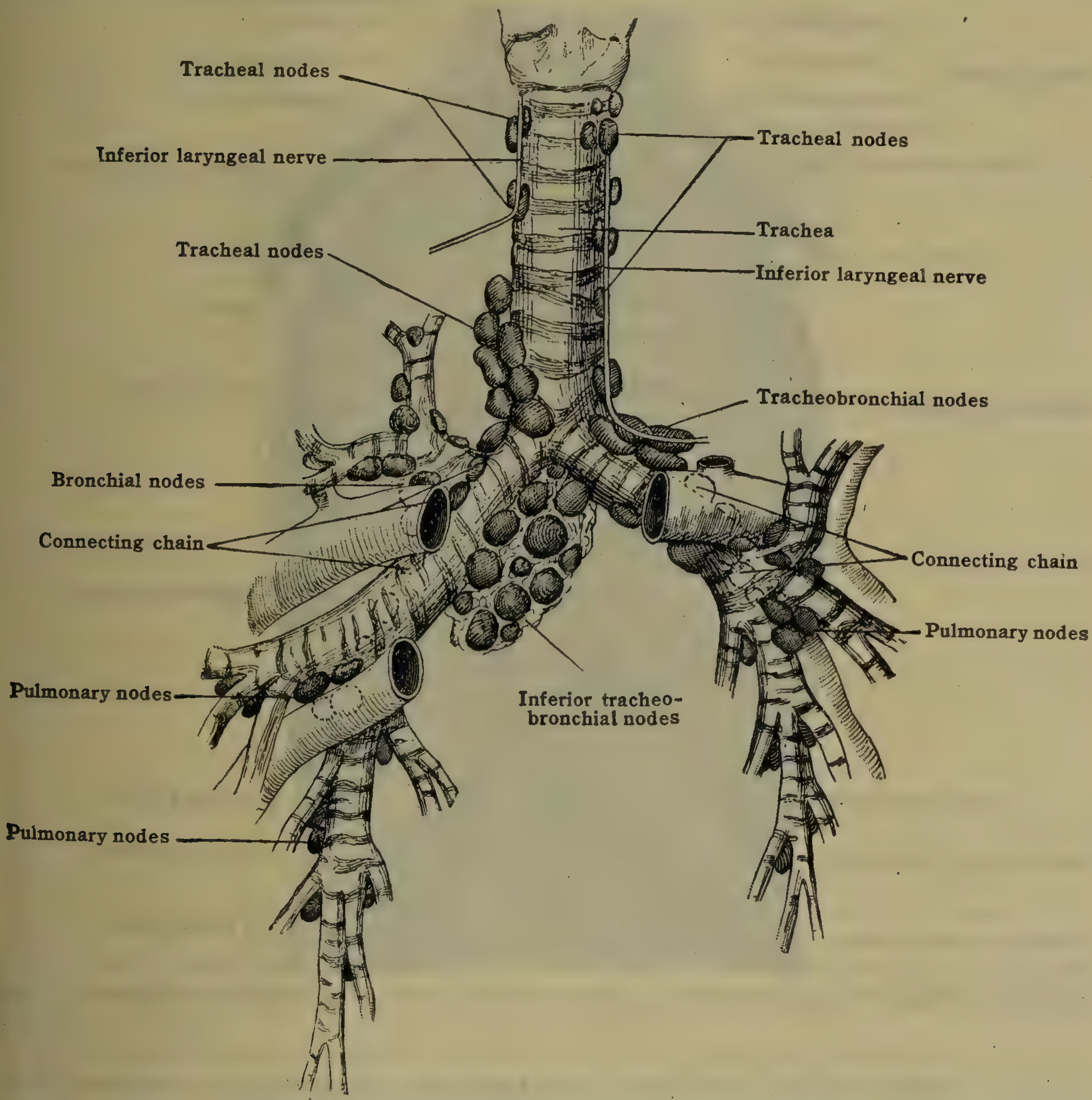


Fig. 643.—The Tracheal and Bronchial Nodes. (Sukiennikow.)

five interspaces uniting usually to form a common trunk on each side, but more marked on the left side, which descends to the cisterna chyli.

The efferent lymph-vessels from the upper intercostal nodes often unite into common trunks which drain several interspaces, and which may pass through a large gland near the thoracic duct before emptying into it. Occasionally such collecting vessels from the right side cross the midline behind the aorta to reach a large gland to the left of the aorta.

The **visceral nodes** of the thorax are arranged in three groups:

1. The **anterior mediastinal nodes** [lgl. mediastinales anteriores] (lymphonodi mediastinales ventrales NK) are situated, as their name indicates, in the anterior mediastinum, and are arranged in an upper and a lower set. The upper set (superior mediastinal group) is situated along the arch of the aorta, and consists of eight or ten nodes, which receive afferents from the pericardium and the

remains of the thymus gland. Their efferent vessels pass upward to join the bronchomediastinal trunk. The lower set consists of from three to six nodes, situated in the lower part of the anterior mediastinum. They receive afferent ducts from the diaphragm (for which reason they are sometimes termed the **diaphragmatic nodes**) and also from the upper surface of the liver. Their efferents pass upward to open into the upper anterior mediastinal nodes.

2. The **posterior mediastinal nodes** [lgl. mediastinales posteriores] eight or ten in number, are situated along the thoracic aorta, and receive vessels from the mediastinal tissue and from the thoracic portion of the esophagus. Their efferents open directly into the thoracic duct.

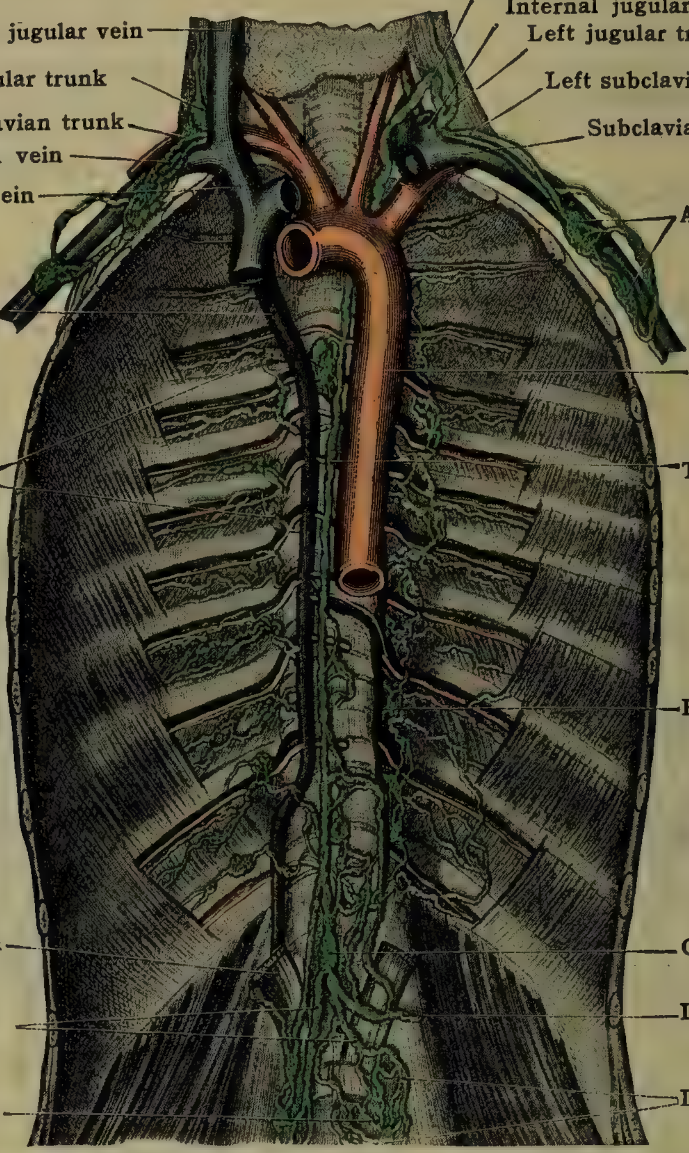


FIG. 644.—THE THORACIC DUCT. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

3. The **tracheal** [lgl. tracheales] and **bronchial nodes** [lgl. bronchiales] (fig. 643) form an extensive group lying along the sides of the lower part of the trachea, and along the bronchi as far as the hilus of each lung. According to their position they are termed tracheal (paratracheal), lateral tracheobronchial, inferior tracheobronchial (nodes of the bifurcation), and pulmonary nodes. The latter occur within the lung, at the bifurcation of the bronchial tubes. The groups receive the drainage of the lower part of the trachea, the bronchi, the lungs, part of the esophagus, and, to a small extent, the heart. Their efferent vessels unite with those from the upper anterior mediastinal and internal mammary nodes to form the bronchomediastinal trunk. (See also fig. 1149.)

3. THE DEEP LYMPHATIC VESSELS OF THE THORAX

The deep lymphatics of the thorax will be taken up in the following order: the thoracic duct; the right terminal collecting trunks; the parietal vessels; and the visceral vessels.

The Thoracic Duct

The **thoracic duct** [ductus thoracicus] (fig. 644), which is the main collecting trunk of the lymphatic system, extends from the second lumbar vertebra along the spinal column and course of the aorta to the junction of the left internal jugular and subclavian veins. It receives all the lymphatics below the diaphragm; the deep lymphatics from the dorsal half of the chest wall; and also, when joined by the left bronchomediastinal, subclavian and jugular trunks, from the remainder of the left half of the body, above the diaphragm. At the caudal end the duct is formed usually by the union of three collecting trunks, one from each of the lumbar groups of nodes, and an unpaired intestinal trunk. At its origin there is frequently a dilated portion known as the **cisterna chyli** (or receptaculum chyli).

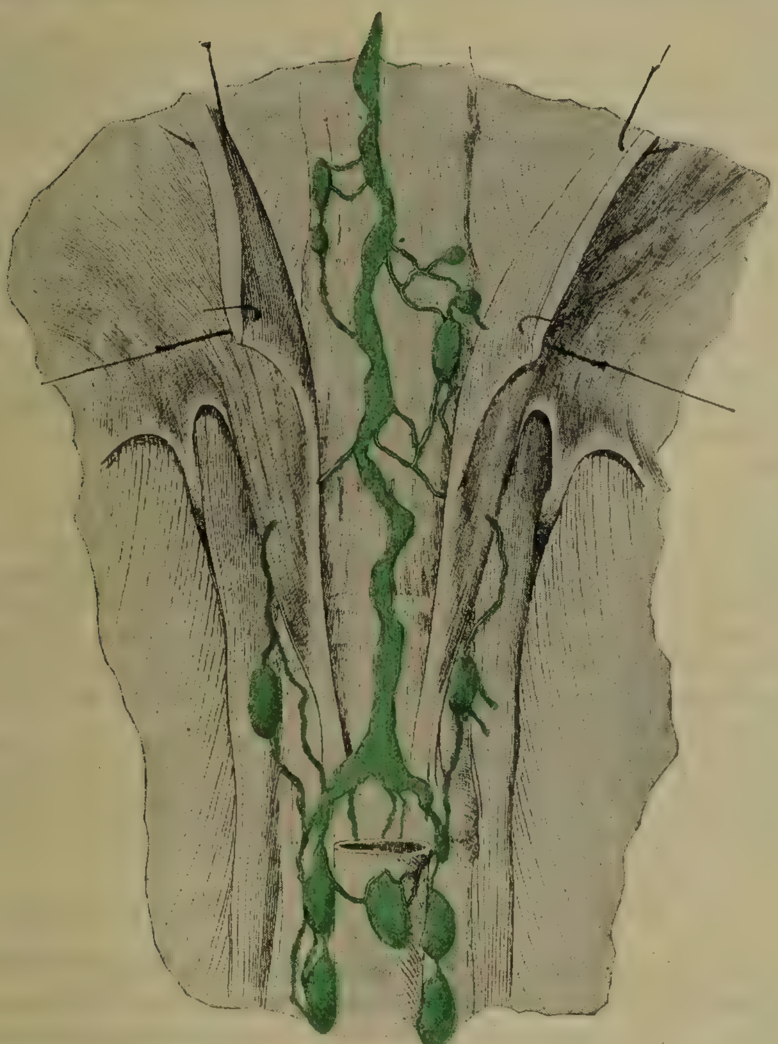


Fig. 645.—Abdominal Portion of the Thoracic Duct. (Poirier and Cunéo.)

This usually ends opposite the body of the eleventh thoracic vertebra, and from here on the duct is from 4 to 6 mm. in diameter, until near its termination, where it is again wider.

In its caudal part, the duct lies dorsal to the aorta in the median line; it passes through the aortic opening in the diaphragm, and then inclines to the right and passes upward between the aorta and the azygos vein to about the fourth, fifth, or sixth thoracic vertebra, where it bends to the left and passes, continuing upward, over the apex of the left lung to the medial side of the left subclavian artery, and in front of the root of the left vertebral artery and vein, and then curves downward to open into the left subclavian vein, close to its junction with the left internal jugular. The duct runs in the wall of the vein a short distance before ending. The termination of the duct is shown in figs. 644 and 1149.

Variations.—There is a wide range of variation from this usual course. The duct is frequently double throughout a part of its course, the two branches being connected by cross anastomoses, and finally uniting into a single trunk before joining the veins. It may be multiple, or a single trunk may pass in front of the aorta instead of behind. In a few instances it has been found emptying into the right instead of the left subclavian vein. There is also a wide range of variation in the height to which the duct ascends in the neck before curving downward to the vein. As regards the termination of the thoracic duct, variations are also frequent; it may bifurcate and end as two ducts. It often connects with the lowermost part of the internal jugular, or the beginning of the innominate. According to Henle, there is one un-

doubted case reported of a thoracic duct ending in the azygos vein near the sixth thoracic vertebra, the duct being obliterated above this point. At the terminal bend the thoracic duct receives the jugular trunk from the neck; it may also receive the subclavian and the bronchomediastinal trunks, but it is more usual for these last two to open either separately or together into the subclavian.

Variations are extremely numerous in the region of the cisterna chyli. Several observers state that, in the majority of cases in man, no definite receptaculum exists (cf. fig. 645). Bartels found one in only 25 per cent. of the cases studied. Instead, there is present a widening of each of the two lumbar trunks, with several anastomoses between them (55 per cent., Bartels), or a widening of these two stems without anastomosis (5 per cent.), or a much elongated widening arising from the growing together of the two lumbar trunks (10 per cent.). In cases where the lumbar trunks remain separate, the intestinal trunk joins the left one. One case has been described in which the thoracic duct ended at the level of the ninth thoracic vertebra. The lymphatics from the body below this point collected into a duct which became superficial just below the termination of the left saphena magna vein, passed cranialward in the subcutaneous tissue of the left body wall, passed through the axilla, and joined the venous system at the usual place. (E. R. Clark.)

Movement of lymph.—In the movement of lymph along the thoracic duct and into the vein, the negative pressure produced in the thorax during inspiration undoubtedly plays an important rôle. In the veins at the base of the neck there is a negative pressure during inspiration, with each relaxation of the atrium which facilitates entrance of the contents of the lymphatic ducts into the veins.

Development.—While the exact mode of its development is still in dispute, enough is agreed upon by the various investigators to explain most of the variations in the thoracic duct. As stated above, it is known that the lymphatics start in the neck in the form of a number of outgrowths from the veins in the region of the junction between the later internal jugular and subclavian veins. A variable number of these connections disappear, while the various combinations of one, two, three or four which are retained furnish the numerous variations in number and position of the ducts which empty into the vein in the adult. Thus the thoracic duct may have one, two or even three openings into the veins, while the jugular, subclavian and bronchomediastinal trunks may join the thoracic duct or may enter the veins separately or in various combinations.

The cisterna develops in connection with branches of veins in the upper lumbar region. All connections with the veins here are soon lost. Around the aorta there develops a plexus, which forms a connection between the anterior plexus and the cisterna. In this plexus two main vessels soon differentiate—the right and left thoracic ducts, which anastomose frequently with one another, and which join, respectively, the right and the left jugulosubclavian angle. Usually the cephalic part of the right and the caudal part of the left duct disappear, leaving the permanent vessel to the right of the aorta for the major part of its course but emptying into the left vein. However, the anterior part of the left duct may disappear, leaving the permanent duct to join the vein on the right side.

Most of the other variations—the frequent presence of longer or shorter doublings of the duct with anastomoses between the two parts and the numerous variations in the region of the cisterna chyli—are easily explained by the fact that they pass through a stage in development in which they form richly anastomosing plexuses around the aorta.

The Right Terminal Collecting Trunks

On the right side the jugular, subclavian, and bronchomediastinal trunks usually open separately into the subclavian vein, the orifices of the first two being near together. When the jugular and subclavian trunks unite, the common trunk is termed the right lymphatic duct [ductus lymphaticus dexter] (truncus lymphaceus dexter NK). This is an unusual form, and it is still more rare for the three ducts to unite to form a common stem (see figs. 644, 646, 1149).

These variations have the same explanation, embryologically, as was given for the corresponding variations on the left side. The subclavian trunk usually passes in front of the subclavian vein, but in some cases passes behind it.

The Deep Lymphatic Vessels

As with the nodes, the deep lymphatic vessels of the thorax may be divided into a parietal and a visceral group. To the former group may be assigned the lymphatics of the intercostal spaces and those of the diaphragm.

The **intercostal lymphatics** form plexuses in each intercostal space, which receive lymph from the periosteum of the ribs and from the parietal pleura, and from which the drainage is either ventral or dorsal. From the dorsal half of each space the drainage is to the intercostal nodes (fig. 644), while from the ventral half it is toward the internal mammary nodes.

The lymphatics of the diaphragm.—There is an exceedingly rich plexus of capillaries both on the thoracic and on the abdominal surface of the diaphragm, especially in the region of the central tendon. These plexuses lie in the subserous layer and are freely connected by vessels which perforate the muscle. There is, however, only slight communication between the plexuses of the right and left

sides of the diaphragm. The vessels lie between the coarse muscle-bundles, forming a very characteristic picture, in which the lymphatics stream outward radially, like the spokes of a wheel. The collecting vessels empty into three groups of small **nodes** on the convex thoracic surface.

The *ventral group* lies ventral to the central tendon. Two or three nodes in the center of this group receive afferents from the liver and none from the diaphragm, but the rest receive vessels from the ventral portion of the diaphragm and the efferents of all pass to the lower set of anterior mediastinal nodes.

The *middle group* consists of from three to six nodes, which lie, on the left side, near the point where the phrenic nerve enters the diaphragm; and on the right side, near the vena cava.

The *dorsal group* of four or five nodes is placed between the crura of the diaphragm. The vessels from the middle and dorsal groups pass to the posterior mediastinal nodes, and also to the upper celiac nodes, which likewise receive the drainage from the dorsal part of the abdominal surface of the diaphragm.

To the visceral group of thoracic lymphatics belong the vessels of the thymus, the lungs, the heart, and the esophagus.

The **lymphatics of the thymus,** according to Severeanu, drain into three sets of nodes, an anterior, a ventral and a dorsal group.

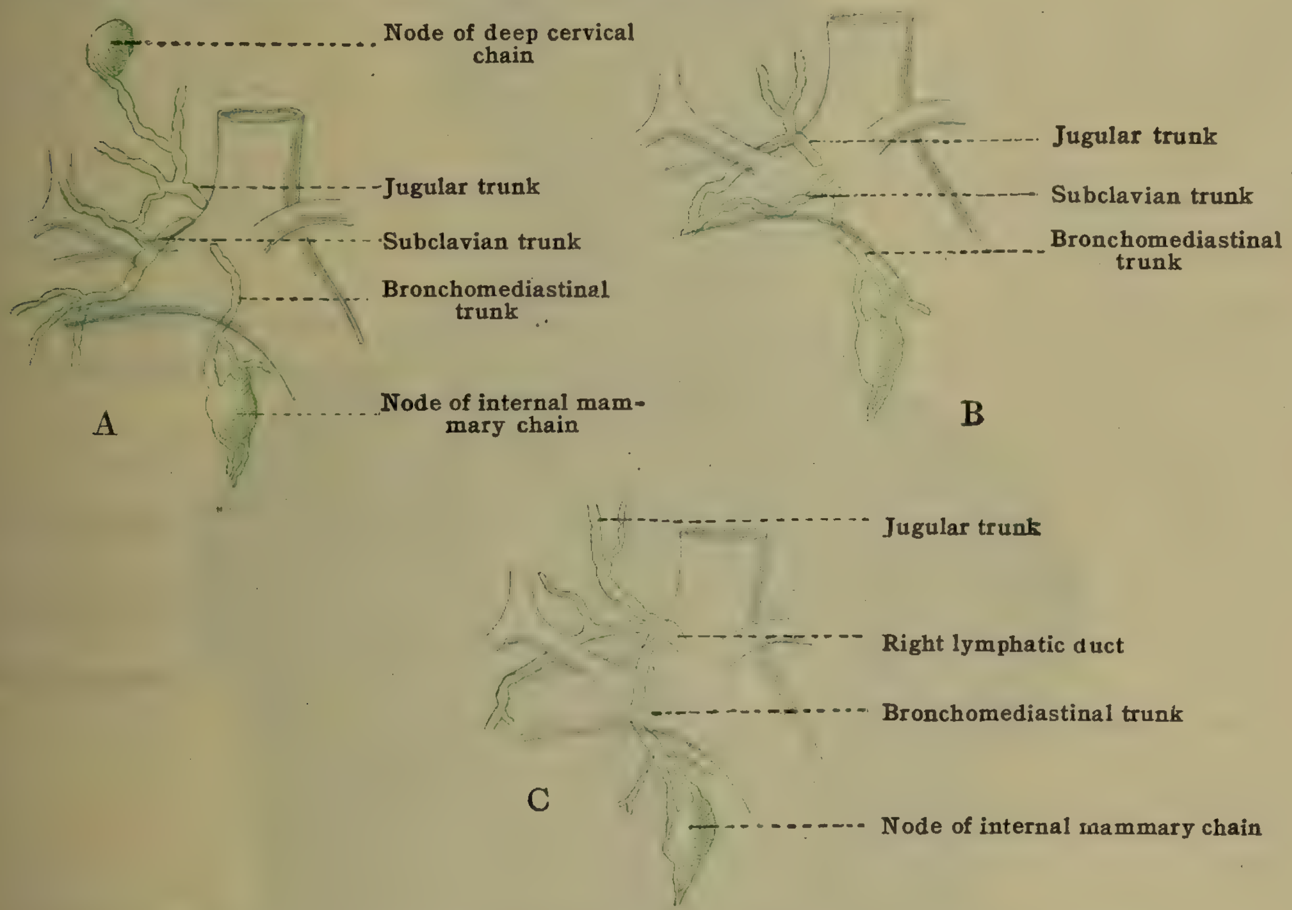


FIG. 646.—TERMINAL COLLECTING TRUNKS ON THE RIGHT SIDE. (Poirier and Cunéo.)

The *anterior* set, one gland on each side, lies lateral to the cephalic end of the thymus, and drains into the jugular or subclavian trunk. The *ventral* set includes 4–6 of the anterior mediastinal lymph-glands. The *dorsal* set, 2 on each side, is made up of anterior mediastinal glands lying between the thymus and the pericardium.

The **lymphatics of the lungs** are arranged in two sets, deep and superficial. The *deep lymphatics* fall into three groups: the lymphatics of (1) the bronchi; (2) the arteries; (3) the veins.

(1) The lymphatics of the bronchi take origin in plexuses which surround the bronchi and bronchioles, and accompany the bronchi to the hilus, communicating with the bronchial nodes (fig. 608). (2) The lymphatics of the arteries originate from the lymphatics of the terminal bronchus. Two branches, with numerous anastomoses, usually accompany each artery. (3) The lymphatics of the veins have an origin similar to that of the arteries, from the bronchial lymphatics, at the point where the smaller bronchioles divide. They accompany the veins to the hilus. An additional set of lymphatics, which have a deep origin, pass to the pleura, in company with the veins which go to the surface. There are no lymphatic capillaries surrounding the alveoli.

The *superficial lymphatics* consist of a rich plexus of vessels lying on the surface of the lung, beneath the pleura. They receive vessels from the deeper lymphatics, and are drained by vessels which pass directly, and independently of the other sets, to the lymph-nodes of the hilus (W. S. Miller).

In studying the development of the lymphatics to the lung, R. S. Cunningham has found that, in the pig, while the lymphatics to the anterior two-thirds of the lung are formed by outgrowths from the thoracic ducts, those to the posterior third are outgrowths from the retroperitoneal sac, and that there is persistent drainage of this portion of the lung into preaortic nodes and cisterna chyli. No such line of drainage has been found in man.

Clinical aspects.—When chronic adhesions form between visceral and the parietal pleura, lymphatic vessels grow across and connect the lymphatics of the lungs with those of the chest wall, diaphragm or pericardium. That the lymph from the lung then drains to unusual lymph glands is indicated by the accumulation of carbon, picked up from the pulmonary alveoli, in such glands as the axillary, internal mammary, intercostal or superior gastric. Whether there is also drainage in the opposite direction is not known.

Lymphatics of the heart.—The superficial (subepicardial) lymphatics of the heart collect to two main stems which accompany the main coronary vessels. The right stem accompanies the right coronary artery to its origin, passes on

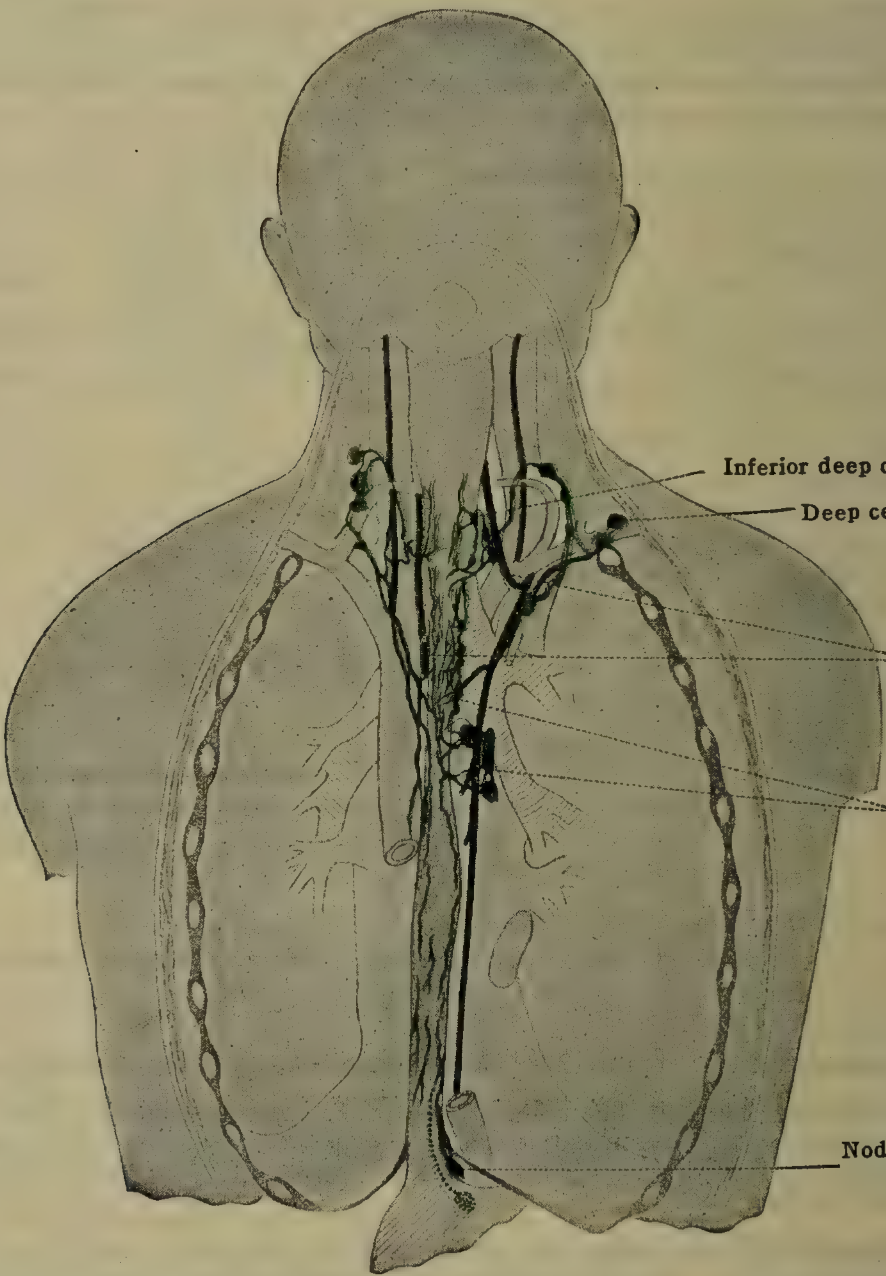


Fig. 647.—The Lymphatics of the Esophagus. (After Sakata.)

over the arch of the aorta and empties into one of the anterior mediastinal lymph-nodes. The left stem, formed by two stems accompanying the circumflex and anterior descending branches of the coronary vein, passes behind the arch of the aorta to an anterior mediastinal lymph-gland. Two small subepicardial intercalated nodes have been described along these trunks.

Subendocardial lymphatics have been described, which connect by vessels passing through the musculature with the superficial lymphatics. Parenchymatous lymphatics have been demonstrated by Bock. The course of their efferent vessels has not yet been described.

The **lymphatic vessels of the esophagus** may be divided into three sets, of which the uppermost pass to outlying nodes belonging to the deep cervical chain, those from the thoracic portion of the tube pass to the bronchial and posterior

mediastinal nodes, while those from its lowermost part pass to the superior gastric nodes (fig. 647).

D. THE LYMPHATICS OF THE ABDOMEN AND PELVIS

In the following section there will be described successively the lymphatic nodes and vessels of the abdomen and pelvis, the lymphatic vessels of the abdominal walls, and the visceral lymphatic vessels.

1. THE LYMPHATIC NODES OF THE ABDOMEN AND PELVIS

The lymphatics which connect directly with the thoracic duct, though complicated, may be described briefly by saying that they follow the aorta and its branches. In the abdomen there are four main chains along the aorta—(1) the

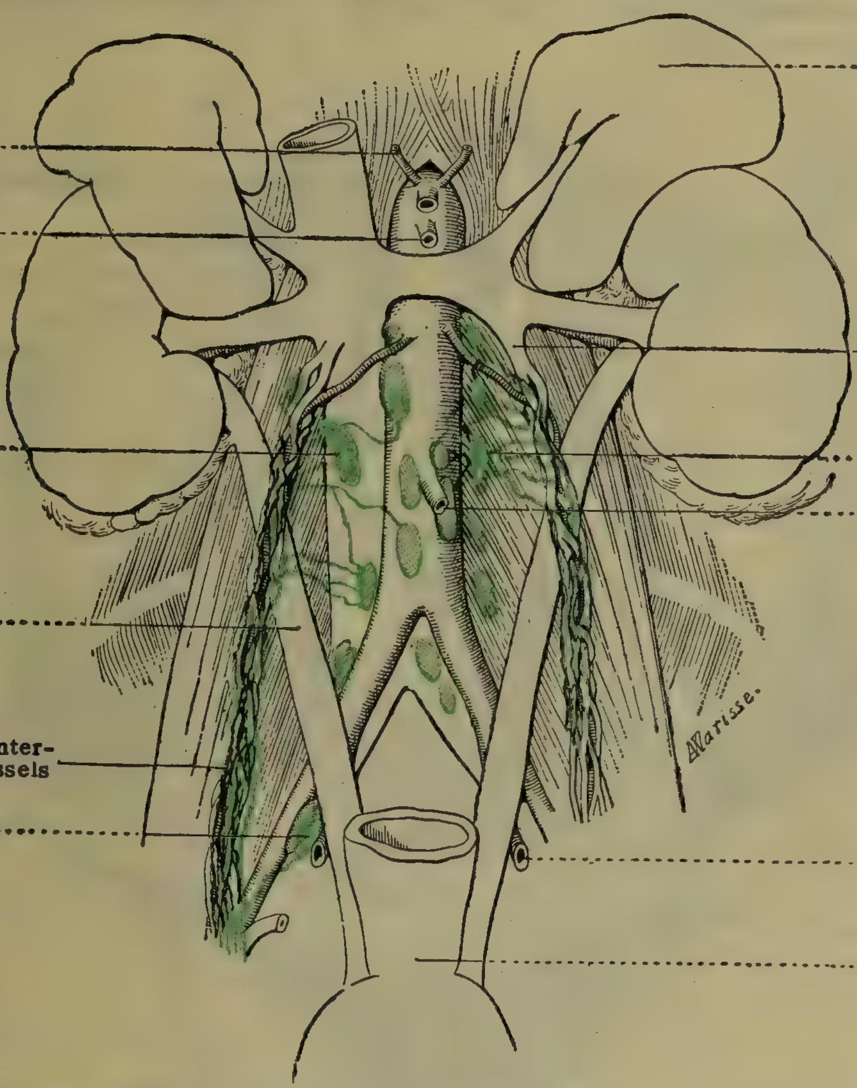


Fig. 648.—Lower Abdominal Nodes in the Newborn. (Poirier and Charpy.)

left lumbar chain; (2) the right lumbar chain; (3) the preaortic chain; and (4) the postaortic chain.

The right and left lumbar nodes [lgl. lumbales], form an almost continuous chain along the abdominal aorta (fig. 648), resting upon the psoas muscles, some of those on the right side being ventral and some dorsal to the inferior vena cava. They receive: (1) the efferent lymphatics of the common iliac nodes, and hence drain the lower limb and external genitalia; (2) the efferent lymphatics that follow the lumbar arteries and thus drain the abdominal wall; (3) the efferents that follow the paired visceral aortic branches, namely, those from the kidneys, suprarenal, and internal reproductive organs. On the right side, the lymphatics from the reproductive organs pass to the nodes ventral to the vena cava; those of the abdominal walls pass to the dorsal set, while those from the kidney pass to both sets. The efferent vessels of the lower lumbar nodes pass to higher ones and so on up the chain, the vessels from the uppermost nodes uniting to form a single **lumbar trunk** on each side. These trunks pass to the thoracic duct, forming two of the so-called trunks of origin of that vessel (fig. 644).

The **preaortic nodes** (cf. fig. 650) of the lumbar chain are arranged in three groups at the root of each of the three unpaired visceral branches of the aorta—

the celiac, the superior mesenteric, and the inferior mesenteric arteries. The **celiac nodes** [lgl. coeliacæ] are from one to three in number, and are in reality parts of chains of nodes extending along the branches of the artery and constituting the **hepatic** [lgl. hepaticæ], **gastric** [lgl. gastricæ superiores et inferiores], and **splenic** [lgl. pancreaticolienales] nodes. They drain the stomach, duodenum, liver, pancreas, and spleen. For nodes of the gastric region, see fig. 652.

The **superior mesenteric** group is larger, and is continuous with the **mesenteric nodes** [lgl. mesentericæ] lying in the root of the mesentery. This group drains the remainder of the small intestine, the cecum and appendix, the ascending and transverse colons, and the pancreas.

The **inferior mesenteric** group (fig. 648) usually has two nodes, one on either side of the artery. It drains the rectum and descending and sigmoid colons. All the nodes in the mesentery and intestinal walls may be considered as outlying nodes of the preaortic group. They will be studied in connection with the visceral lymphatics.

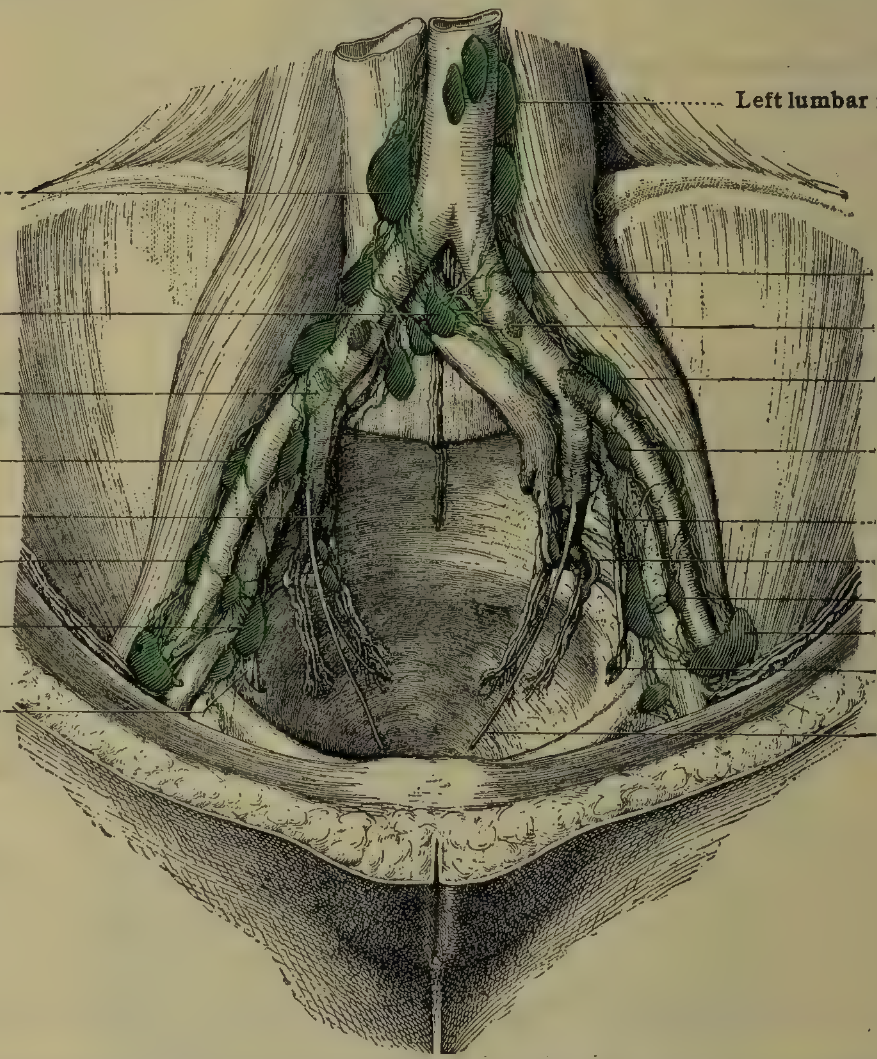


FIG. 649.—ILIAC AND HYPOGASTRIC NODES. (Cunéo and Marcille)

The inferior mesenteric nodes drain into the neighboring lumbar nodes, and also directly upward to the superior mesenteric nodes, and then again to the celiac nodes. From the last a single stem, the **intestinal trunk** [truncus intestinalis] (fig. 644), arises and passes either to the right lumbar trunk or directly to the thoracic duct, forming the third of the so-called trunks of origin of the duct.

The **postaortic nodes** are not true regional nodes, but receive vessels from the lumbar and preaortic chains.

Below the bifurcation of the aorta there are three large chains, the common iliac, the external iliac, and the hypogastric.

The **common iliac nodes** [lgl. iliacæ], are in three groups (fig. 649). The *lateral* set consists of about two nodes, which are in reality a part of a continuous chain extending along the side of the aorta, common iliac, and external iliac arteries. A second set of two to four *posterior nodes* lies behind the artery. These two groups receive the efferent vessels of the external iliac and hypogastric chains. The *medial* set usually consists of two nodes which rest upon the

promontory of the sacrum. They receive vessels from the sacral nodes, together with most of those from the pelvic viscera, namely, from the prostate, neck of the bladder, neck of the uterus, the vagina, and part of the rectum. The efferent lymphatic vessels of the common iliac nodes pass to the lumbar (aortic) chain.

External iliac nodes (figs. 649, 657–660).—These are likewise in three sets—lateral, intermediate, and medial. The *lateral* chain consists of three or four nodes, the lowest one being behind the crural arch. They receive: (1) some

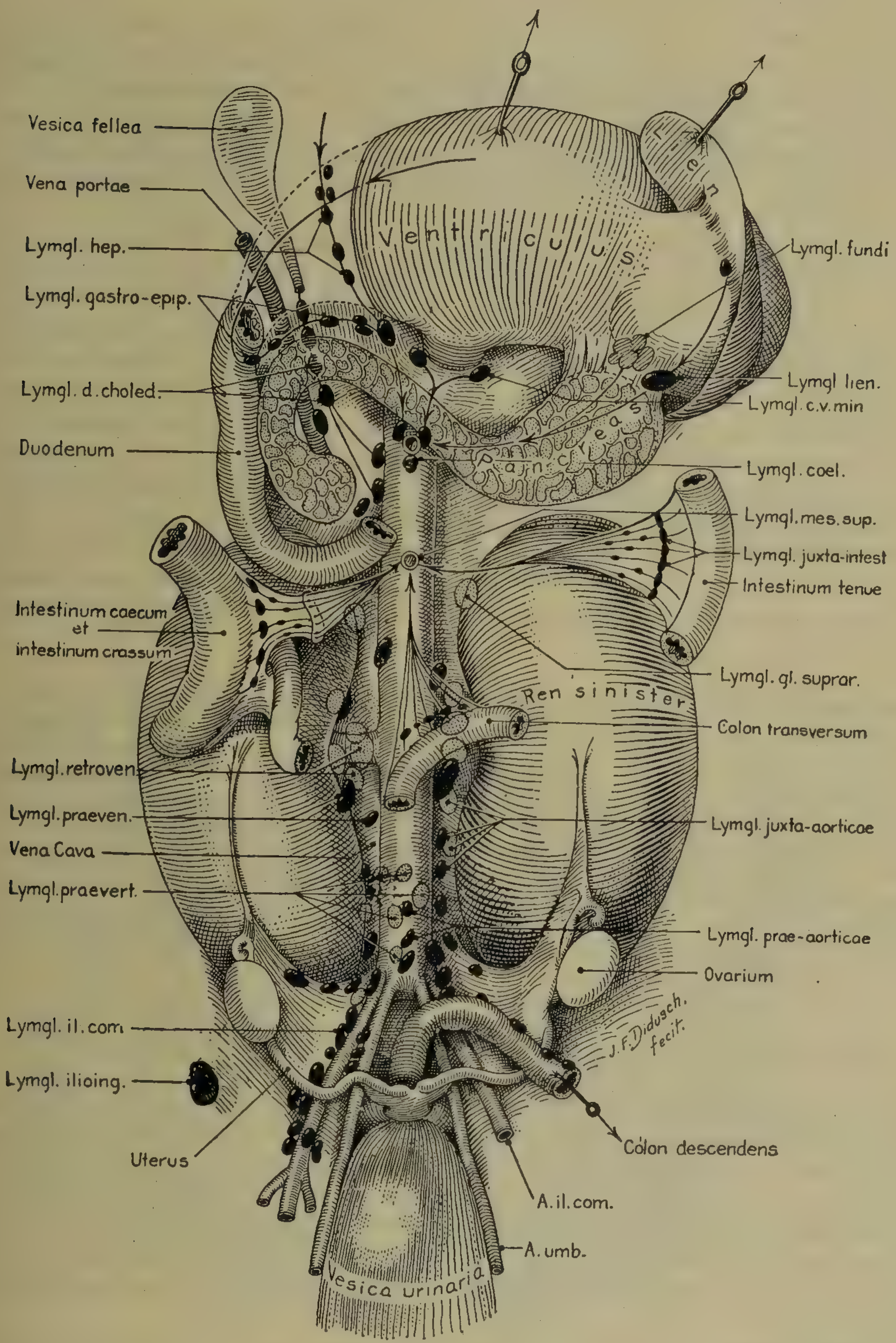


FIG. 650.—ABDOMINAL LYMPH-NODES OF A 20 CM. PIG FETUS. Solid black: derivatives of the retroperitoneal sac; stippled: derivatives of the iliac sac. (After Reichert.)

of the vessels of the superficial and deep inguinal nodes; (2) vessels from the glans or clitoris, which come through the inguinal canal; (3) vessels from the part of the abdominal wall supplied by the deep epigastric and deep circumflex arteries, along which there may be a few outlying nodes—the **epigastric nodes** [lgl. epigastrical].

The *intermediate* chain consists of two or three nodes behind the artery. When there are three, the lowest ('retrocrural') is likewise near the femoral ring. It

receives vessels from the bladder, prostate, neck of the uterus, and upper portion of the vagina. The *medial* chain consists of three or four nodes, and is the continuation of the deep inguinal nodes. Its lowest nodes are likewise near the femoral ring, while the next node is large and constant, and usually lies within the pelvis. This chain receives many vessels: (1) from the superficial and deep inguinal nodes; (2) from the glans and clitoris through the femoral canal; (3) from the abdominal wall; (4) from the neighborhood of the obturator vessels; (5) from the neck of the bladder, the prostate, and membranous part of the urethra; (6) from the hypogastric chain.

Thus, to sum up the nodes of the external iliac chains, they are a part of a chain which includes the lumbar, common iliac, external iliac, and inguinal nodes. It will be noted that this extensive chain stops, for the most part, with the deep inguinal group. The external iliac nodes receive the efferents of the superficial and deep inguinal nodes; the intermediate and medial groups receive vessels from the pelvis. The efferent vessels of all the nodes in the chain pass to the higher nodes.

The **hypogastric nodes** [lgl. hypogastricæ] (figs. 649, 657–660).—These nodes are in groups near the origin of the branches of the hypogastric (internal iliac) artery. Thus they occur near the origin of the obturator, the uterine, or prostatic, the trunk of the inferior gluteal (sciatic) and pudic, the middle hemorrhoidal, and the lateral sacral arteries. All the nodes are beneath the pelvic fascia, and are connected by numerous anastomoses. They receive lymphatics from the structures supplied by the corresponding arteries, namely, from the pelvic viscera, the perineum, and the posterior surface of the thigh and gluteal region. Their efferent vessels pass partly to the middle group of the common iliac nodes, and partly to the posterior nodes of the same chain.

The sacral nodes [lgl. sacrales].—These nodes, 5 or 6 in number, lie in the hollow of the sacrum, in or near the mid-line. They receive afferent vessels from rectum and prostate, and their efferents pass to the hypogastric and lumbar nodes.

Development—Miss Sabin and Reichert have shown, in the pig, that the primary lymph-glands of the abdomen develop out of the primary lymph-sacs, in two fundamental groups: (1) the group of glands, ventral to the aorta, extending from the celiac artery to the bifurcation of the aorta, which form from the retroperitoneal sac, and(2) the groups of glands dorsal and dorsolateral to the aorta, extending from the level of the suprarenals to the bifurcation of the aorta, with extensions along the iliacs, which develop from the paired iliac sacs. In general, the ventral group receives the drainage from the structures situated within the abdominal cavity, while the dorsal and dorsolateral groups drain organs and structures outside the abdominal cavity, including body-wall and lower extremities. There is, however, an intermediate group of organs—diaphragm, kidney, suprarenal, ureter, and ducts of sex glands—which drain into both sets. Secondary sets, such as the mesenteric, gastric and hepatic glands, develop at a distance from the primary sets (cf. fig. 650).

2. THE LYMPHATIC VESSELS OF THE ABDOMINAL WALLS

The lymphatic vessels of the abdominal walls are arranged in two sets, one of which is subcutaneous and the other deep or aponeurotic. The **subcutaneous** vessels form a rich network through all the subcutaneous tissue of the abdomen, anastomosing above with the subcutaneous plexus of the thorax, which drains the upper (supraumbilical) part of the anterior abdominal wall. The vessels chiefly converge toward the inguinal region, those from the posterior wall curving forward along the crest of the ilium, and terminate in the superficial inguinal nodes (fig. 664).

The **deep** vessels drain along four principal lines. (1) A set of collecting vessels follows the line of the deep epigastric artery to terminate in the lower external iliac nodes; (2) a second set follows the deep circumflex iliac vessels to the same nodes; and (3) a third set follows the lumbar vessels to terminate in the nodes of the lumbar chain; (4) the upper part of the anterior abdominal wall drains into the sternal nodes, following the superior epigastric vessels.

A group of small **epigastric nodes**, which may be regarded as offsets from the iliac chain, occur on the lymph-vessels which accompany the deep epigastric vessels, not far from their termination, and a second less constant group of usually three small **umbilical nodes** occurs in the vicinity of the umbilicus in the network covering the posterior layer of the sheath of the rectus abdominis muscle.

3. THE VISCERAL LYMPHATICS OF THE ABDOMEN AND PELVIS

The lymphatics to the viscera follow along the course of the blood-vessels. At the point where the artery of an organ branches from the aorta there is a group of nodes which represents the main regional group, and a second chain of nodes extends along the artery. The final arrangement of nodes and vessels varies with each organ. The lymphatics (vessels and nodes) of the alimentary tract, suprarenal gland, urinary and reproductive tracts will be successively considered.

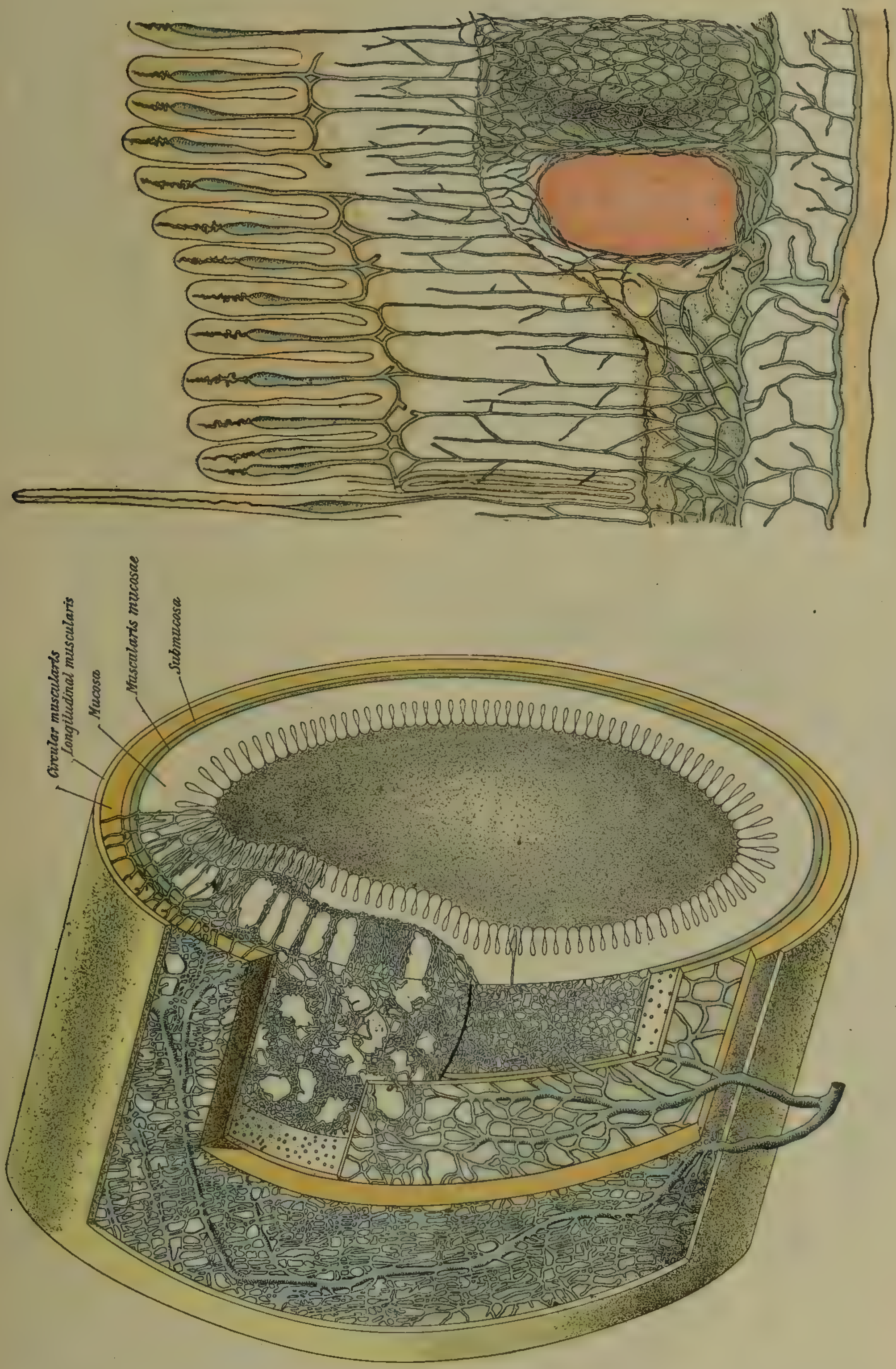


FIG. 651.—THE LYMPHATIC VESSELS OF THE INTESTINE. (After Mall.)

In almost all organs there is a peripheral or capsular lymphatic plexus, which anastomoses with the parietal lymphatics, these anastomoses being particularly well developed in the case of the liver. In addition there are one or two deep plexuses in the great majority of the organs which drain partly directly to their regional nodes and partly by way of the peripheral plexus.

THE LYMPHATICS OF THE ALIMENTARY TRACT

The lymphatics of the mouth, pharynx, and esophagus have already been described (pp. 785, 798). In general, throughout the abdominal part of the alimentary canal, the distribution of nodes is as follows: (1) There are primary

regional nodes situated at the roots of the arteries (celiac and the superior and inferior mesenteric arteries); these nodes drain large segments of the intestine; (2) groups of definite and constant nodes placed along the branches of the arteries within the mesentery; these drain a definite smaller segment of the intestine; (3) chains of nodes along the anastomotic loops of the arteries, close to the intestinal wall; these are of the type called 'intercalated nodes'; (4) solitary or compound follicles, situated within the submucosa or capillary zone of the lymphatics.

What may be taken as the typical arrangement of the lymphatic vessels in the intestine may be seen in fig. 651. There are three zones in which the capillary plexuses are spread out, namely, in the subserosa, the submucosa, and the mucosa. There is an abundant plexus of large capillaries just beneath the serosa; in the submucosa the plexus is also formed by large capillaries, while the mucosal plexus is finer. The lymph-follicles lie in the zone of the mucosal plexus, and it is from this that the central chyle vessels of the villi arise. The spiral tips of the central lacteals shown in fig. 651 are probably artefacts. The collecting vessels are formed by the union of vessels from the submucous and subserous plexuses. They traverse the three sets of nodes just described. The movement of chyle from the villi is undoubtedly aided by spontaneous contractions of the villi (King, Versar). Its further progress is aided, by the peristaltic movements of the intestine, and, in some animals, by the contractions of the mesenteric lymphatics (Florey).

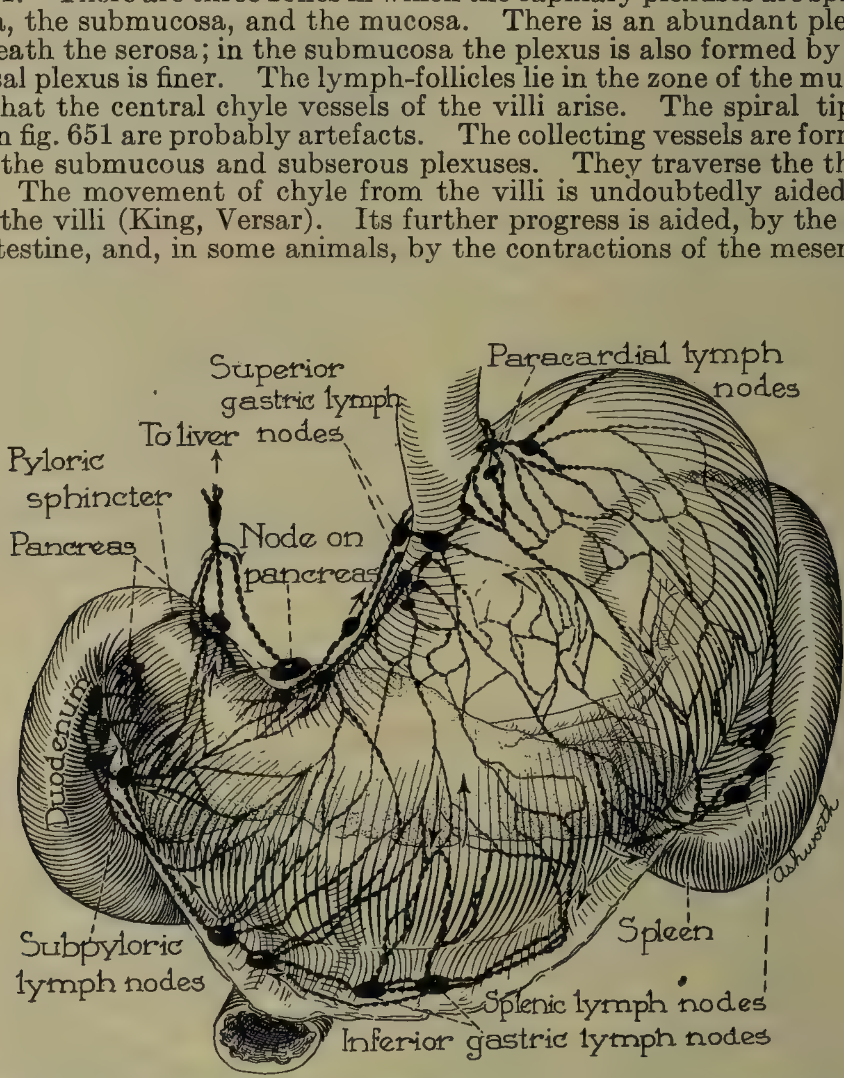


FIG. 652.—THE LYMPHATIC DRAINAGE OF THE STOMACH. (From Dr. Horton, in The Proceedings of the Staff of the Mayo Clinic, 1927, Volume 2.)

The lymphatics of the stomach (fig. 652).—The stomach differs from the rest of the alimentary canal in its blood-supply in having a ventral anastomotic loop, namely, that along the lesser curvature. Along this loop is the **superior gastric chain** [lgl. gastricæ superiores] of nodes, lying between the folds of the lesser omentum, some of them being on the posterior surface of the stomach. This is the most important group of nodes draining the stomach, and it has been shown that the lymph-vessels from the pylorus run obliquely across the stomach to the main mass of nodes near the cardia, an important point in the surgery of the pylorus. The efferent vessels of the chain pass to the celiac nodes. The vessels of the greater curvature pass to a group of **inferior gastric nodes** [lgl. gastricæ inferiores], situated along the right gastroepiploic artery, while those of the fundus follow the short gastric and left gastroepiploic vessels to the nodes which lie along the splenic artery [lgl. pancreaticolienales], both these sets of nodes also draining to the celiac group. There is a zone half-way between the lesser and greater curvatures, in which the lymphatics are scanty. The lymphatics of the cardia connect with those of the esophagus, and the mucosal plexus of the pylorus is continuous with that of the duodenum.

The lymphatics of the duodenum.—The lymphatics of the duodenum depart somewhat from the type, owing to its relations with the pancreas and the bile-ducts. The collecting vessels end: (1) in nodes ventral to the pancreas, which

follow the pancreaticoduodenal artery to the hepatic chain; (2) in nodes dorsal to the pancreas, which follow the superior mesenteric artery to the superior mesenteric nodes. There are anastomoses between the lymphatics of the duodenum and those of the pylorus, of the pancreas, and of the chain along the common bile-duct.

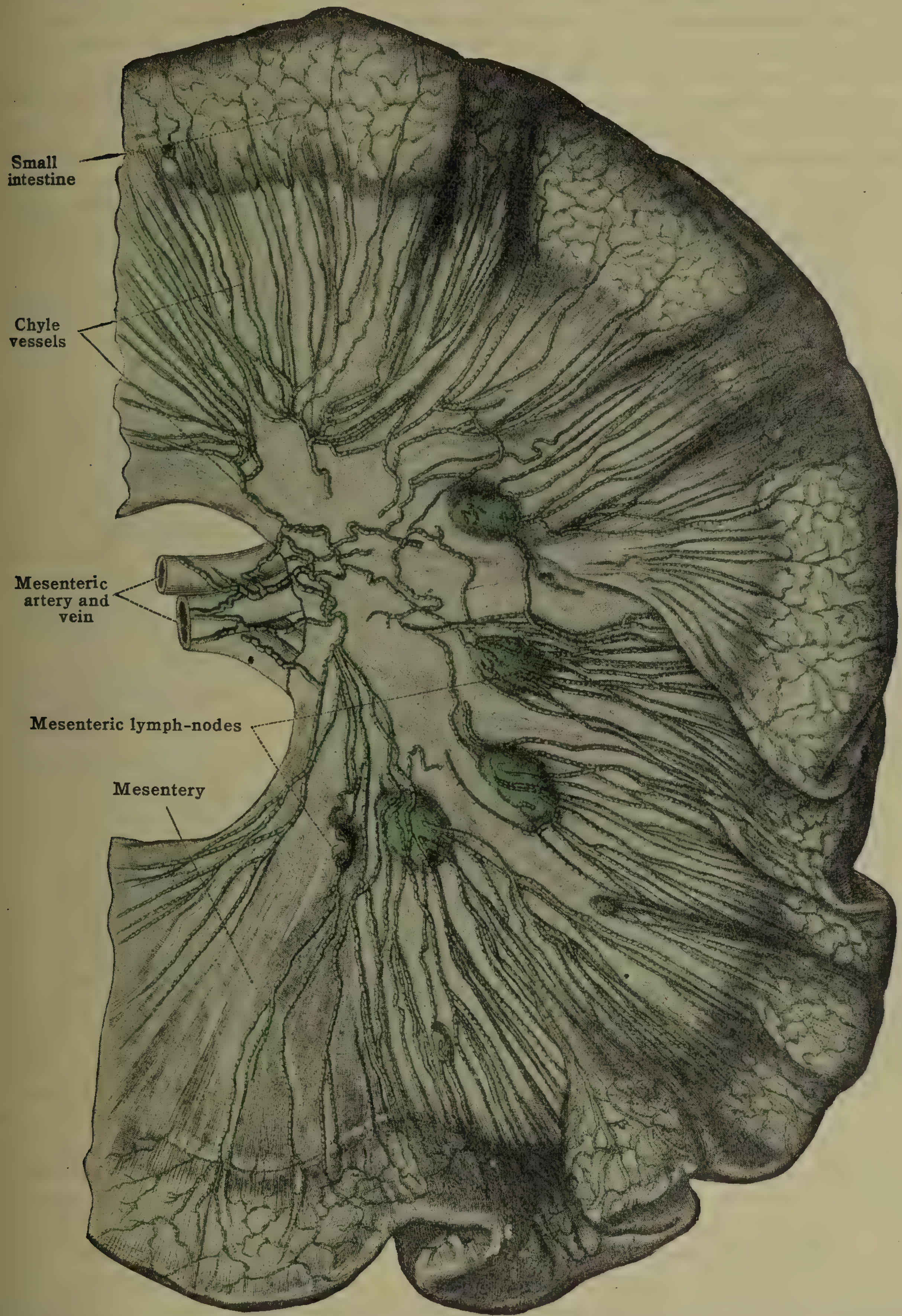


Fig. 653.—Lymphatics of the Small Intestine. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The **lymphatics of the jejunoileum** (fig. 653) have already served as the type of the arrangement of the intestinal lymphatics (see above). During the absorption of fats from the intestines, the mesenteric lymphatics contain the chyle and appear milk-white in color. The group of **mesenteric nodes** to which the lymphatics of the small intestine pass is the largest and one of the most important in the body, its individual nodes numbering from 130 to 150.

The lymphatics of the ileocecal region (figs. 654, 655).—The surgical importance of the lymph-nodes in connection with the vermiform process (appendix) warrants a detailed description of them, in which the observations of Brödel will be followed. The drainage of the cecum and appendix is along the ileocolic artery, and is carried on by three sets of collecting vessels—(1) an anterior cecal set, which generally pass through one or more outlying nodes before reaching the ileocecal mesenteric nodes; (2) a similar posterior set; and (3) an appendicular set, three to six in number, which usually pass directly to the ileocecal nodes. The appendix thus has an independent drainage into one or two ileocecal nodes, about 3 cm. above the ileum. The ileocecal chain drains through the mesenteric nodes to the superior mesenteric group.

The lymphatics of the large intestine.—Along the ascending colon there are but few nodes on the terminal vascular arches, but the number increases along the transverse colon, especially at its two angles. These nodes, together with those along the descending and sigmoid colons, are termed the **mesocolic nodes,** [lgl. mesocolicæ] and they drain partly to the superior mesenteric and partly to the inferior mesenteric nodes, their efferents following the corresponding arteries. The lymphatics of the transverse colon connect with those of the great omentum. Those of the descending colon are more scanty, and connect below with those of the sigmoid colon and rectum.

The lymphatics of the rectum and anus.—There are three lymphatic zones of the rectum and anus. (1) An **inferior zone,** corresponding to the anal integument, in which the capillary networks, both superficial and deep, are extremely abundant, and from which from three to five collecting vessels on either side pass to the inguinal region and end in the medial superficial inguinal nodes. (2) A **middle zone,** corresponding to the transition zone of epithelium—that is, with the mucous membrane below the columns of Morgagni. Here the network is coarse, and has its meshes arranged vertically; its ducts drain partly into nodes situated along the inferior and middle hemorrhoidal arteries, and partly pass to nodes in the mesorectum, situated along the superior hemorrhoidal artery and known as the **anorectal** nodes. (3) The **superior zone** corresponds to the remainder of the rectal mucous membrane, and contains a rich network whose collecting vessels pass to the anorectal glands, and thence along the superior hemorrhoidal arteries to the mesocolic and inferior mesenteric nodes.

Lymphatics of the liver.—The lymphatic drainage of the liver is complicated and has great need of being entirely restudied from the standpoint of development. Its course is mainly to the celiac nodes, but on the way it passes through a secondary group of three to six **hepatic nodes,** situated along the hepatic artery. Some of these nodes are along the horizontal part of the artery, parallel to the superior border of the pancreas, while the rest follow the artery in its vertical course along with the portal vein, and become continuous at the portal fissure with two distinct chains of nodes, one of which follows the hepatic artery and portal vein, and the other the cystic and common bile-ducts. These nodes are variable, but one constant node is at the junction of the cystic and hepatic ducts. A part of the drainage of the liver is also through the **diaphragmatic nodes** of the anterior and posterior mediastinal groups.

The superficial lymph-vessels of the liver have been studied by Sappey. Those from the superior surface include three sets. From the dorsal part vessels pass through the diaphragm with the vena cava, and end in the adjacent posterior mediastinal nodes. Some of these vessels from the right lobe pass in the coronary ligament to the celiac nodes, and some from the left lobe to the superior gastric nodes. The second set of vessels from the superior surface runs over the ventral border to the hepatic nodes situated in the portal fissure. The third and most important set arises near the falciform ligament, and passes partly dorsalward to the anterior mediastinal group of nodes on the upper surface of the diaphragm, and to the nodes around the vena cava, and partly ventralward to the hepatic nodes of the portal fissure.

The collecting vessels of the inferior surface of the liver pass to the nodes situated in the portal fissure, either along the artery or the bile-ducts.

The lymphatics of the **gall-bladder** join the hepatic nodes along the cystic and common bile-ducts, and also the superior pancreatic nodes.

Lymphatics of the pancreas.—The lymph-vessels which drain the pancreas fall, according to Bartels, into four groups: left, anterior (upper), right and

posterior (lower). (1) The left group drain the tail of the pancreas and pass to the splenic lymph-nodes, at the hilus of the spleen. (2) Anteriorly lymphatics pass to the superior pancreatic, superior gastric and hepatic nodes. (3) To the right, lymphatics pass to the pancreaticoduodenal lymph-nodes. (4) Posteriorly lymphatics pass to the aortic, mesenteric, mesocolic, and inferior pancreatic nodes. The splenic, superior pancreatic, inferior pancreatic, and pancreatico-duodenal nodes form a closely associated group [lymphoglandulæ pancreatico-lienales]. Anastomoses exist between the lymphatics of the pancreas and those of the duodenum.

The **lymphatics of the spleen** form a subcapsular plexus from which vessels pass through the hilus to the **splenic nodes** (of the pancreaticolienal group). These nodes are variable in number and are situated along the course of the splenic

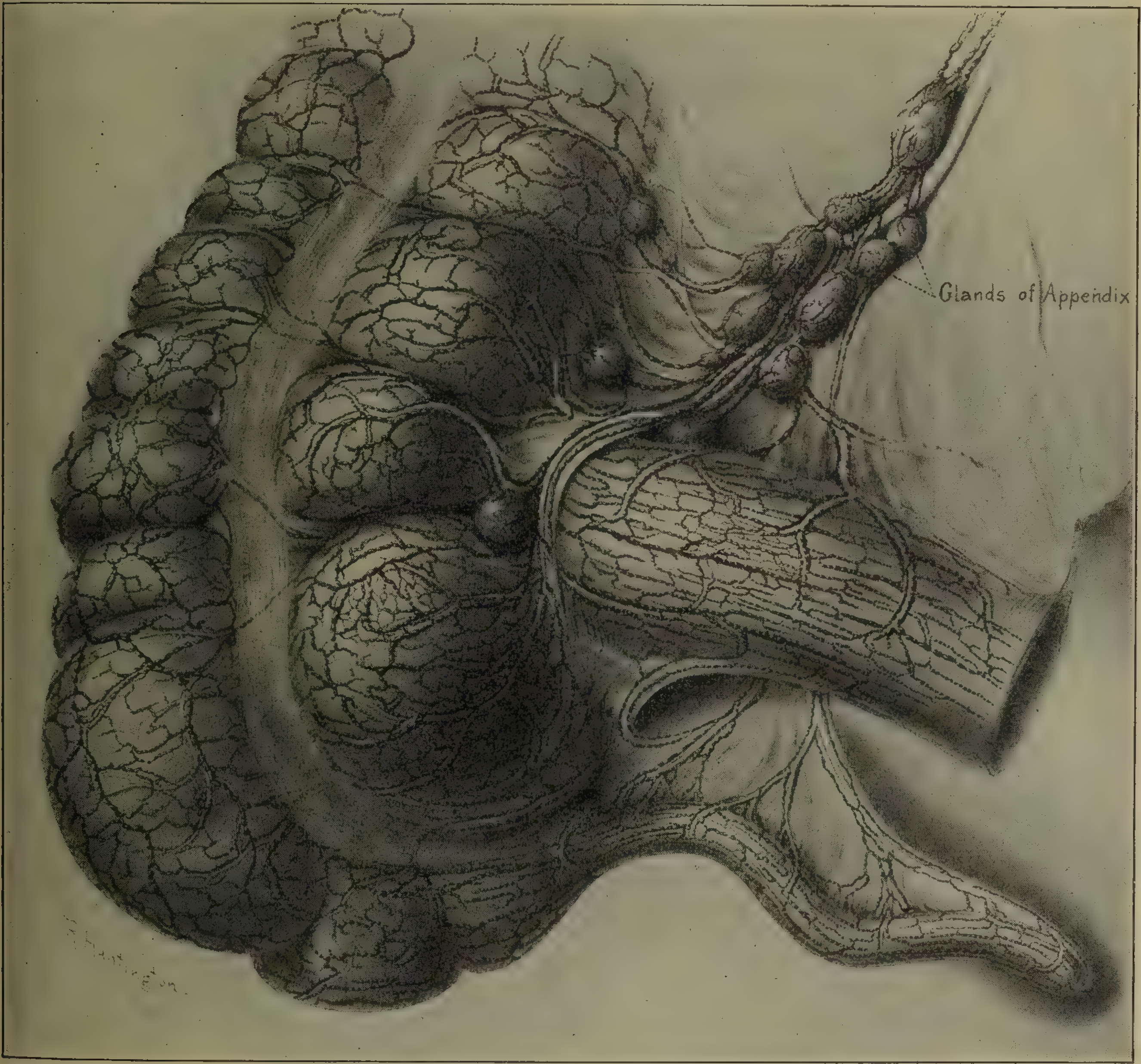


Fig. 654.—The Lymphatics of the Ileocecal Region, Anterior View. (After Kelly.)

vessels. In addition to the spleen, they drain the fundus of the stomach and a part of the pancreas.

The Lymphatics of the Suprarenal Gland and of the Urinary Tract

The lymphatics of the suprarenal gland.—The lymphatic vessels coming from the capsular and parenchymatous plexuses pass, on the right side, into two or three anterior para-aortic nodes, and a small retrovenous gland, near the crus of the diaphragm; on the left side, into para-aortic nodes, and, in part, through the diaphragm, in company with the splanchnic nerve, to a posterior mediastinal gland, lying between the ninth thoracic vertebra and the aorta. Anastomoses occur with the lymphatics of the kidney.

In addition to the capsular lymphatics proper, Kumita describes a subserous plexus, which is present over both kidney and suprarenal, which anastomoses with the lymphatics of the liver and diaphragm. The efferents of this plexus collect, on the right side, to a gland placed

to the right of the inferior vena cava, anterior to the right renal vein, and on the left side to a gland anterior to the left renal vein.

The lymphatics of the kidney.—The lymphatic vessels from the deep capsular and parenchymatous lymphatics of the kidney run to the nodes of the lumbar chain (fig. 656). On the right side, part of the nodes concerned lie ventral and part dorsal to the renal vein; one of the nodes lies as far caudalward as the bifurcation of the aorta; and one or two vessels may pass to preaortic nodes. On the left side the vessels end in four or five nodes of the lumbar group. The efferents of these nodes end in the thoracic duct.

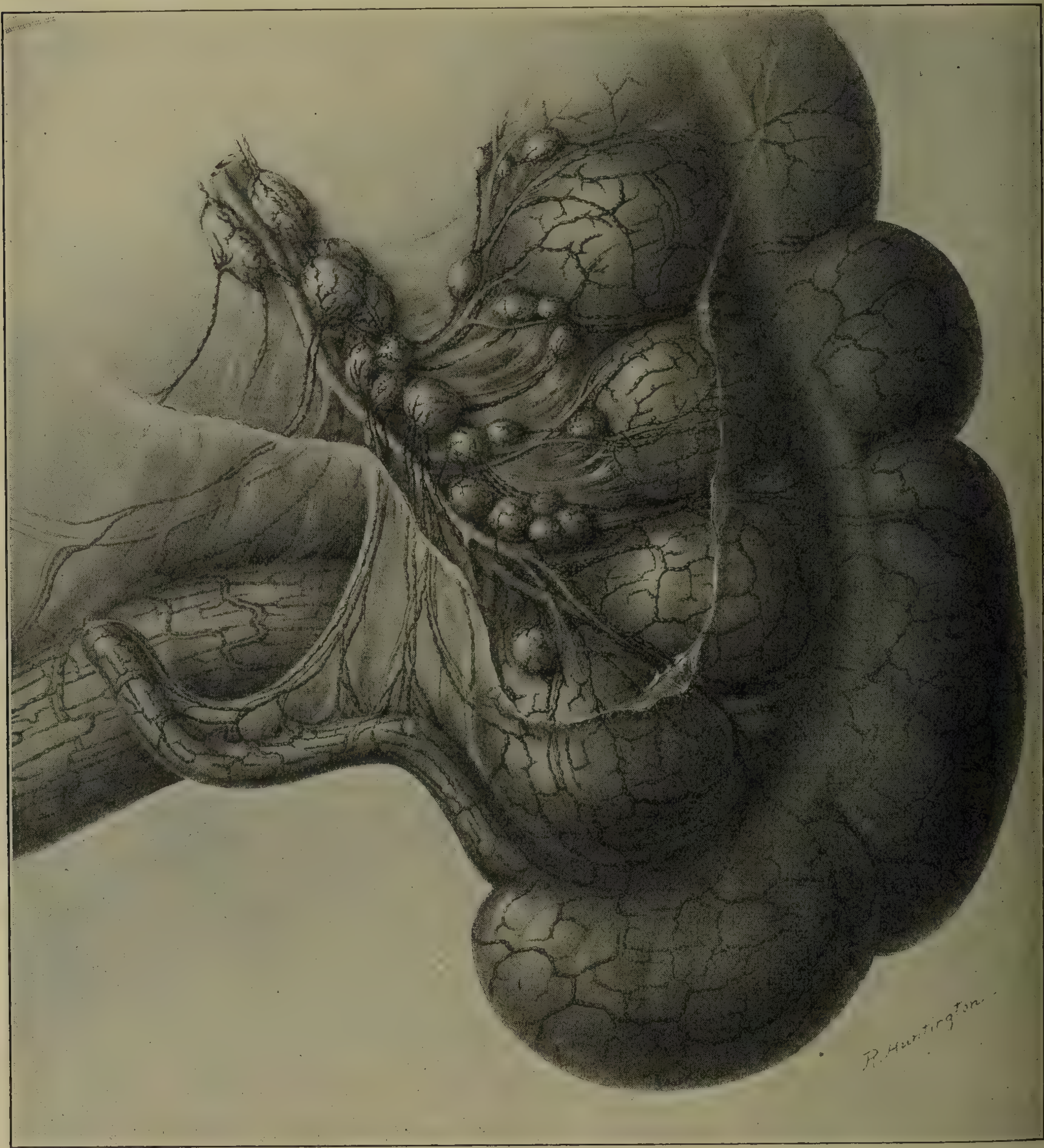


Fig. 655.—The Lymphatics of the Ileocecal Region, Posterior View. (After Kelly.)

The lymphatics of the ureter.—According to Sakata, the lymphatics of the ureter fall into three groups: (1) An anterior (upper) group, which run to the anterior lumbar nodes, or join the renal lymphatics; (2) a middle group which pass to the posterior lumbar and interiliac nodes; (3) a posterior (lower) group which pass to hypogastric nodes and which anastomose with lymphatics of the bladder.

The lymphatics of the bladder (fig. 657).—The collecting vessels from the anterior part of the inferolateral surface pass to a node of the external iliac group, situated near the femoral ring; those from the upper part of the inferolateral surface and anterior part of the superior surface pass to the middle node of the middle group of the external iliac chain; and those from the rest of the superior

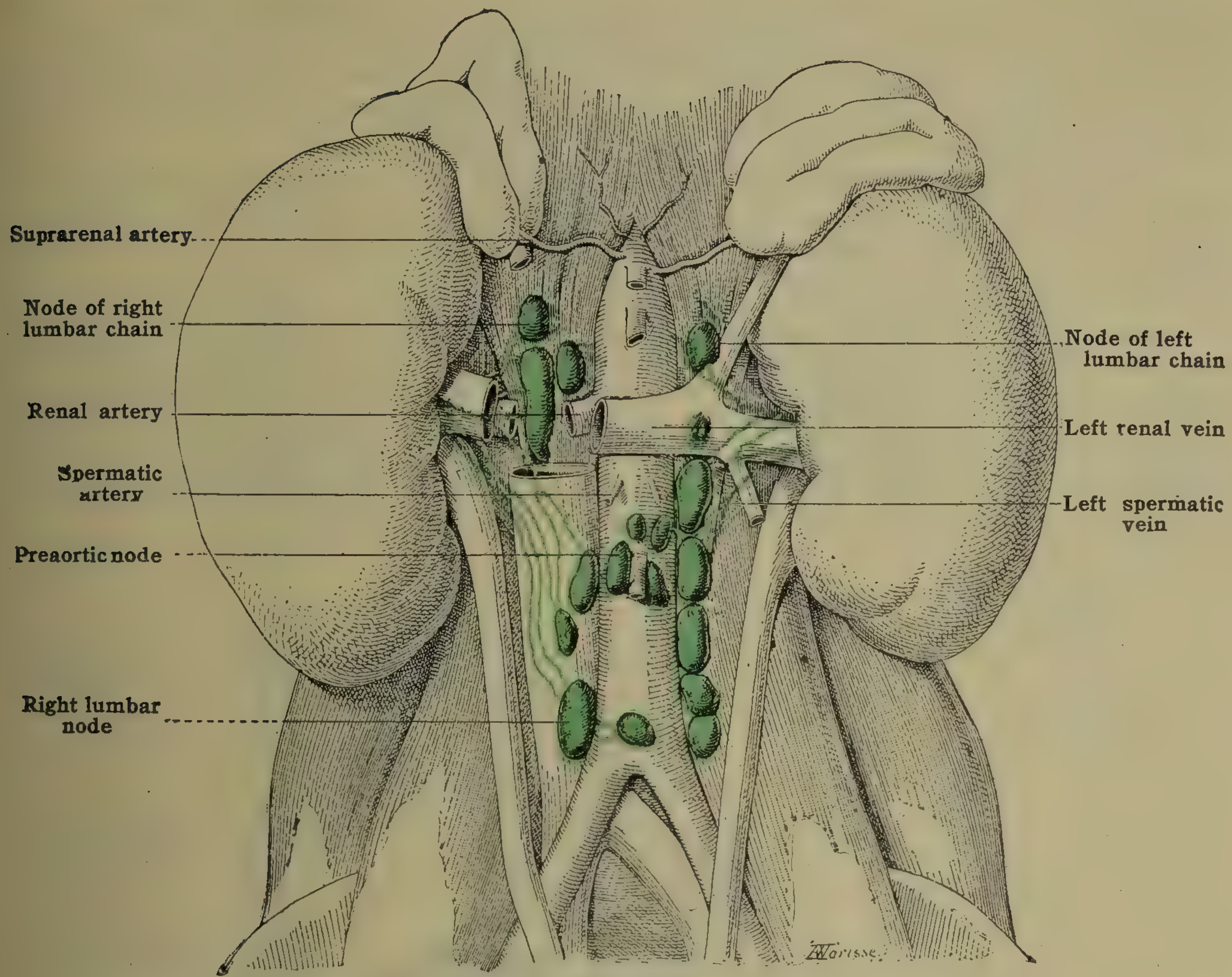


FIG. 656.—LYMPHATICS OF THE KIDNEY. (After Poirier and Cunéo.)

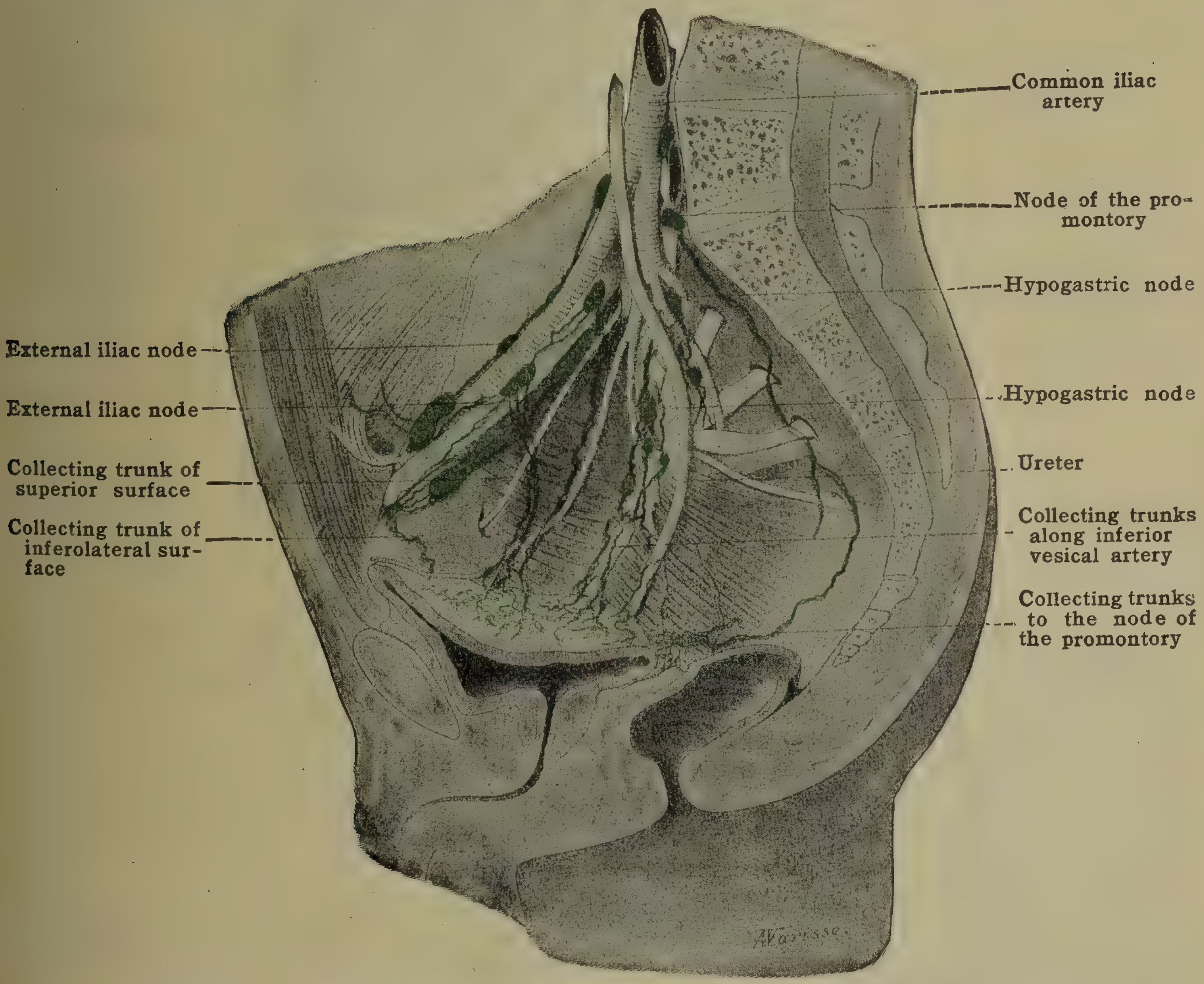


FIG. 657.—LYMPHATICS OF THE BLADDER. (After Cunéo and Marcille.)

surface and the base of the bladder pass either to the hypogastric nodes or beyond these to the nodes at the bifurcation of the aorta (nodes of the promontory). In this latter group end also the vessels from the neck of the bladder. Along some of the lymphatics of the bladder are intercalated lymph-nodes, which have been termed anterior and lateral vesical nodes.

The lymphatics of the prostate (fig. 658).—The lymphatics of the prostate have been studied in the dog by Walker and in man by Bruhns. The collecting vessels, six to eight on each side, pass along the prostatic artery to the nodes along the hypogastric artery.

These nodes are connected with those along the external and common iliac arteries, and it is possible, from an injection of the prostate, to fill the entire chain of nodes as far as the renal artery. A trunk from the posterior surface runs up over the bladder and curves outward to the middle node of the middle group of the external iliac chain, and still other vessels from the posterior surface run first downward, pass around the rectum, and then ascend to the lateral sacral nodes. From the anterior surface a descending trunk may follow the deep artery of the penis, and the internal pudic to the hypogastric nodes (fig. 658). The lymphatics of the prostate anastomose with those of the bladder. ductus deferens and rectum.

Fig. 658.—The Lymphatics of the Prostate. (After Cunéo and Marcille.)

The lymphatics of the urethra.—1. *In the male* (figs. 659, 660).—The capillary plexus of the urethra is in the mucous membrane. The collecting vessels from the mucous membrane of the glans follow the dorsal vein. Those from the cavernous and membranous portions of the urethra start from the inferior surface and curve around the corpora cavernosa, as seen in fig. 659, to join the others along the dorsal vein. These vessels run with the vein to the symphysis, where they form a plexus in which there may be some intercalated nodes (fig. 660). From this plexus vessels pass in various directions: Three or four vessels pass to the deep inguinal and external iliac nodes, and one vessel enters the inguinal canal and ends in one of the external iliac nodes. There is also a communication, along the dorsal vein of the penis, with the prostatic plexus and the external iliac nodes (fig. 659).

The vessels from the membranous portion either follow the internal pudic artery, or pass to the symphysis and end in the external iliac nodes, or pass

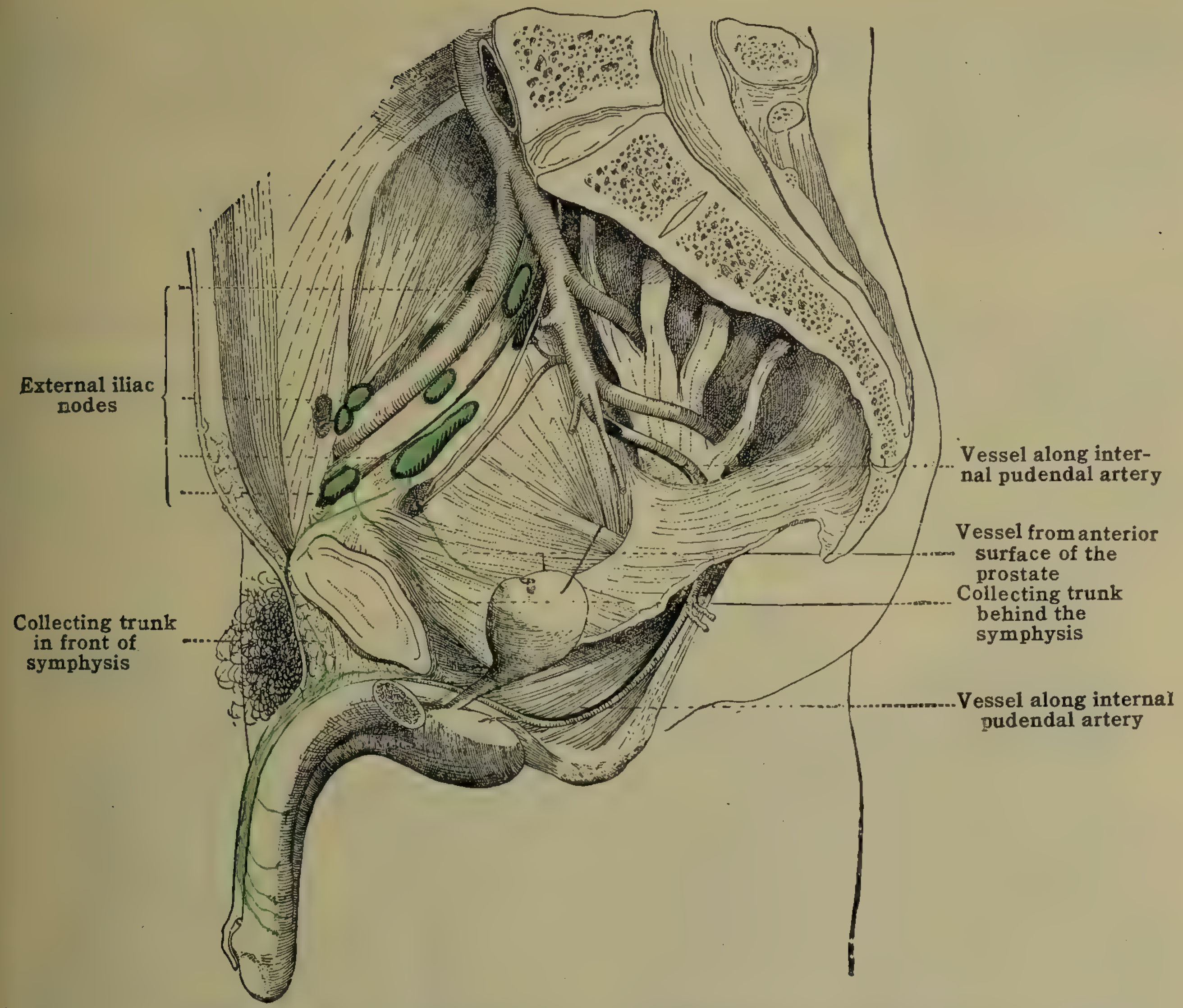


FIG. 659.—LYMPHATICS OF THE CAVERNOUS AND MEMBRANOUS PORTIONS OF THE URETHRA. (After Cunéo and Marcille.)

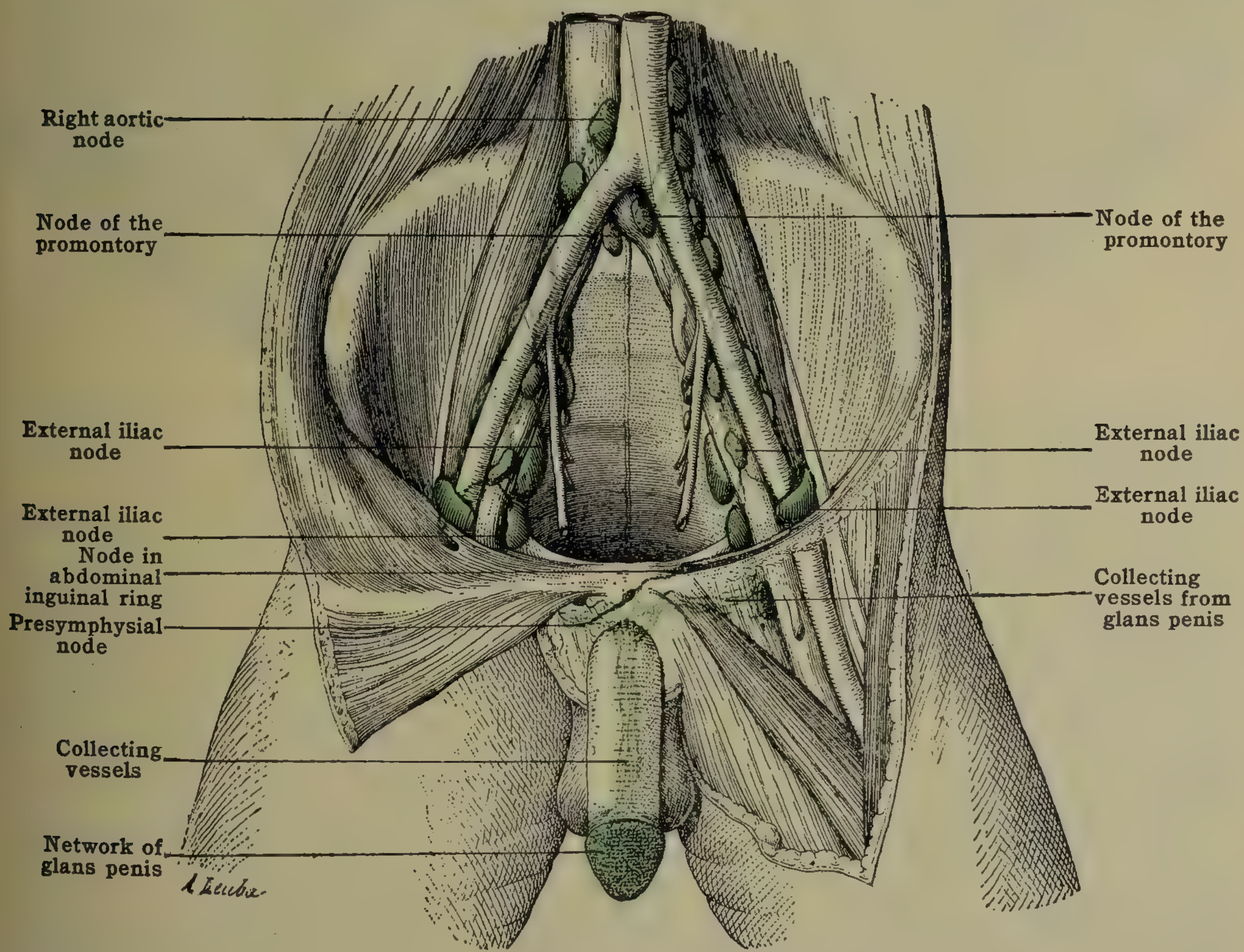


FIG. 660.—LYMPHATICS OF THE GLANS PENIS IN A NEW-BORN CHILD. (Cunéo and Marcille.)

over the surface of the bladder and thence to the external iliac chain. The lymphatics of the prostatic urethra run with the prostatic vessels. The lymphatics of the urethra anastomose with those of the bladder and those of the glans.

2. *In the female* the lymphatic vessels of the urethra end in the external iliac and hypogastric nodes.

Lymphatics of the Reproductive Organs

In the Male (Figs. 658–660)

The lymphatics of the external genitalia will be first described and then those of the internal organs.

Fig. 661.—Lymphatics of the Perineum. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The **lymphatics of the scrotum** form a rich plexus which has been pictured by Teichmann (fig. 622). The collecting vessels, ten to fifteen on either side, arise near the raphe and pass to the root of the penis, where some curve lateralward to the superior medial superficial inguinal nodes; while others, coming from the lateral surface of the scrotum, pass to the corresponding inferior nodes. This pathway is important in the extension of scrotal cancer.

The lymphatics of the penis.—(1) The cutaneous lymphatics form a plexus from which collecting vessels at first follow the dorsal vein and finally end in the superficial inguinal nodes. (2) The lymphatics of the gland form an exceedingly rich plexus from which vessels follow the dorsal vein of the penis, as described under the urethra, and end in the deep inguinal and external iliac nodes (fig. 660). (3) The lymphatics of the erectile structures are little known.

The lymphatics of the testis are both superficial and deep, the latter being exceedingly hard to inject. The collecting vessels follow the spermatic cord and blood-vessels to end in the lumbar nodes.

The lymphatics of the ductus deferens and vesiculæ seminales.—In the ductus deferens only a superficial set has been injected, and its vessels pass to the external iliac nodes. The plexus of the vesiculæ seminales is double, superficial and deep, and its vessels pass to the external iliac and hypogastric nodes.

Lymphatics in the Female

(Figs. 661–663)

The lymphatics of the vulva.—Throughout the vulva there is an exceedingly rich, superficial lymphatic plexus, from which collecting vessels pass to the symphysis and there turn lateralward to the medial superficial inguinal nodes (fig. 661). The fact that the capillary plexus is continuous from side to side and that there is a plexus of the vessels in front of the symphysis makes the nodes of both sides liable to infection from a unilateral lesion.

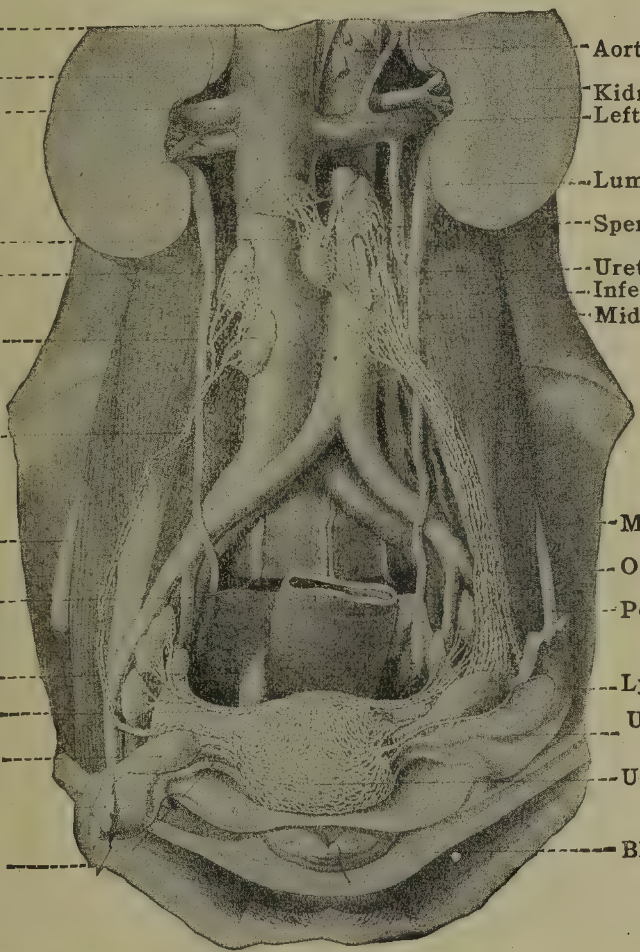


FIG. 662.—LYMPHATICS OF THE INTERNAL GENITAL ORGANS IN THE FEMALE. (After Poirier.

The lymphatics of the clitoris.—The lymphatics of the glans of the clitoris form an abundant network from which collecting vessels pass toward the symphysis pubis, and thence principally to the deep inguinal nodes, one or two, however, passing through the inguinal canal to terminate in the lower external iliac nodes.

The lymphatics of the ovary.—The ovary has a remarkably rich lymphatic plexus, from which from four to six vessels leave the hilus and follow the ovarian blood-vessels to the lumbar nodes. One vessel may run in the broad ligament to join the internal iliac group.

The **lymphatics of the uterine** (**Fallopian**) **tube** form three capillary networks from which collecting vessels run in part with those of the ovary, and in part with the uterine lymph-vessels.

The lymphatics of the uterus.—According to Poirier, the lymphatics of the uterus arise from three capillary plexuses, a mucous, a muscular, and a peritoneal. The collecting vessels from the *body of the uterus* (fig. 662) are in three sets: (1) Those from the fundus, consisting of four or five vessels, run lateralward through the broad ligament and the suspensory ligament of the ovary and follow the ovarian vessels to the lumbar and preaortic nodes. They anastomose with

the lymphatics from the ovary opposite the fifth lumbar vertebra; (2) some small vessels from the fundus follow the round ligament of the uterus and terminate in the inguinal nodes; and (3) others from the body of the uterus pass laterally with the uterine vessels and terminate in the iliac nodes.

The collecting vessels from the *cervix* (figs. 662, 663), five to eight in number, form a large lymphatic plexus just after leaving the cervix. From this plexus run three sets of vessels. Two or three vessels pass lateralward with the uterine artery in front of the ureter, and end in the external iliac nodes; a second set passes behind the ureter and ends in a node of the hypogastric group; and a third set from the posterior surface runs downward over the vagina and then backward and upward to end in the lateral sacral nodes and node of the promontory of the sacrum.

The lymphatics of the vagina (fig. 663).—There are two lymphatic plexuses in the vagina, a superficial and deep—the latter, the mucosal plexus, being exceedingly rich. The collecting vessels are in three groups. The superior set

Fig. 663.—Lymphatics of the Vagina. (After Poirier.)

(uterovaginal) drains the upper third of the vagina and takes the same course as those from the lower cervical portion of the uterus; the middle set follows the vaginal artery to the hypogastric nodes; and the inferior set runs to the lateral sacral nodes and to those of the promontory. The capillary network of the lower part of the vagina is continuous with the plexus of the vulva, which drains to the inguinal nodes.

E. THE LYMPHATICS OF THE LOWER EXTREMITY

1. THE LYMPHATIC NODES OF THE LOWER EXTREMITY

The principal group of nodes of the lower extremity is situated in the inguinal region, and hence is known as the **inguinal group** (figs. 664, 665). It is in many respects similar to the axillary group, although it is not quite equivalent to it developmentally. The nodes composing it are divisible into a superficial and a deep group, the former containing many more and larger nodes than the latter. Furthermore, it is convenient to divide each of these groups into an upper and a

lower set, the dividing line being an arbitrary line drawn horizontally through the point where the saphenous vein pierces the fascia of the fossa ovalis. The nodes above this line are termed collectively the **inguinal nodes** [lgl. inguinales], while those below it are known as the **subinguinal nodes** [lgl. subinguinales).

The superficial inguinal nodes lie along the base of the femoral trigone immediately below Poupart's ligament, superficial to the fascia lata. In thin

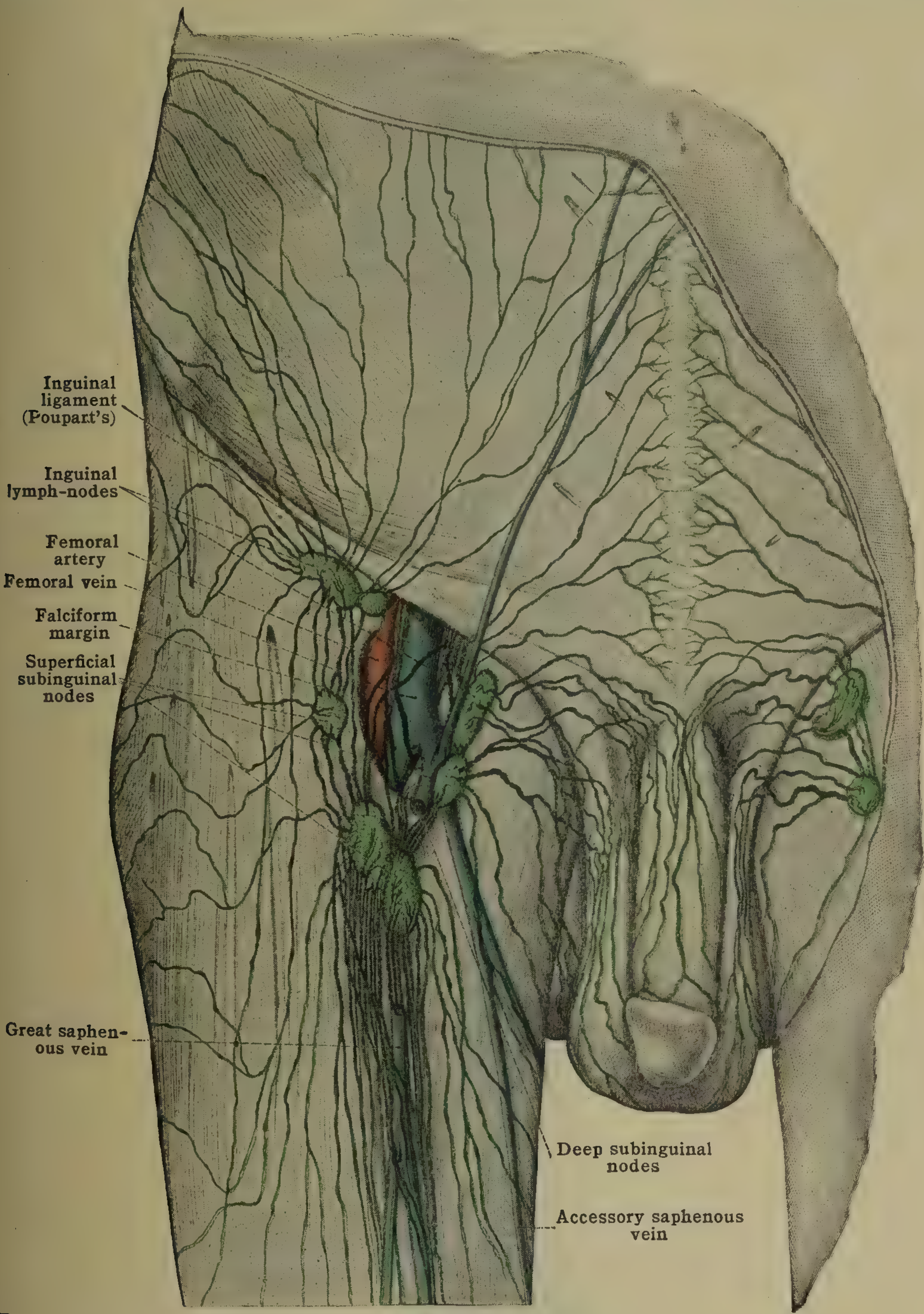


FIG. 664.—THE SUPERFICIAL INGUINAL NODES. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

persons, they are often palpable. Their number varies from ten to twenty. They receive the subcutaneous drainage of the anterior and lateral abdominal walls, the gluteal region, the external genitalia and the perineal region. Their efferents descend to the fossa ovalis, which they perforate along with the saphenous vein and terminate in the lower external iliac nodes.

The **superficial subinguinal nodes** occupy the lower part of the femoral trigone and receive the entire superficial drainage of the lower extremity, as well as

a few vessels from the gluteal region and from the perineum. Their efferents pierce the fossa ovalis and pass partly to the deep subinguinal nodes and partly directly to the lower external iliac nodes.

The deep inguinal nodes.—The deep nodes are small, and vary from one to three. They lie medial to the femoral vein, the highest one (*node of Cloquet or of Rosenmüller*) being placed in the femoral ring and being of especial surgical

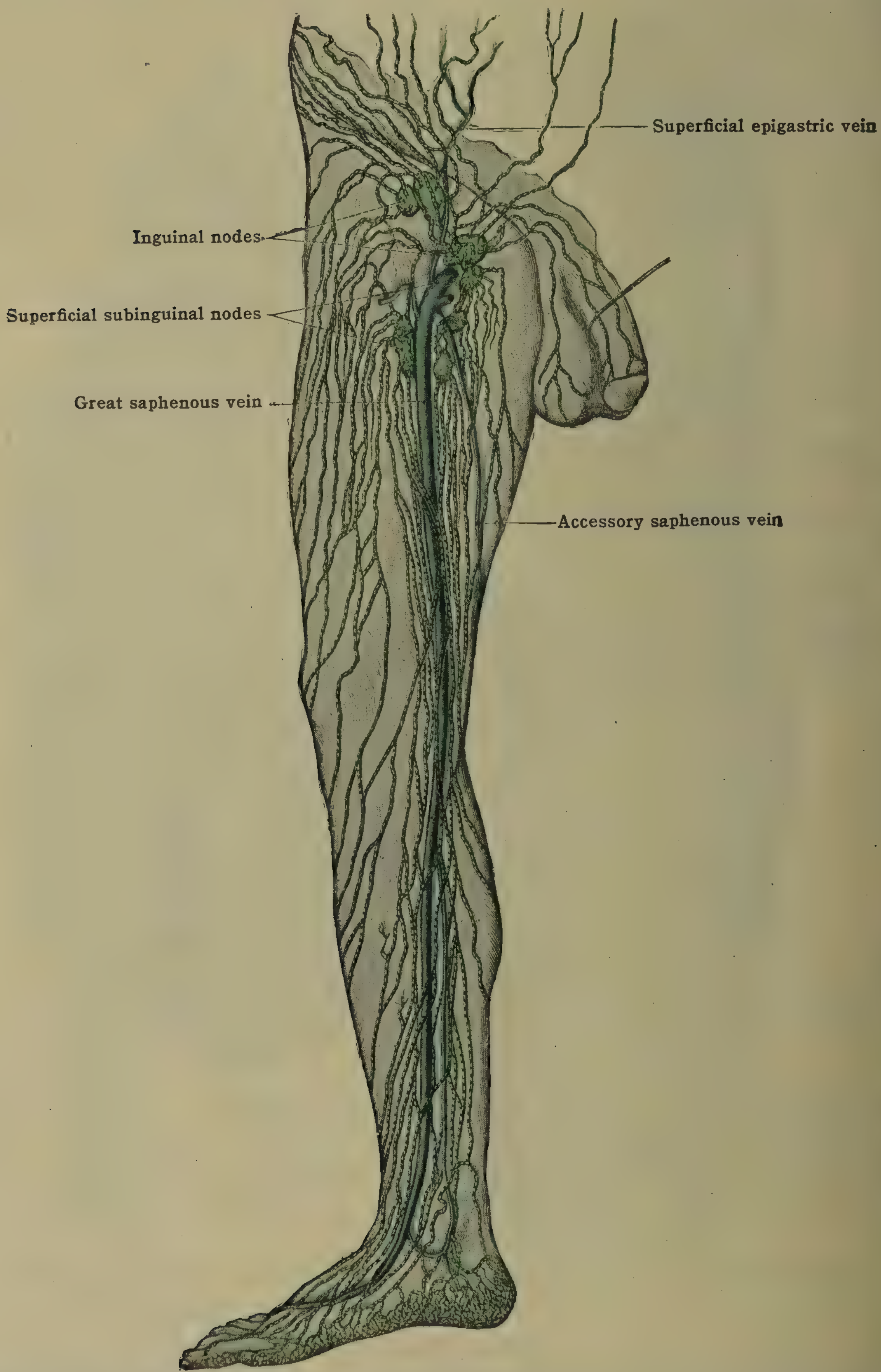


Fig. 665.—The Superficial Lymphatics of the Lower Extremity. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

interest in that, when enlarged, it may simulate a strangulated hernia. The lowest node is below the point where the great saphenous joins the femoral vein. These deep nodes receive the deep lymphatics of the lower extremity, also vessels

from the glans penis or clitoris, and some of the vessels from the superficial subinguinal nodes. Their efferent vessels enter the external iliac nodes.

In addition to the inguinal group of nodes there are some other nodes in the lower limb situated along the course of the deep vessels. Thus there is an inconstant node in the course of the anterior tibial vessels below the knee, and

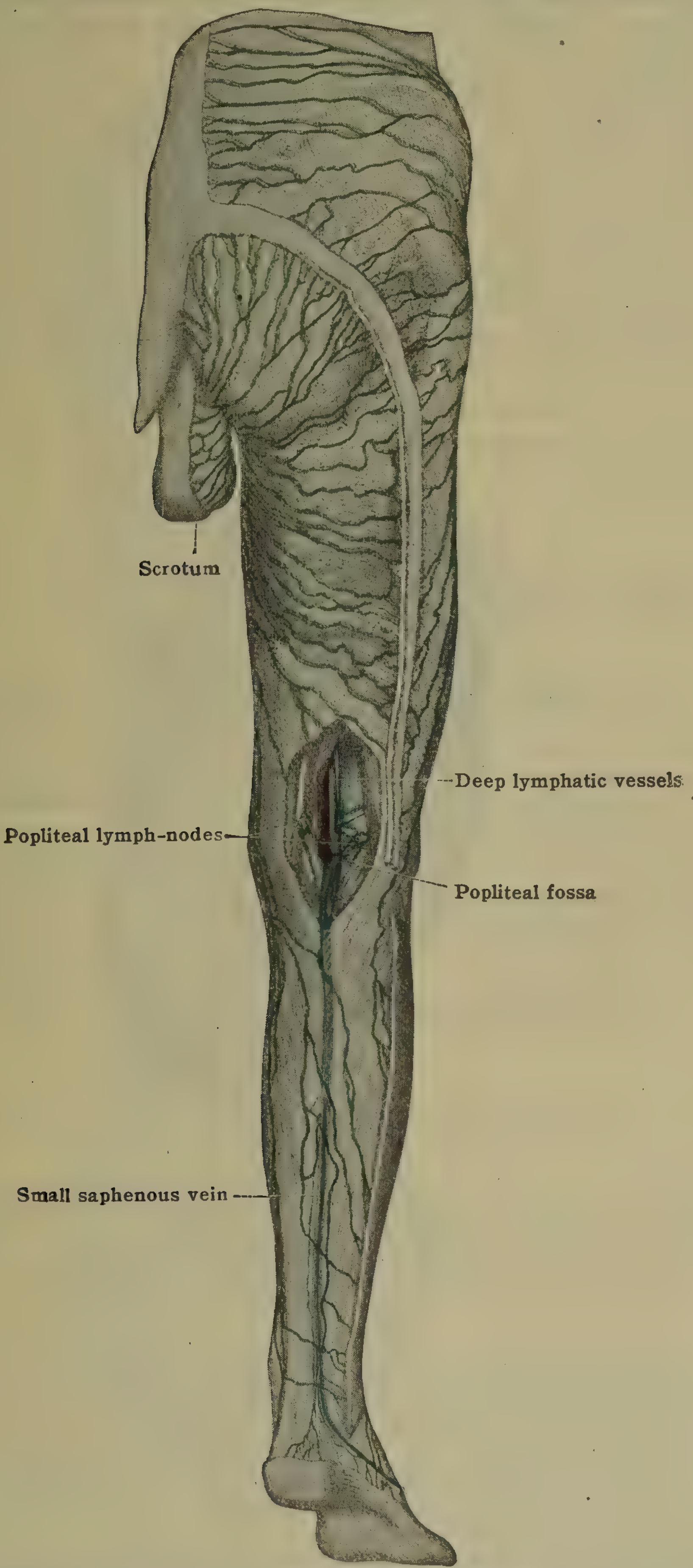


Fig. 666.—The Lymphatics of the Back of the Lower Extremity. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

there is a small group of **popliteal nodes** [lgl. popliteæ], in the popliteal space (fig. 666), which receive the lymphatics accompanying the lesser saphenous vein, also those which accompany the posterior tibial and peroneal vessels, and those which drain the knee-joint.

2. THE LYMPHATIC VESSELS OF THE LOWER EXTREMITY

As in the upper extremity, the subcutaneous capillary plexus of the lower varies greatly in complexity, being most abundant in the soles of the feet. The collecting vessels form two main groups. The medial, larger group (fig. 665) follows the great saphenous vein, and ends in the superficial subinguinal nodes, while the lateral group curves around to join the medial, partly in the leg and partly in the thigh. Two or three vessels from the heel follow the lesser saphenous vein to the popliteal space. The vessels from the upper and dorsal part of the thigh curve around on both sides to reach the superficial inguinal nodes. The vessels of the anus and perineum, as well as those from the external genitalia, except from the glans penis or the clitoris, pass to the medial nodes of the superficial inguinal group.

The deep vessels follow the course of the arteries of the lower extremity, those accompanying the dorsalis pedis and anterior tibial arteries coming into relation with the anterior tibial node (when present), and then passing backward to join the vessels which accompany the posterior tibial and peroneal arteries. These

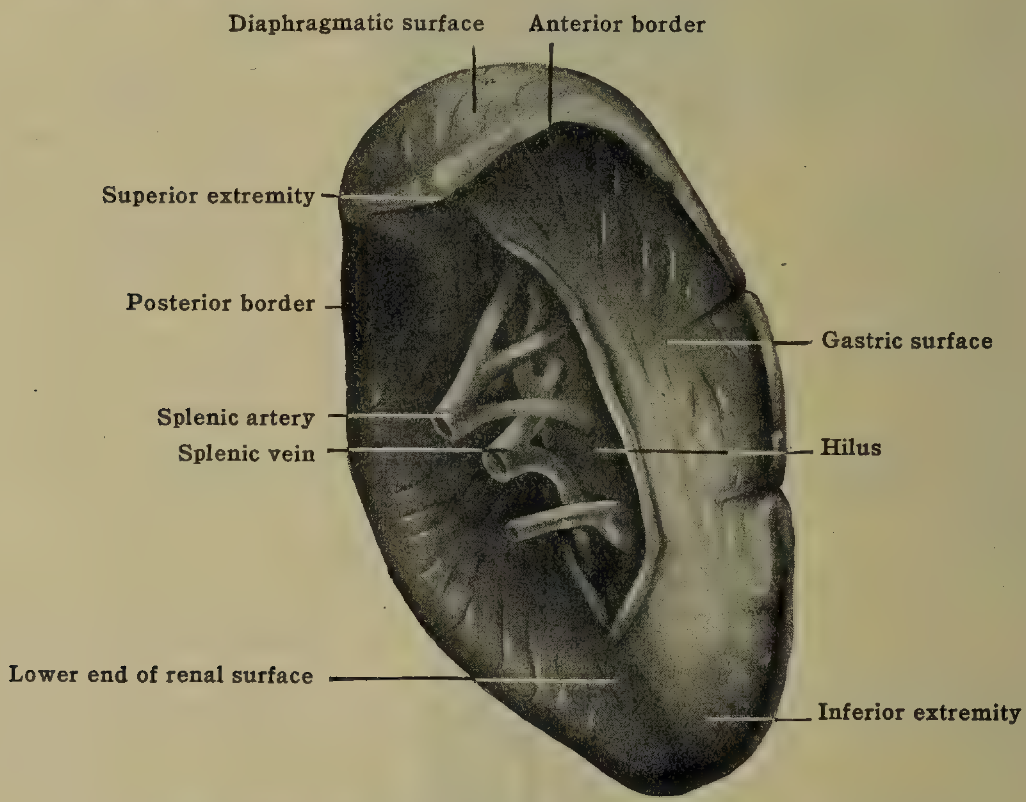


Fig. 667.—Wedge-shaped Spleen, Visceral Surface.

terminate in the popliteal nodes, from which efferents follow the course of the femoral artery and terminate in the deep inguinal nodes. The deep lymphatic vessels accompanying the gluteal and obturator arteries pass to the hypogastric nodes.

Lymphatics of the hip-joint.—According to Clermont, they accompany, in the main, the arteries about the joint. (1) Satellites of the anterior circumflex artery, draining almost the entire ventral surface, pass to the lateral inferior external iliac node. (2) Satellites of the posterior circumflex artery, draining the dorsal and medial surfaces, empty into the medial inferior external iliac node, occasionally into one of the deep inguinal nodes. (3) Satellites of the obturator vessel, draining the round ligament, empty into the obturator or hypogastric nodes. (4) Satellites of the inferior gluteal vessels, draining the dorsal surface, empty into three small nodes along the internal pudic and inferior gluteal arteries. Less important ('accessory') vessels are: satellites of the superior gluteal artery leading to a gluteal node; vessels from the dorsal surface which cross the lateral border of the pectineus to reach the medial inferior external iliac node; and vessels from the ventral surface, crossing parallel to the cotyloid notch, passing under the psoas to the lateral inferior external iliac or one of the deep inguinal nodes.

Lymphatics of the knee-joint.—According to Tanasesco the lymphatics draining the structures around the knee-joint in the main follow the arteries about the joint and pass largely to the more deeply placed of the popliteal nodes. Some (superficial) follow the great saphenous vein to the subinguinal nodes, and sometimes deep vessels pass the popliteal nodes and, accompanying the femoral artery, run to the deep inguinal or inferior external iliac.

SPLEEN

The **spleen** [lien] has approximately the shape of an elongated, ovoid body, or that of a slightly curved wedge (figs. 667, 668), with three (or four) surfaces, and three rounded borders. Its largest surface is the convex, **diaphragmatic surface** [facies diaphragmatica], posterolaterally facing the curve of the diaphragm (figs. 671, 672). The latter separates the spleen from the pleural cavity

FIG. 668.—TETRAHEDRAL SPLEEN, VISCERAL SURFACE.

and ribs. The visceral surface (facies visceralis NK) includes a gastric (pars gastrica NK) and a renal portion (pars renalis NK). The deeply concave, **gastric surface** [facies gastrica] rests ventro-medially against the fundus of the stomach. It includes the **hilus**, which receives the splenic vessels, and behind which the spleen is in contact with the tail of the pancreas (fig. 671). The slightly concave, **renal surface** [facies renalis] rests posteromedially against the convex,

FIG. 669.—SPLEEN SHOWING TUBERCLE ON THE INTERMEDIATE BORDER.

anterior surfaces of the left kidney (fig. 672) and suprarenal. The more caudal portion of this area touches, to a variable extent, the left colic flexure. An enlarged basal or **colic surface** often gives the spleen a more tetrahedral shape (figs. 668, 670).

The spleen has an **anterior** and a **posterior border.** The anterior border [margo anterior] (margo acutus NK) forms a rather sharp, considerably convex line, on which sometimes slight serrations (lobulations) are noticeable. The

posterior border [margo posterior] (margo obtusus NK) is almost straight and less prominent than the anterior margin. The anterior border touches the fundus of the stomach, the posterior the lumbar region of the diaphragm. In the tetrahedral spleen, an **inferior** border separates the colic from the diaphragmatic surface. The spleen also shows a **superior** (extremitas vertebralis NK) and an **inferior extremity** (extremitas ventralis NK), the latter occupying a more ventral position. Between the gastric and renal surfaces of the spleen, usually somewhat on the gastric surface, runs an elevated ridge, sometimes called the intermediate border, which may present a distinct tubercle (fig. 669). Along the margins of this ridge the visceral layer of the peritoneum is attached. It surrounds the entire organ from which it is reflected as the gastrolienal and phrenolineal ligaments.

The **shape** of the spleen varies considerably in different individuals. Even in the same individual it changes its shape to some extent in accommodating itself to the surfaces of the contracted or distended viscera. When the stomach is empty and the colon distended, the tetrahedral form is more pronounced. In the opposite case, the colic surface may disappear entirely.

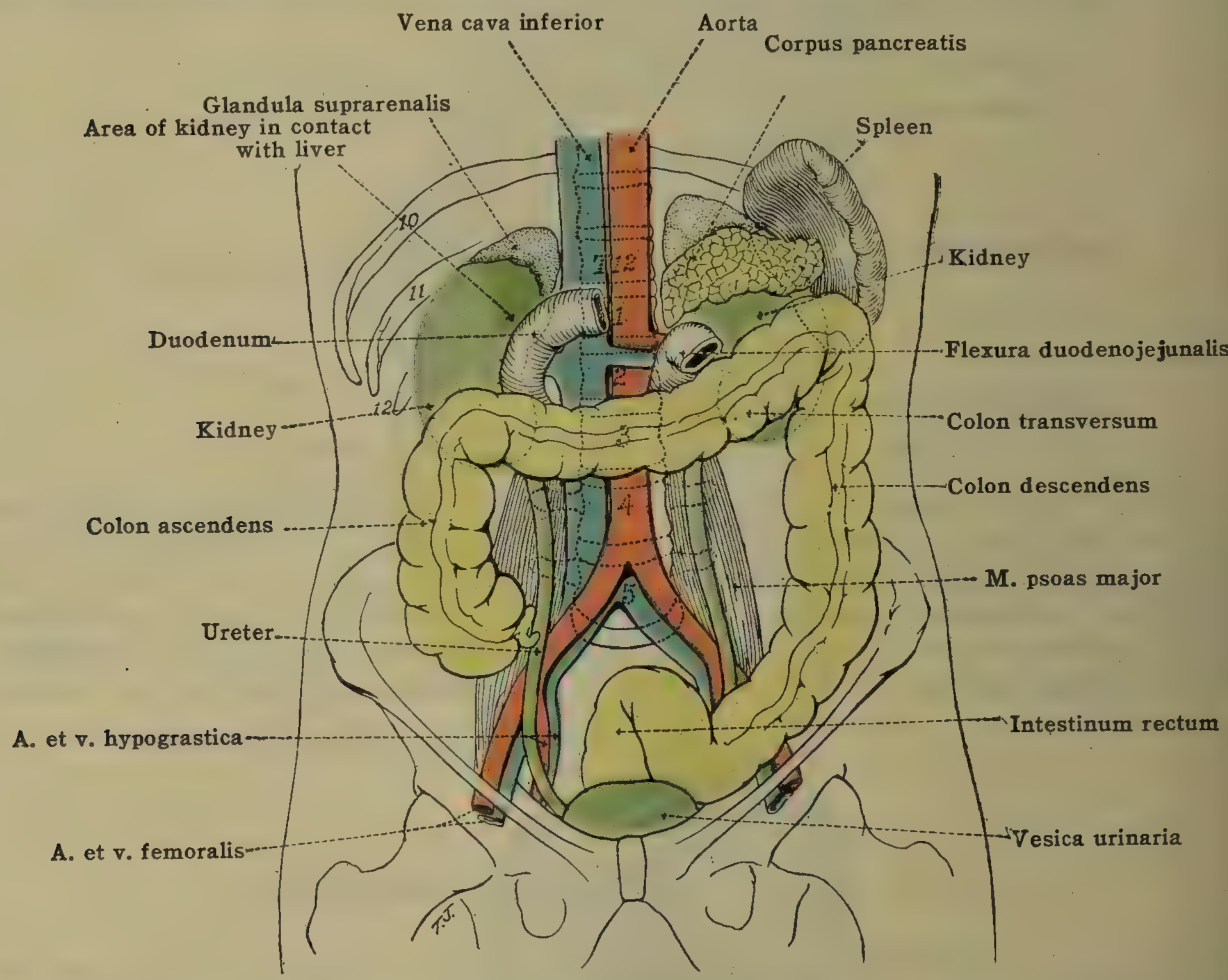


FIG. 670.—TOPOGRAPHIC RELATIONS OF THE SPLEEN, ETC. ANTERIOR VIEW.

The spleen has a rather dark, brownish red **color,** which after death soon changes to a purplish tint. Its **consistency** is soft. It is surrounded by a tough, fibrous capsule, containing many elastic elements, which allow for considerable expansion of the splenic substance, and numerous smooth muscle-fibers. The latter are present, to some extent, in the trabeculæ. The peritoneum is closely applied to the capsule.

The size of the spleen is also subject to great individual variation. Normally it cannot be palpated, but if markedly enlarged its lower end extends downward and forward toward the umbilicus and is readily felt below the costal margin. It easily enlarges under increased blood-pressure. A few hours after meals its size is increased. The length of the organ varies from 10 to 14 cm.; the width from 6 to 10 cm.; the thickness from 3 to 4 cm.; and the weight varies from 80 to 300 grams or more. After the age of 40 years, a slight involution of the spleen sets in.

Topography.—The spleen lies obliquely in the left hypochrondiac region (fig. 1032), its cranial end sometimes reaching into the epigastric region. It is situated in a shallow excavation, formed dorsally by the kidney and suprarenal, laterally by the costal part of the diaphragm, cranially by the dome of the diaphragm, caudally by the left colic flexure and phrenocolic ligament (fig. 983), ventromedially by the stomach. The long axis of the organ runs about parallel with the tenth rib (fig. 670), the spleen lying laterally to a line drawn from the left sternoclavicular

articulation to the tip of the eleventh rib. The upper extremity lies in the region of the costal angle, the lower nearly reaches the midaxillary line. The width of the spleen extends through the 9th and 10th intercostal spaces.

Moody and Van Nuys have made a roentgenographic study of the size and position of the spleen in living, healthy young adults. They find that, in the erect posture, the length of the shadow cast by the spleen varies, in 80% of males, from 11.0 to 15.0 cm., the extreme range being 9.0 to 17.0 the figures for females being 1 cm. less; while the width of this shadow is most commonly from 6.0 to 7.0 cm. in males, and 5.0 to 6.0 cm. in females. The caudal pole of the spleen was found to extend much lower in the living than in the cadaver. Instead of stopping at the level of the eleventh thoracic vertebra, as usually described, they found that the range of the caudal pole of the spleen is from the upper half of the first lumbar to the upper half of the fifth lumbar vertebra, the most frequent position being the upper half of the third lumbar vertebra. There is evidence that the spleen diminishes in size after death, and also, that, as has been shown definitely in cats and dogs (Barcroft), the human spleen diminishes in size after exercise

Ligaments.—Nowhere, except near the hilus, is the spleen attached to the peritoneum. Therefore, it easily slides in its bed and follows the movements of the diaphragm. An important suspensory ligament of the spleen is the **gastrolienal** (gastrosplenic) **ligament** (fig. 981); its peritoneal layers are continued from

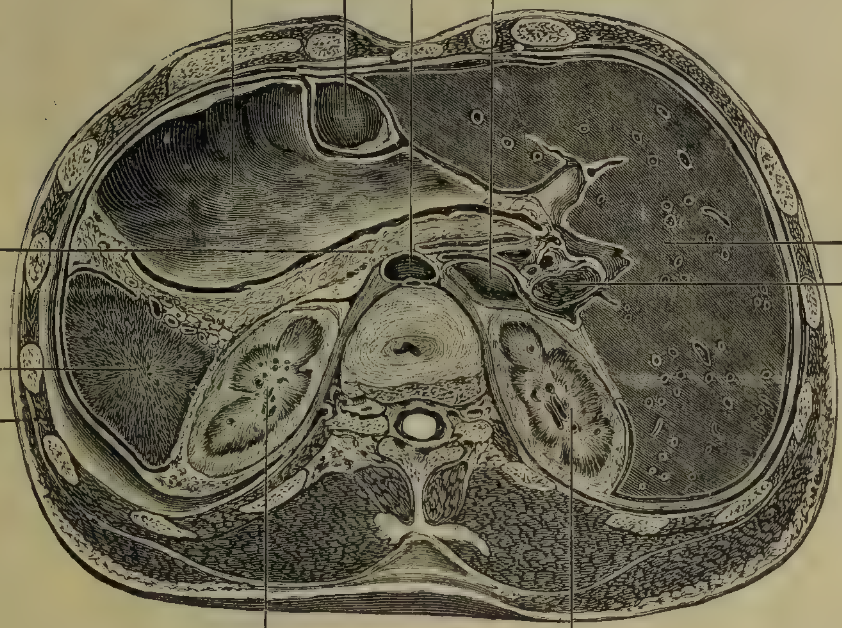


Fig. 671.—Cross-section of the Body at the Lower Part of the Epigastric Region. (Rüdinger.)

the anterior (greater sac) and posterior (lesser sac) surfaces of the stomach to the anterior and posterior borders of the hilus, respectively. The anterior layer is continued over the entire surface of the spleen, and then meets the posterior layer to be reflected from the hilus of the spleen to the adjacent surface (fig. 979). This double reflection forms the short **phrenolienal** (lienorenal) ligament which carries the splenic vessels and the tail of the pancreas. This ligament is variable in form and extent. The **phrenocolic** ligament, although not attached to the spleen, supports the lower extremity of the organ (fig. 983).

Blood-supply.—The *splenic artery* and *vein* run in the phrenolienal ligament to the hilus. The artery is rather tortuous, especially in older persons, and lies above the vein. It branches several (about six) times into the vessels of the superior and inferior group before reaching the organ. The splenic vein is likewise formed outside the hilus by several tributaries.

At the hilus some *lymph-vessels* are found which send a few branches into the capsule and larger trabeculæ. No lymph-vessels go through the splenic tissue proper. About 8 or 10 lymph-nodules, connected with these vessels, are found near the hilus, between the layers of the gastrolienal ligament (splenic nodes), and some along the superior border of the pancreas (pancreaticosplenic nodes).

Nerve-supply.—Nerve-fibers from the median and anterior parts of the celiac plexus form a dense network, the *splenic plexus* and follow the splenic artery into the organ. Fibers from the right vagus can also be traced in. The few medullated fibers are probably sensory

Development.—The spleen develops in the mesenchyma of the dorsal mesogastrium. A diffuse accumulation of leucoblasts is noticeable at the beginning of the second fetal month (8 to 10 mm. embryos). This area very soon becomes considerably vascularized, especially the veins forming loose capillary plexuses. Later, angioblasts are carried into this zone, and the spleen begins to assume its hemopoietic function. During fetal life, red as well as white blood-cells are formed in the spleen. After birth the formation of erythrocytes ceases. For further details on the development of the spleen, see p. 39.

Variations.—Sometimes *lobulated spleens* are found, in which the above-mentioned notches along the anterior border are exaggerated. Deep incisions may appear also on the diaphragmatic surface and on the posterior border so that the entire organ seems to be divided up into lobes. Such a spleen probably represents an atavistic type, the organ being lobated in the lower vertebrates and even in some mammals.

Another, not uncommon, abnormality is the formation of *accessory spleens*. These usually are small nodules in the neighborhood of the main organ. Sometimes their number is quite excessive. In man over 400 have been counted in a single individual, widely distributed through the peritoneal cavity; in dogs and cats, over 800. Occasionally, a group of such small

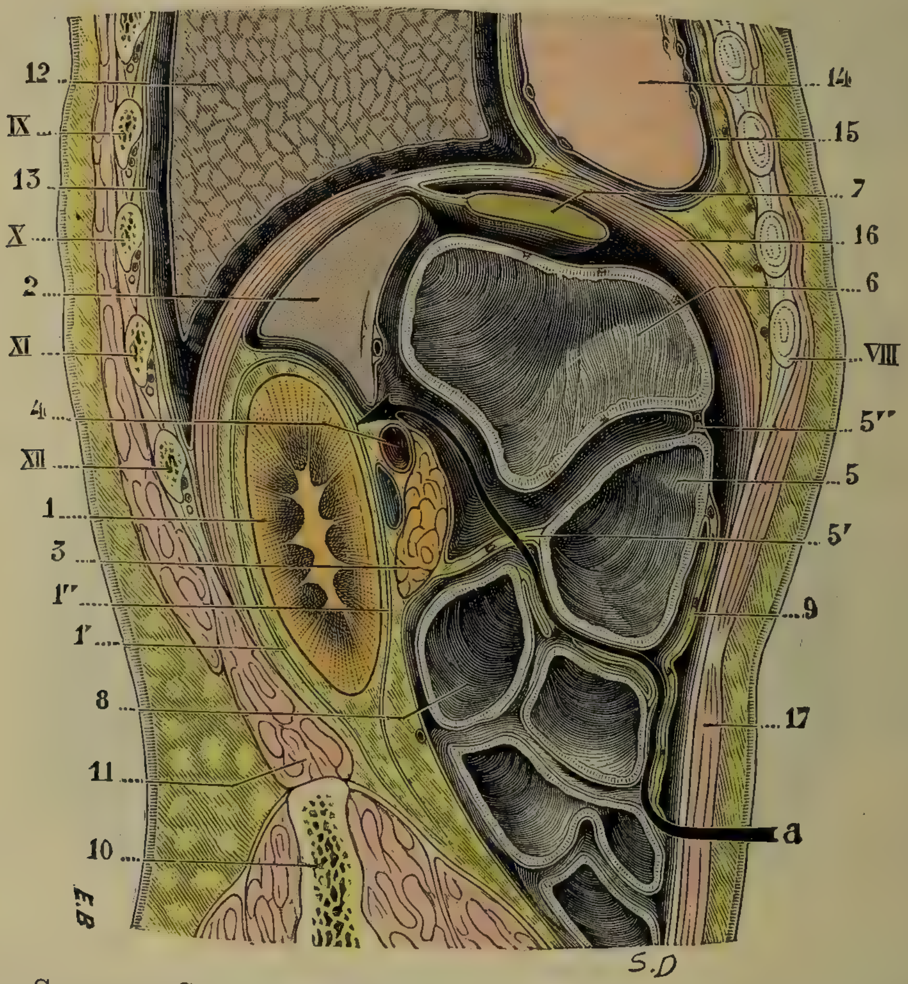


FIG. 672.—SAGITTAL SECTION THROUGH THE LEFT SIDE OF THE BODY, SHOWING THE RELATIONS OF THE SPLEEN. IX, X, XI, XII, corresponding ribs. 1, Left kidney; 2, spleen; 3, pancreas; 4, splenic vessels; 5, transverse colon; 6, stomach; 7, left lobe of liver; 12, lung; 14, heart; 16, diaphragm. Line *a* indicates inferior surgical route. (Testut and Jacob.)

nodules (isolated lobules) takes the place of the main organ. Whether in the above mentioned cases all these numerous nodes actually represent *accessory spleens* or *hemal nodes*, is still an open question. It is difficult to make a differential diagnosis of very small nodules. There is, however, no doubt that the body of the spleen can break up into its units. A congenital absence of the spleen is extremely rare.

Comparative.—In fishes, turtles and frogs the spleen exists as an elongated body developed in the mesentery parallel and in close proximity to the digestive tube, along the upper, middle, or lower part of the intestine. This distribution has led to the suggestion that the spleen is to be thought of as originally an organ extending along the entire course of the digestive tube, different portions of which are suppressed in different animals. In urodeles, reptiles, birds and most mammals it forms a compact sometimes lobulated body near the stomach.

References for lymphatic system.—(*Development*): Sabin, Amer. Jour. Anat., vols. 1, 3, 4, 9, also in Keibel and Mall's Human Embryology; Lewis, Amer. Jour. Anat., vols. 5, 9; Huntington and McClure, Amer. Jour. Anat., vol. 10; Clark, E. R., Amer. Jour. Anat., vol. 13; Clark, E. R., and E. L., Carnegie Inst. Contrib. to Embryol., No. 45, 1920. (*Regeneration*): Meyer, Johns Hopkins Hosp. Bul., vol. 17; Clark and Clark, Anat. Rec., Suppl., vol. 48, p. 13, 1931. (*General*): Bartels, in von Bardeleben's Handbuch d. Anatomie; Sappey, Description et Iconographie des Vaisseaux Lymphatiques, Paris, 1885; Teïchmann, 'Das Saugadersystem,' Leipzig, 1861. (*Muscle, etc.*): Aagaard, Anat. Hefte, Bd. 47. (*Connective tissue*): von Recklinghausen, Die Lymphgefässe u. ihre Beziehung zum Bindegewebe, Berlin, 1862. (*Stomata*): MacCallum, Johns Hopk. Hosp. Bull., 1903, 14: 105, (*Lung*): Miller, Anat. Rec., vol. 5; Cun-

ningham, R. S., Carnegie Inst. Contrib. to Embryol., No. 12. (*Teeth*): Schweitzer, Arch. f. mikr. Anat., Bd. 74. (*Activity*): Florey, Jour. Physiol., vol. 63, 1927; Drinker and Field, Am. Jour. Physiol., No. 97, 1931; Menkin, Jour. Exp. Med., vol. 53, 1931. (*Hemal nodes*): A. W. Meyer, Proc. Am. Ass. of Anat., Anat. Rec. vol. 2, p. 62; and Amer. Jour. Anat., vol. 21. (*Spleen*): Mall, Am. Jour. Anat., vol. 2, 1903; Weidenreich, Arch. f. mikr. Anat., Bd. 58, 1901; Shepherd Jour. Anat. and Physiol., vol. 37, 1902; Mollier, Arch. f. Mikr. Anat. Bd. 76, 1911; Sabin, in Keibel-Mall, 1911; Moody and Van Nuys, Amer. Jour. Roentg. and Rad. Therap., vol. 20, 1928.

SECTION VIII

THE NERVOUS SYSTEM

By IRVING HARDESTY, A.B., Ph.D., D.Sc.

PROFESSOR OF ANATOMY, THE TULANE UNIVERSITY OF LOUISIANA

THE nervous system of man, both anatomically and functionally, is the most highly developed and extensively distributed of all the organ-systems of the body. It consists of an aggregation of peculiarly differentiated tissue-elements, so arranged that through them stimuli may be transmitted from and to the functional apparatuses of all the other organ systems of the body. It is a mechanism with parts so adjusted that stimuli affecting one tissue may be conveyed, controlled, modified, and distributed to other tissues so that the appropriate reactions result. While protoplasm will react without nerves, while muscle will contract without the mediation of nerves, yet the nervous system is of the most vital importance to the higher organisms in that the stimuli required for the functioning of the organs are so distributed throughout their component elements that the necessary harmonious and coordinate activities are produced. For this purpose the nervous system permeates every organ of the body; nerve cell-bodies, accumulated into groups, give rise to the nerves which ramify and divide into smaller and smaller branches till the division attains the individual nerve-fibers of which the nerves are composed, and even the fibers bifurcate repeatedly before their final termination upon their allotted tissue elements from which they receive stimuli and to which they trasmit impulses. So intimate and extensive is the distribution throughout that could all the other tissues of the body be dissolved away, still there would be left in gossamer its form and proportions—a phantom of the body composed entirely of nerves.

The parent portion or **axis** of the system, known as the central nervous system, extends along the dorsal midline of the body, surrounded by bone and, in addition, protected and supported by a series of especially constructed membranes or meninges, the outermost of which is the strongest. The cephalic end of the axis, the **encephalon,** is remarkably enlarged in man, and is enclosed within the largest portion of the bony cavity, the cranium, while the remainder of the central axis, the **spinal cord**, continues through the foramen magnum and lies in the vertebral canal.

The intimate connection of the axis with all the parts of the body is attained by means of forty-six pairs of nerves, which are attached to the axis at somewhat regular intervals along its extent. They course from their segments of attachment through the meninges and through their respective foramina in the bony cavity to the periphery. Of these *craniospinal nerves,* fifteen pairs pass through the cranium and are attached to the encephalon, and thirty-one pairs to the spinal cord. Some of the cranial nerves and all of the thirty-one pairs of spinal nerves contain both *afferent fibers*, which convey impulses from the peripheral tissues to the central axis, and *efferent fibers*, which convey impulses from the axis to the peripheral tissues. The different pairs of nerves possess the two varieties of fibers in varying proportions.

Close to the spinal cord, each spinal nerve is separated into two roots—its posterior or *dorsal root* and its anterior or *ventral root.* The afferent fibers enter the axis by way of the dorsal roots, which are, therefore, the sensory roots, and the efferent fibers leave the axis by way of the ventral or motor roots.

As usually studied, the nervous system is considered in two main divisions:—

(1) The *central nervous system*, composed of—(*a*) The spinal cord, or medulla spinalis, and (*b*) the brain or encephalon.

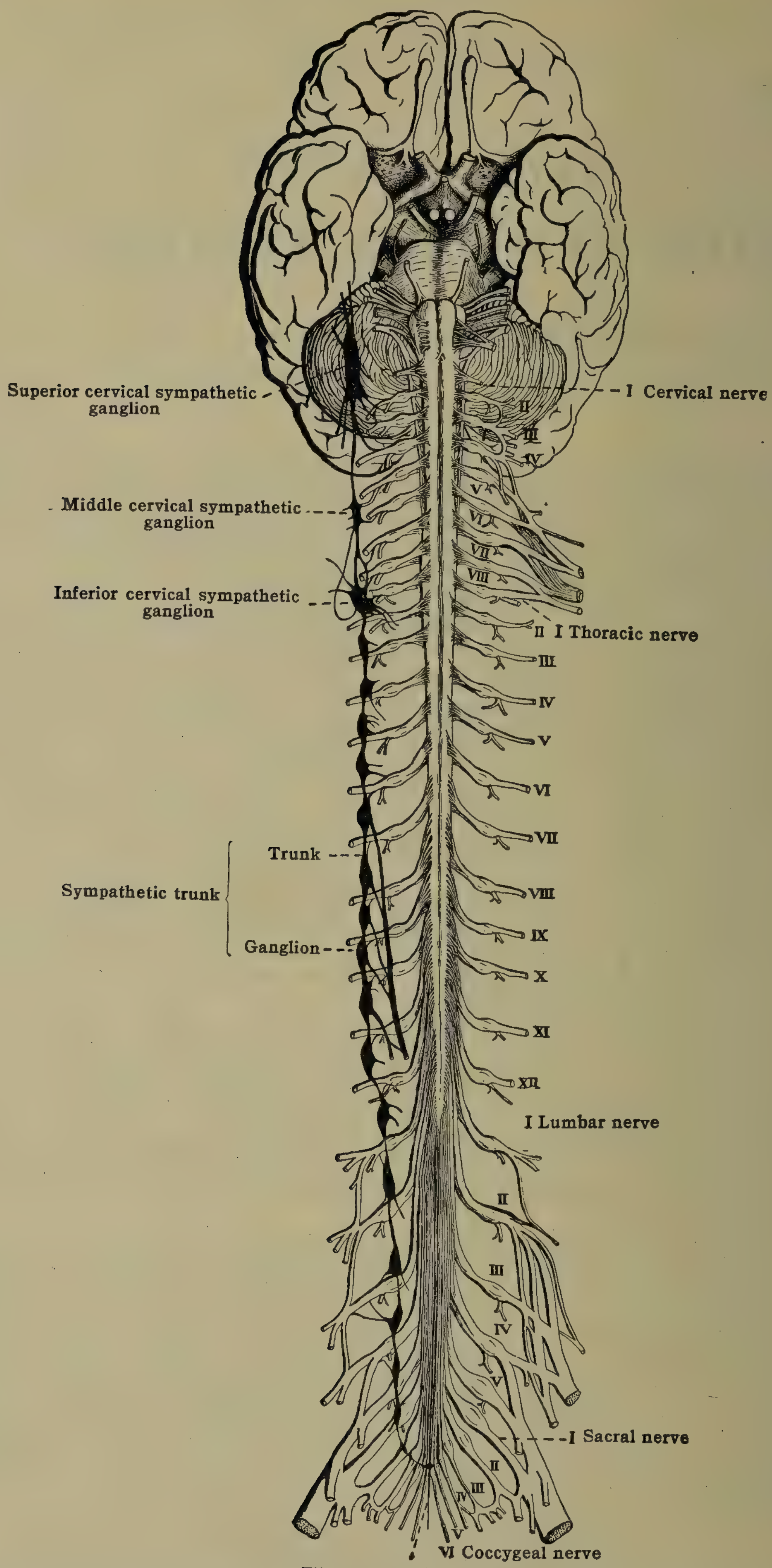


Fig. 673.—Showing the Ventral Aspect of the Central Nervous System, with the Proximal Portions of the Craniospinal Nerves attached and the Relation of the Proximal Portion (Sympathetic Trunk) of the Sympathetic Nervous System. The Encephalon or Brain is Straightened Dorsalward from Position with Reference to the Spinal Cord. The Spinal Ganglia and the Dorsal and Ventral Roots of the Spinal Nerves may be noted.

(Composite drawing in part after Allen Thomson from Rauber—modified.)

(2) The *peripheral nervous system*, composed of—(*a*) The craniospinal nerves, with the organs of special sense and (*b*) the sympathetic nervous system.

All these parts are so intimately connected with each other that the division is purely arbitrary. The craniospinal nerves are anatomically continuous with the central system; their component fibers either arise within or terminate within the confines of the central system, and thus actually contribute to its bulk. The sympathetic system, however, may be more nearly considered as having a domain of its own. By communicating rami, it is intimately associated with the craniospinal nerves and thus with the central system, both receiving impulses from the central system and transmitting impulses to portions of the central structure. But, while its activities are largely under the control of the central system, it is thought possible that impulses may arise in the domain of the sympathetic system and, mediated by its nerves, produce reactions in the tissue it supplies without involving the central system at all. (See myenteric reflexes.) For this reason, as well as because of the structural peculiarities of the sympathetic system, the nervous system is sometimes divided into—(1) the craniospinal system, consisting of (*a*) the central system and (*b*) the craniospinal nerves; (2) the sympathetic nervous system, consisting of (*a*) its various peripheral ganglia and their outgrowths forming its plexuses (sympathetic system proper) and (*b*) efferent fibers arising within the central system and terminating in sympathetic ganglia (visceral efferent or preganglionic fibers). (*c*) These visceral efferent and the sympathetic fibers proper combined are usually referred to as the 'autonomic nervous system.'

Within and closely proximal to the central system or axis are grouped the parent cell-bodies whose processes comprise the nerve-fibers of the craniospinal nerves. Other groups of nerve cell-bodies, distributed in the periphery without the bounds of the central system, give rise to the fibers, nerves and plexuses of the sympathetic proper. Any group of such cell-bodies situated in the periphery, whether belonging to the craniospinal or sympathetic system, is known as a *ganglion*. A group of cell-bodies situated within the central system and giving origin to a given bundle of nerve-fibers is known as a *nucleus*.

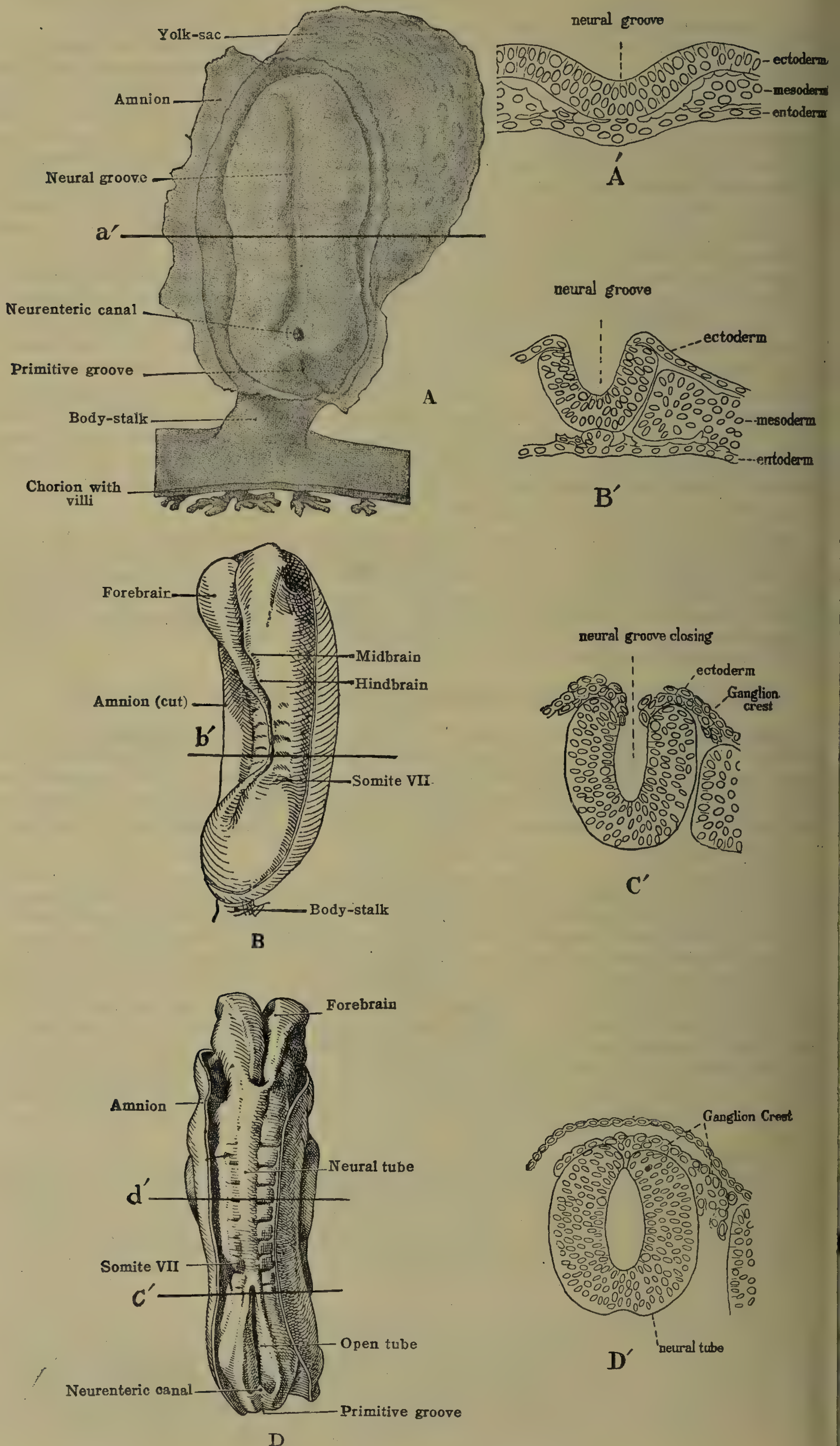
THE DEVELOPMENT OF THE NERVOUS SYSTEM

The essential elements of the nervous system, the nerve cell-bodies and the essential portion of all nerve-fibers, central, craniospinal and sympathetic, develop from one of the embryonic germ layers, the ectoderm, and all, except the olfactory ganglion cells, arise from a given region of that germ layer. Further a portion of the supporting tissue of the nervous system, the neuroglia, is considered as of the same origin.

In its development the nervous system is precocious. It is the first of the functional apparatuses to begin differentiation and is the first to acquire its form. The first trace of the embryo appears on the developing ovum as the *embryonic area*, and the rapidly proliferating cells of this area shortly become arranged into the three germinal layers:—the outer layer or *ectoderm*, the middle layer or *mesoderm*, and the inner layer or *entoderm*. Early in the process of this arrangment there is formed along the axial line of the embryonic area a thickened plate of ectodermal cells, the *neural plate*. In the further proliferation of these cells, the margins of the neural plate, which lie parallel with the long axis of the embryonic area, rise slightly above the general surface, forming the *neural folds*, and the floor of the plate between the folds undergoes a slight invagination, the process resulting in the *neural groove* (fig. 674, A, A′ and B, B′). As development proceeds and the embryonic area assumes the form of a distinct embryo, the neural folds or lips of the groove gradually converge, and beginning at the oral end, finally unite. Thus the groove is converted into the *neural tube*, extending along the dorsal midline and enclosed within the body of the embryo by the now continuous ectoderm above (fig. 674, C′ and D, D′).

For a time the neural tube remains connected with the inner surface of the general ectoderm along the line of fusion by a residual lamina of ectodermal cells. This lamina is known as the *ganglion-crest* (neural crest). It is a product of the proliferation of the ectoderm during the process of fusion, consists of the cells which composed the transition between the closing lips of the original groove and the general ectoderm, and whose fusion aided in the closure of the tube. The ectoderm soon becomes separated from the ganglion crest and the cells of the crest become distinctly differentiated from the cells of the neural tube. The essential elements of the entire nervous system together with the neuroglia are derived from the cells of the neural tube and the cells of the ganglion-crest.

Before the caudal extremity of the tube is entirely closed, its oral end undergoes marked enlargement and becomes distended into three vesicular dilations, the anterior, middle, and posterior primary *brain-vesicles*. The anterior of these primary vesicles gives off a series of secondary vesicles. These are followed by further dilations, flexures of its axis, and by localized thickenings of its walls. The portion of the tube included in the three primary vesicles develops into the encephalon or brain. The remainder of the tube becomes the spinal cord. This latter portion retains the simpler form. By the proliferation and migration laterally of the


Yolk-sac
Amnion
Neural groove
a′
Neurenteric canal
Primitive groove
Body-stalk
Chorion with villi
A
neural groove
ectoderm
mesoderm
entoderm
A′
neural groove
ectoderm
mesoderm
entoderm
B′
Forebrain
Midbrain
Hindbrain
Amnion (cut)
b′
Somite VII
Body-stalk
B
neural groove closing
ectoderm
Ganglion crest
C′
Forebrain
Amnion
Neural tube
d′
Somite VII
c′
Open tube
Neurenteric canal
Primitive groove
D
Ganglion Crest
neural tube
D′

cells lining this portion of the tube, there results a comparatively even, bilateral thickening of its walls so that the mature spinal cord retains a cylindrical form throughout its length.

The proliferating and migrating cells of the wall of the neural tube are known as *germinal cells*. Their cell-boundaries are soon lost and the entire wall becomes a syncytium. The products of their division are apparently indifferent at first, but later they become differentiated into two varieties: (1) *spongioblasts*, or those nuclei which will control the development of neuroglia, and (2) *neuroblasts*, or those which will increase in size, acquire individual cytoplasm, give off processes and become nerve cell-bodies. As described below, the processes given off by a neuroblast are of two general characters: (1) a long process or axone which goes to form nerves, nerve-roots, and nerve-fasciculi, and (2) dendritic processes which are numerous, branch much more frequently and extend but a short distance from the cell-body. An adult cell-body with all its processes is known as a *neurone* and the neuroblasts of the developing system become transformed into the neurones of the varying sizes, shapes, and arrangements of processes

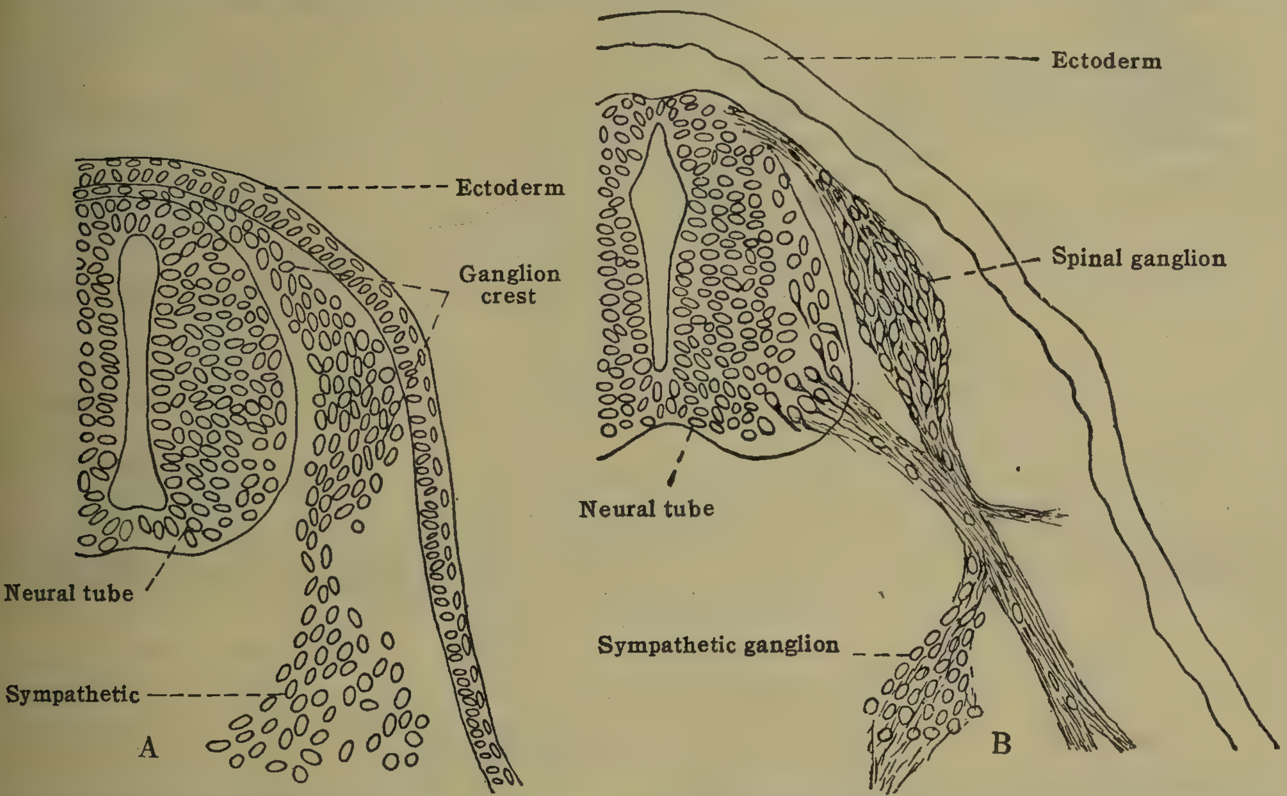


Fig. 675.—Diagrams of Transverse Sections of Embryonic Spinal Cords showing the Migration of the Elements of the Ganglion Crest to form the Spinal and Sympathetic Ganglia and the Origin of the Dorsal and Ventral Roots of the Spinal Nerves.

A, a stage following D′ of fig. 674. B, a later stage in which the ganglia and the components of the nerve are assuming their form resulting from the further migration and from processes being given off by the neuroblasts.

characteristic of different divisions and localities of the nervous system. Usually the first process to be noted is that which will become the axone or nerve-fiber.

Neurones whose cell-bodies belong to the peripheral nervous system are not elaborated within the walls of the neural tube or central nervous system. These, comprising the spinal ganglion neurones and those of the sympathetic system, are derived from the cells of the ganglion-crest. The wedge-shaped lamina of cells, comprising the ganglion-crest, through rapid cell division, gradually extends outward and ventralward over the surface of the neural tube along either side. Soon the proliferation becomes most active in regions proximate to the mesodermic somites or body segments and this activity, together with the stress of the growing length of the body, results in the ganglion-crest (originally a continuous lamina) becoming segmented also. The segments or localized ganglion-masses thus formed are the beginning not only of the spinal ganglia, but also of the ganglia of the entire sympathetic system. The elements of the segmented crest assume a more lateral position, and then occurs a separation of their ranks. A portion of them remain in a dorsolateral position near the wall of the neural tube and develop into the neurones of the *spinal ganglia* (the sensory neurones of the spinal nerves), but others wander further out into the periphery and become the neurones of the

Fig. 674.—Dorsal Surface Views of Human Embryos and Diagrams of Transverse Sections Illustrating the Development of the Neural Tube.

A, dorsal view of human embryo at beginning of infolding of neural plate to form neural groove. Amnion partly removed. (Graf Spee, from Keibel and Mall.) A′, diagram of portion of a transverse section of an embryo as though taken through A at the line a′. B, dorsal view of human embryo of 7 somites, neural tube not yet closed, Mall Collection. (Dandy, from Keibel and Mall.) B′, diagram of portion of a transverse section of an embryo as though taken through B at the line b′. C′, diagram of portion of a transverse section of an embryo as though taken through D at line c′. D, dorsal view of human embryo of 8 somites, 2.11 mm. long, neural tube closed except at caudal end. (Kollmann, from Keibel and Mall.) D′, diagram of a portion of a transverse section of an embryo as though taken through D at line d′.

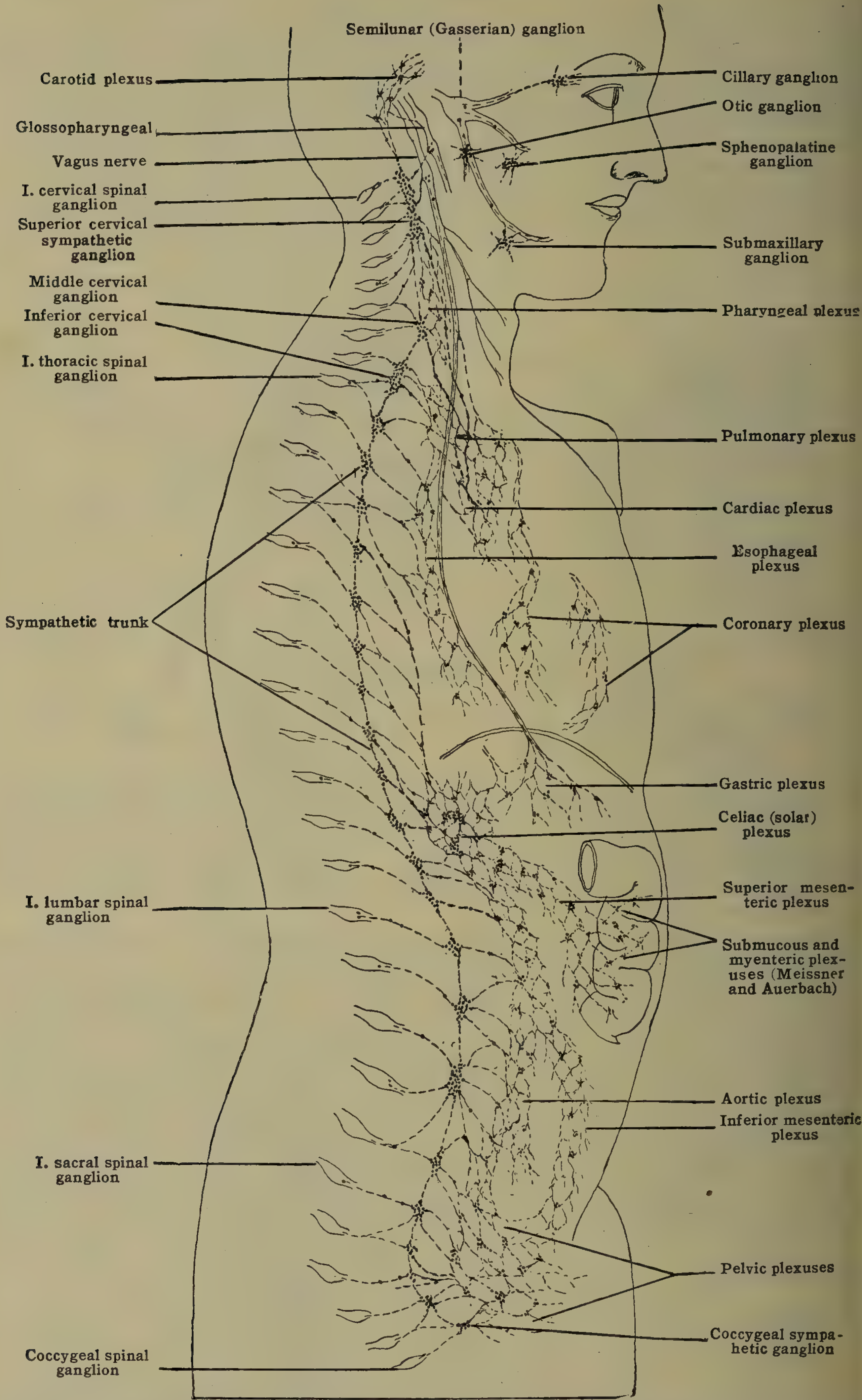


FIG. 676.—DIAGRAM SHOWING THE CHIEF PATHS OF MIGRATION OF THE CELLS FROM THE EMBRYONIC GANGLIA OF THE SPINAL AND CRANIAL NERVES TO FORM THE ADULT SYMPATHETIC SYSTEM. (AFTER SCHWALBE, MODIFIED.)

sympathetic. Certain of those in this more nomadic group settle within the vicinity of the vertebral column and by sending out their processes, form the *sympathetic trunk* or the proximal chain of sympathetic ganglia (vertebral ganglia); others migrate further, but in more broken rank, and become the ganglia of the *prevertebral plexuses* or *collateral ganglia* (as the cardiac, celiac and hypogastric plexuses), or the scattered intermediate chain of ganglia; while still others wander into the very walls of the peripheral organs and occur singly or in groups in such plexuses as those of Auerbach and Meissner, within the tunics of the walls of the alimentary canal. These latter groups comprise the *terminal ganglia* of the sympathetic. Scattered along between these proximal, intermediate, and distal groups there are to be found small straggling

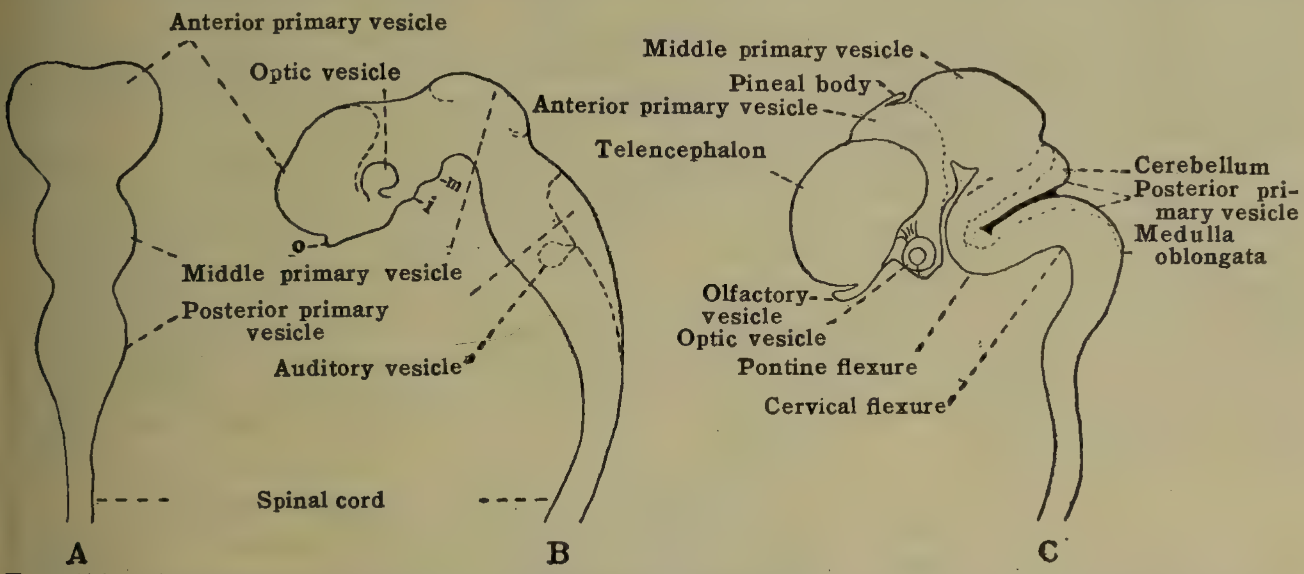


FIG. 677.—DIAGRAMS OF PORTION OF HUMAN NEURAL TUBE SHOWING THE THREE PRIMARY BRAIN VESICLES AND SOME OF THE SECONDARY VESICLES DERIVED FROM THEM.

A, diagram of dorsal view of early stage. B, lateral view at about the third week. C, lateral view at about the eighth week. After His, modified. m, mamillary vesicle; i, infundibular recess; o, olfactory vesicle.

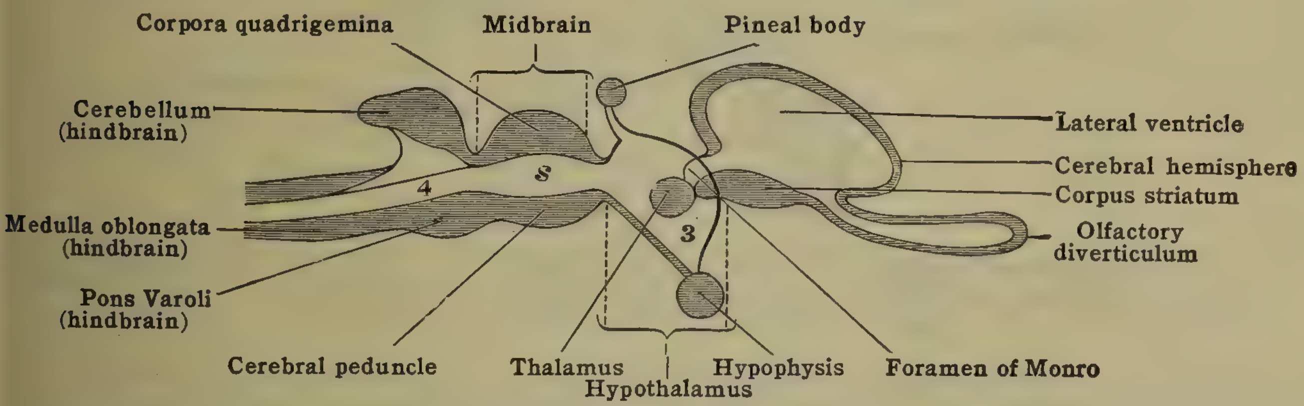


FIG. 678.—DIAGRAMMATIC SAGITTAL SECTION OF A VERTEBRATE BRAIN. (After Huxley.) 4, fourth ventricle; *s*, cerebral aqueduct; 3, third ventricle.

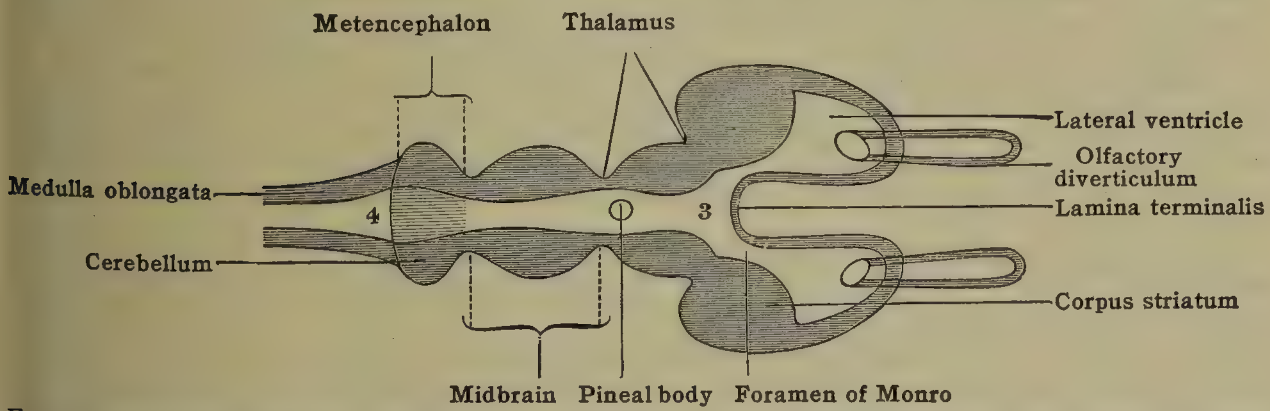


FIG. 679.—DIAGRAMMATIC HORIZONTAL SECTION OF A VERTEBRATE BRAIN. (After Huxley.) 4, fourth ventricle; 3, third ventricle.

ganglia, many of which contain so few cell-bodies that they are indistinguishable with the unaided eye. All these sympathetic neurones, however, are probably directly anatomically associated with and under the control of the neurones of the central system through *visceral efferent fibers* passing to them by way of the rami communicantes or by way of the peripheral distribution of the spinal and cranial nerves. It should be mentioned here that independent or intrasympathetic (myenteric) reflexes are claimed (see Sympathetic System).

The ganglia of the sensory portions of all those cranial nerves attached to the inferior of the three main divisions of the brain and all the sympathetic ganglia of the head have an origin similar to that of the spinal and sympathetic ganglia in the remainder of the body.

The behavior of the walls of the three primary vesicles, into which the oral end of the neural tube is converted, is much more complex than in case of the spinal cord. Their walls do not thicken uniformly and, to give rise to the form of the adult brain, the anterior and the posterior of the three vesicles give off secondary vesicles.

The walls of the posterior primary vesicle give rise to the posterior of the main divisions of the brain, the hindbrain or *rhombencephalon*, the cerebellum developing from the anterior portion only of its dorsal wall, and the medulla oblongata and pons from its ventral wall. Its cavity persists and enlarges into the fourth ventricle of the adult, while the posterior portion of its dorsal wall does not develop functional nervous tissue but persists as a thin roof-membrane known as the *choroid tela of the fourth ventricle*. The cells which form the ganglia of the cochlear and vestibular nerves arise probably from the dorsolateral regions of this vesicle.

From the middle primary vesicle comes the midbrain or *mesencephalon*, the corpora quadrigemina [colliculi] developing from its entire dorsal wall and the *substantia nigra* from its ventral wall, which wall later is also occupied by the *cerebral peduncles*. The constriction between the middle and posterior vesicles becomes the *isthmus* of the rhombencephalon.

The anterior or first primary vesicle undergoes greater elaboration than either of the other two. At an early period it gives off a series of secondary vesicles or diverticula. First, two ventrolateral outpouchings occur, the *optic vesicles*, which later become the optic stalks and optic cups of the embryo. A medial protuberance becomes evident in its anterodorsal wall and from each side of this quickly starts a lateral diverticulum. The two lateral diverticula thus arising from the protuberance are the beginning of the two *cerebral hemispheres* or the *telencephalon*, and the vesicular cavities contained persist as the two *lateral ventricles* of the brain. Soon, each of these vesicular rudiments of the hemispheres gives off ventrally from its anterior part a narrow tube-like diverticulum, each continuous into the larger cavity of the parent primary vesicle. These are the olfactory vesicles which are transformed into the

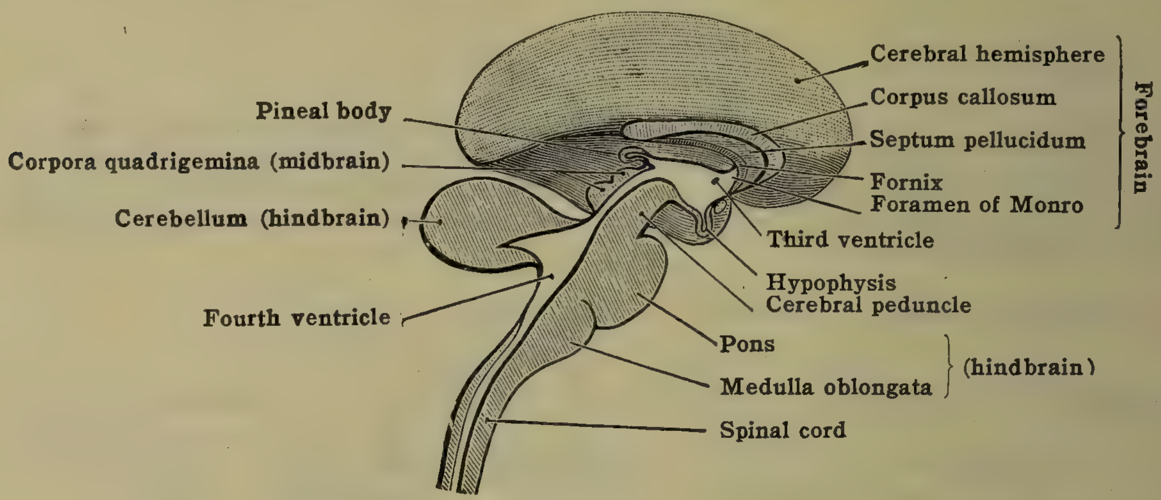


Fig. 680.—Diagram of Mesial Section of the Human Brain showing the Segments and the Flexures and Expansion of the Cerebral Hemispheres over the Other Portions of the Brain. The Olfactory Vesicle and Thalamus are not shown.

olfactory bulbs and *olfactory tracts* of the adult encephalon. (See fig. 677, B. and C.) As development proceeds, the cavities of the olfactory vesicles become occluded in man. However, in many of those animals in which the olfactory apparatus attains greater relative development than in man, these cavities persist as the olfactory ventricles. The cavities of the optic vesicles never persist as ventricles in the adult. They form stalks which represent the future courses of the *optic nerves*, while from their dilated extremities are developed the retinæ, pigmented portions of the ciliary bodies and portions of the iris of the ocular bulbs.

In addition to that which forms the cerebral hemispheres, the remaining portion of the anterior primary vesicle becomes the *diencephalon* or interbrain. The lateral walls of this part of the vesicle thicken to form the *thalami*, the posterior end of its dorsal wall gives off a secondary vesicle which becomes the *pineal body* (*epiphysis*), and from its ventral wall projects the infundibular recess which becomes the posterior lobe of the *hypophysis* with its infundibulum and tuber cinereum.

The adult human brain is characterized by the preponderant development of the cerebral hemispheres. The secondary vesicles forming these expand till, held within the cranial cavity, the hemispheres come to extend posteriorly completely over the diencephalon and the mesencephalon and even overlap the cerebellum to its posterior border. Their cavities, which persist from their origin from the anterior primary vesicle, are correspondingly large (the lateral ventricles) and comprise two of the *four ventricles* of the adult brain. The *third ventricle* becomes a narrow cavity situated between the two thalami. It represents the original cavity of the anterior primary vesicle from which the structures above mentioned arose as secondary vesicles. It remains continuous with the lateral ventricles by the two *interventricular foramina*, known also as the *foramina* of *Monro*, one into each cerebral hemisphere. The *fourth ventricle* of the adult represents the cavity of the posterior primary vesicle and comes to lie between the cerebellum and the pons and medulla oblongata, since the cerebellum likewise extends posteriorly from its region of origin. The cavity of the middle primary vesicle becomes the *cerebral aqueduct*, or aqueduct of Sylvius, passing under the corpora quadrigemina and connecting the fourth or posterior ventricle with the third ventricle of the adult.

Development of the nerve-fibers.—All axones begin as outgrowths or processes of the cytoplasm of neuroblasts. Most of such processes are sent out at a very early stage in the development of the nervous system and extend to the tissues they are to innervate when these tissues

are as yet quite near the neural tube and incompletely differentiated. Then, as the structures of the body elaborate and assume their final forms and positions more remote from the central nervous system, the axones terminating in them must necessarily grow and be drawn out with the structures. At need, later axones are sent out by neurones developing later to supply the growth demands. Such axones follow the general paths made by those already extending to the tissues requiring them. Being processes of the cytoplasm of the cell-body, the growth and life of all axones (and dendrites) is under the control of the nucleus in the cell-body. They grow by absorbing nourishment, or having added to them substances, from the lymph in the tissue stroma through which they pass, which stroma may be either ectodermal or mesodermal in origin.

The great majority of axones in the central nervous system and all in the peripheral system, with the exception of the olfactory nerves, have isolating sheaths about them. The sheath is an acquired structure and is not added till a relatively late period of development. These sheaths are of two general varieties, sheaths consisting merely of a fibrous coat with the nuclei belonging to it, and sheaths in which there has been added a coating of fat or myelin, *medullary sheaths*. A *nerve-fiber* consists of an axone and its sheath whether medullated or non-medullated.

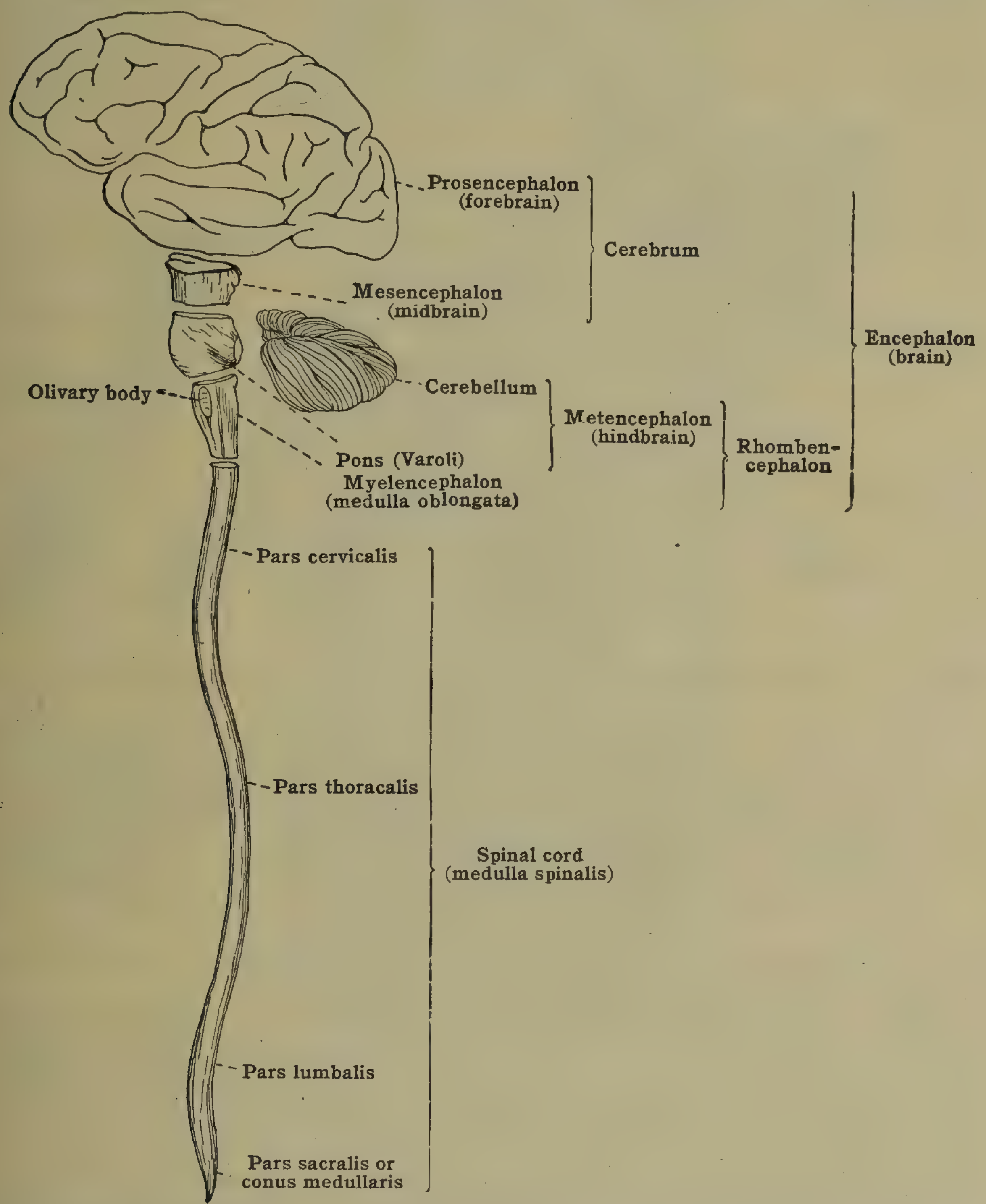


FIG. 681.—DIAGRAM ILLUSTRATING THE GROSS DIVISIONS OF THE CENTRAL NERVOUS SYSTEM.

In the embryo, axones are given off from the developing neurones at a time when the entire ectodermic neural tube and embryonic ganglia and the mesodermic tissue surrounding them are each void of definite cell boundaries, each being a continuous mass of nucleated protoplasm, a *syncytium*. From these syncytia are developed the fibrous connective tissues of the later framework supporting the nervous system. Of this, the fibrous tissue, *neuroglia*, is derived from the ectodermal syncytium, while the white and elastic fibrous tissues are derived from the mesodermal or mesenchymal syncytium. Before any connective tissue fibrils are developed in either syncytium, before and at the time of the ingrowth of blood-vessels into the developing ganglia and the neural tube from the mesenchyme about them, there occurs an invasion of the mesenchymal syncytium into the ectodermal syncytium. This invasion occurs both as inde-

pendent ingrowths and fusions at the periphery of the neural tube and by the mesenchymal tissue being carried in by the ingrowing blood-vessels. After the mixture of the nuclei resulting from this fusion of the syncytia from the two sources, nuclei of mesodermal origin cannot be distinguished from those of ectodermal origin. Further, axones outgrowing from the embryonic ganglia and neural tube carry with them adhering portions of the ectodermal syncytium into the surrounding mesenchymal syncytium (figs. 682, A and 683).

As development proceeds further, each syncytium becomes resolved into a reticulum of granular endoplasmic processes, containing the nuclei, with transparent exoplasm occupying its meshes. Fibers soon form in the exoplasm and from these develop the connective-tissue fibers, whether neuroglia within the central nervous system or mesenchymal fibrous tissue both without and within it. Certain of these fibrils of course surround the axones imbedded among them and from condensations of such fibrils are derived the fibrous sheaths of the axones, the sheath nuclei being acquired from the adjacent nuclei of the original syncytium. These sheaths become more dense or pronounced as the axones extend and the fibrous tissue increases with growth, but there are always present fine marginal fibrils by which the sheaths grade into the looser fibrous tissue about them. It is generally believed that the tissue giving rise to these axone sheaths is of mesodermal origin. However, in amphibian larvæ, Harrison has shown that some sheath nuclei at least are derived from the nuclei of the ectodermal syncytium of the ganglion crest, and Neal has noted in elasmobranchs the fact that nuclei migrate from the ventral wall of the neural tube along with the axones growing out to form the ventral roots of the spinal nerves. Whether all or any of these nuclei are originally ectodermal, and, if so, whether

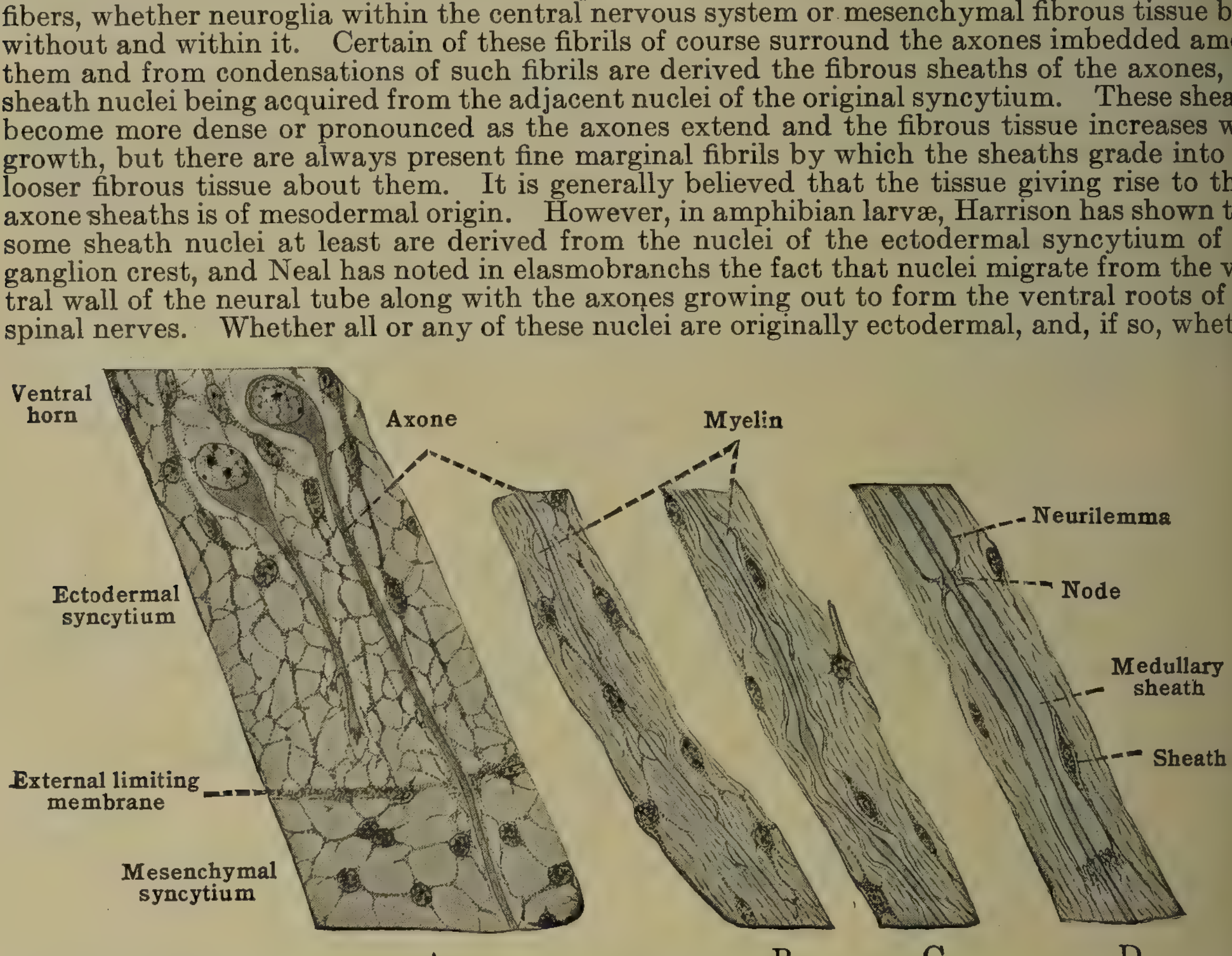


Fig. 682.—Drawings Illustrating the Origin of the Axone and the Development of the Medullary Sheaths.

A, ventral portion of transverse section of an embryonic spinal cord involving a small portion of the future ventral horn and part of the mesenchymal (mesodermal) syncytium outside the external limiting membrane of the cord. B, later stage of ventral root (peripheral) axone with myelin droplets adhering to it and fibrillated stroma surrounding it. C, stage in which myelin droplets, supported by fibrils of stroma, have increased and accumulated to form a practically continuous myelin or medullary sheath. D, final stage with medullary sheath of even thickness, showing a node, and showing a neurilemma, sheath nucleus and fibrous framework of the myelin ('neurokeratin') derived from the fibrils of the original stroma.

such ectodermal tissue gives rise to all axone sheaths, especially in the higher animals, are questionable contentions.

Axones possessing only fibrous sheaths, or none at all, comprise the *non-medullated nerve-fibers*. The majority of the sympathetic fibers are of this variety, and Ranson has found numerous non-medullated fibers present in the spinal and cranial nerves and spinal cord. The general form of non-medullated sympathetic fibers may be seen in fig. 689, C.

Medullated fibers are those which possess an investing coat of fat or myelin in addition to the fibrous sheath. Most of the fibers in the central nervous system and most of those belonging to the craniospinal nerves proper acquire myelin sheaths. Myelin begins to appear upon axones shortly after the beginning development in the syncytium of the fibrils of the fibrous connective tissue, and thus after the beginnings of what will become the fibrous sheaths. The fibrous portions of the sheaths in the central nervous system develop less rapidly and are far more scant than those of the medullated fibers of the peripheral nerves. Probably because of this, it has been claimed that myelin begins to appear on the axones of the central system before the appearance of the fibrous sheath. In man, the first appearance of myelin occurs at about the fourth month, but myelinization is not completed till after birth. The craniospinal nerves contain completely medullated fibers before the central system does.

Myelin first appears as small droplets adhering to the axone at irregular intervals. These droplets increase in size and number and gradually accumulate to form a practically continuous sheath of fat immediately investing the axone. They probably result from the coalescence of finer droplets floating in the surrounding fibrillated stroma. However, collecting upon the axone, the myelin retains the form of an emulsion, and as it increases in amount it incloses the adjacent fibrils which serve as a framework supporting the droplets of the emulsion in its meshes.

Thus supported, the increasing myelin does not inclose the adjacent nuclei and endoplasm of the original syncytium. Probably because of the fibrous support of the myelin thus obtained, medullating fibers may be often seen presenting the beaded appearance shown in fig. 682, C, instead of an even distribution of the emulsion after it has become continuous along the axone. The 'beads' probably reflect the uneven beginning of the accumulation indicated in B of this figure. Increasing further, the myelin becomes a cylinder of even thickness, the adjacent nuclei being pressed away against its surface and the adjacent fibrils also condensed upon it. Thus, there is good reason to believe that the fibrous portion of the sheath, the *primitive sheath* or *neurilemma*, of the medullated axone arises as a condensation of the fibrils of the surrounding stroma during development, that the sheath cells represent certain of the nearest nuclei incorporated from the original syncytium, and that the so-called *neurokeratin* of the myelin

FIG. 683.—CROSS-SECTION OF THE NEURAL TUBE IN AN EMBRYO PIG OF 9 MM. Showing the ectodermal and mesodermal syncytia during the period of their fusion and before the formation of either neuroglia or connective tissue.

represents the fibrous framework of the myelin inclosed by it during its accumulation upon the axone. The theory that the myelin arises as a differentiated portion of the axone and the theory that it is formed by the neurilemma have been advanced. That it is accumulated from already synthesized fat droplets in the immediately surrounding fluid of the stroma and adheres to the axone, added droplets coalescing there, in preference to other tissue elements because of some biotaxic physical or chemical peculiarity of the axone, is more probably correct.

As the medullary sheath approaches completeness, constrictions may be observed at more or less regular intervals at which the myelin emulsion is absent. These are the *nodes of Ranvier.* The process by which they arise is not clearly understood. While the fiber is growing in length, new myelin is added at the nodes. The internodal segments of the sheath increase in length with age, and each segment may possess from one to several sheath nuclei.

In adolescence, fibers whose medullary sheaths are in various stages of completeness may be found both in nerve bundles in the central system and in the craniospinal nerves, and in both, the sheaths of some axones certainly never acquire myelin. Also, in the adult, fibers

whose medullary sheaths present the beaded appearance may be observed, probably repre-senting cases of arrested accumulation of myelin. According to Westphal there is a slight in-crease in the thickness of the sheath with age. Larger axones acquire thicker sheaths of myeli than smaller ones. For the craniospinal fibers, in transverse sections, the area of the section o the medullary sheath averages equal to the area of the section of the axone (Donaldson an Hoke.) Some fibers of the sympathetic system are medullated but in such the myelin sheath i relatively thinner than in the craniospinal system. Beaded sheaths are frequent in sympa-thetic rami, though non-medullated fibers are most abundant.

Fig. 684.—Showing Some of the Varieties of the Cell-bodies of the Neurones of the Human Nervous System, including the Dendrites and Small Portions of the Axones. Axone Sheaths not included.

A. From spinal ganglion. *B*. From ventral horn of spinal cord. *C*. Pyramidal cell from cere-bral cortex. *D*. Purkinje cell from cerebellar cortex. *E*. Golgi cell of type II from spinal cord. *F*. Fusiform cell from cerebral cortex. *G*. Sympathetic ganglion cell. *a*, axone; *d*, dendrites; *c*, collateral branches; *ad*, apical dendrites, axial stem shorter than normal; *bd*, basal dendrites; *p*, peripheral process.

FUNDAMENTALS OF CONSTRUCTION

The functionally mature nervous system consists of peculiarly differentiated essential cell elements held in place by two forms of supporting tissue and supplied with abundant blood-vessels.

The nervous element is distinguished from all other units of the structure of organs in that its cell-body gives off outgrowths or processes of peculiarly great length and characteristic form. Knowledge of the possible lengths and complexity of these processes is comparatively recent and, to include them together with their parent cell-body, which has long been known as the *nerve-cell*, the term neurone is used. The **neurone**, therefore, may be defined as the nerve cell-body with all its processes, however numerous and far reaching they may be. As a class of tissue elements, all neurones possess characteristics distinguishing them from other tissue elements, but the varieties within this class vary greatly. They vary in form both according to function and according to their locality in the nervous system. They vary in different animals, those in the higher animals being more complex in form. Fig. 684 gives illustrations of the external form of the cell-body of a few of the types found in the human nervous system.

The cell-body of the neurone gives off two general types of processes, dendrites and the axone:

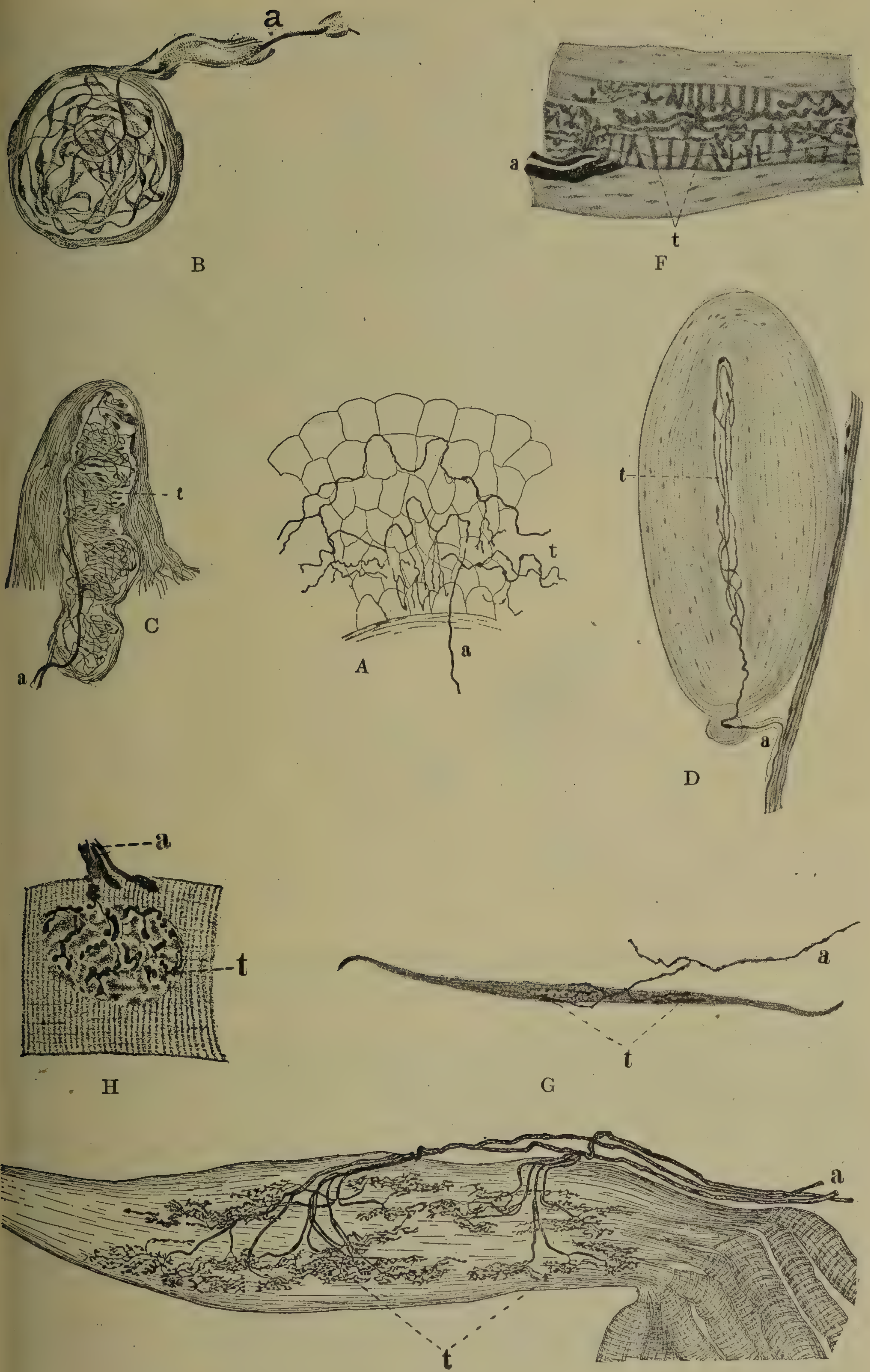


FIG. 685.—SHOWING SOME VARIETIES OF PERIPHERAL TERMINATIONS OF AXONES.

A. 'Free termination' in epithelium (after Retzius). B. Krause's corpuscle from conjunctiva (after Dogiel). C. Meissner's corpuscle from skin (after Dogiel). D. Pacinian corpuscle (after Dogiel). E. Termination upon tendon sheath (Huber and De Witt). F. Neuromuscular spindle (after Ruffini). G. Motor termination upon smooth muscle-fiber. H. Motor 'end-plate' on skeletal muscle fiber (after Böhm and von Davidoff). a, axone; t, telodendria.

(1) The dendritic processes or **dendrites.** These are the more numerous, the shorter, and the more frequently branching processes. They branch dichotomously and with rapid decrease in diameter as they branch. They serve to increase the absorbing surface of the cell-body for purposes of nutrition. Nerve impulses transmitted to the neurone are received by them and, therefore, they also serve to increase the recipient surface of the neurone. They never acquire medullary sheaths. Since they convey impulses toward the cell-body, they are known as *cellipetal processes.* Their absorbing and receptive surfaces are further increased by the presence of thickly placed, very minute projections known as 'pin-head processes' or *gemmules.*

(2) The **axone** (neuraxis). Each neurone possesses properly but one of these processes. It arises from the cell-body more abruptly and quickly becomes smaller in diameter than are most dendrites before the latter decrease by branching. It is the longest process, in most cases very much longer than dendrites. Computation shows that some axones may contain nearly 200 times the volume of the parent cell-body of the neurone. Occasionally the axone gives off a few small branches near the cell-body. These are known as *collaterals* and are given off at practically right angles instead of dichotomously. Regardless of its branching, the axone maintains a practically uniform diameter throughout its long course. Its usual nervous function is to convey the impulses away from the cell-body, either to transmit them to the other neurones by contact upon their dendrites or cell-body proper, or to appropriate elements of the other tissues of the body. Thus the axones are the *cellifugal processes.* There is one well-known partial exception to this, namely, a part of the axone of the spinal ganglion type of neurone, the peripheral sensory neurone. The axone of this bifurcates a short distance from the cell-body into a peripheral and a central branch. See fig. 684, A, and fig. 690. The peripheral branch collects sensory impulses from the tissues of the body, the skin, etc., and, in conveying them to the central system, must necessarily convey them toward the cell-body as far as the point of bifurcation. Thence the impulse goes on in the central branch, still toward the central

Fig. 686.—Schemes showing Two Forms of Synapses or Terminations of Axones upon Cell-bodies of other Neurones.

A. In ventral horn of spinal cord. B. In spinal ganglia.

system but now, in conformity, away from the cell-body of the neurone. While the continued vitality of the axone is dependent upon the cell-body, in the peculiar case of the spinal ganglion neurone the impulse does not necessarily pass through the cell-body. Experiments with the lower animals have shown that the impulses pass in the fiber from the peripheral tissues to the central system when the cell-body has been cut away.

Terminations of axones.—At its final termination, well beyond its collateral branches and usually a considerable length from its cell-body, the axone practically always divides into two or more *terminal branches,* and each of these breaks up, now dichotomously, into numerous terminal twigs. These terminal twigs are known as *telodendria.* Telodendria vary in number and character of form according to the tissues in and upon which they terminate. Functionally, they are of three classes: Those terminating upon and in the other (peripheral) tissues of the body are either (1) *sensory* or (2) *motor.* In order to transmit impulses from one neurone to another, telodendria of the axone of one neurone are placed in contact with the dendrites or cell-body of another neurone forming (3) *synapses.* Upon approaching its termination, every axone loses its sheath, its telodendria being necessarily bare.

Afferent or sensory axones, receiving impulses from the skin or other epithelial surfaces break up into very numerous telodendria each of which terminates directly upon the surface of the epithelial cell, such as the cells of the germinative (Malpigian) layer of the skin or those of its basal or columnar layer. Such telodendria are known as *free terminations.* Free terminations are also to be found in the connective tissues of the body. A second variety of peripheral termination of afferent axones is the *encapsulated form.* These are known as 'end organs' and 'corpuscles' and are named according to their complexity and position. Three of the different forms of them are shown in fig. 685, B, C, and D. These are always situated in fibrous connective tissue from which their capsules are derived. Their most elaborate form is the lamellated or Pacinian corpuscle. Besides the motor axones terminating upon the fibers of voluntary or skeletal muscle, sensory impulses are carried from this tissue and one of

the forms of telodendria for this purpose terminates upon the muscle-fiber. This is known as the 'neuromuscular spindle.' In it, the axone penetrates the sarcolemma and breaks into telodendria which coil spirally about the muscle-fiber. The most extensive and elaborate form of sensory telodendria are those which spread out in plate-form upon tendons sheaths.

Efferent peripheral axones convey impulses to muscle and the secretory cells of glands (secretory axones). The efferent craniospinal axones terminate upon skeletal (voluntary) muscle-fibers and upon the cell-bodies of sympathetic neurones, the axones of which latter terminate upon cardiac muscle, smooth muscle-fibers, and (secretory) in glands. Upon skeletal muscle, the terminal branch of the axone loses its sheath and breaks up into numerous telodendria which themselves branch and show very evident, irregular varicosities, the whole of which spread out in plate-form, and lie in contact with the substance of the muscle-fiber. In man and all mammals, the area covered is usually somewhat oval and is marked by a granular differentiation of the muscle substance. This with the telodendria is known as a *motor end-plate.* The telodendria of sympathetic axones ending upon cardiac and smooth muscle-fibers are fewer and simpler than those of craniospinal axones upon skeletal muscle. They consist of a few fine fibrils, with very small varicosities along them and at their ultimate terminations, which run longitudinally along the muscle-fiber in close relation with its substance. Those upon gland-cells are similar in character except that they often form a loose pericellular plexus about and upon the cell. The varicosities of telodendria are sometimes called *end-feet* and closer study of them has shown that they themselves consist of fine plexuses of the neurofibrils described below as contained in the cell-body of the neurone and extending throughout all its processes. Boek and Agduhr have found that a sympathetic axone may sometimes accompany a craniospinal axone to an end-plate on a skeletal muscle-fiber, presumably serving to maintain muscle tone. Tower claims that these accompanying fibers are not sympathetic.

Synapses.—Every functionally complete nerve pathway consists of two or more neurones arranged in series, a *neurone chain.* Very often, the series consists of many more than two, the impulses being transmitted from neurone to neurone. The axone, bearing the impulse away from the cell-body of one neurone, gives off terminal branches, each of which loses its sheath and breaks up into telodendria which twine themselves upon the dendrites or cell-body of another neurone. The impulse is transferred from one neurone to another by means of contact rather than by embryologically direct anatomical continuity of the parts of the two neurones. Such terminations of axones are known as synapses.

In the terminal arrangement of the telodendria, synapses assume forms varying from compact '*pericellular baskets*' and '*climbing fibers*' to the more open arborizations composed of fewer twigs in simpler arrangements, '*end-brushes.*' In case of the spinal ganglion type of neurone, in the majority of which the cell-body has no dendritic processes, the telodendria of the visiting axone form an anastomosing pericellular plexus inclosing the entire cell-body. This and the simple end-brush form of synapses are illustrated in fig. 686. It should be mentioned that, contrary to the general belief that impulses are transmitted by simple contact of the neurones in the series, it has been claimed that the ultimate twigs of the telodendria frequently penetrate the substance of the receiving cell-body and are fused in continuity. If during the processes of growth such penetration occurs, instead of being an appearance produced by the technique employed, it is better considered as merely an exception to the general rule.

Internal structure of the neurone.—The cell-body of the neurone consists of a large, spherical, vesicular nucleus and a cytoplasm continuous into its axone and dendritic outgrowths. Its nucleus is further characterized by having most usually but one nucleolus, large, spherical and densely staining, situated in a karyoplasm containing otherwise a remarkably small amount of chromatin. Of the cytoplasm, the two most interesting structures are its fibrillar and its granular components.

The **fibrillar structure,** known as the *neurofibrillæ,* represents a growth and elaboration of the spongioplasmic reticulum of the original embryonal cell. The filaments increase in thickness during the development of the neurone, and, in the sending out of its processes, the meshes of the original reticulum become so drawn out in the processes as to give the appearance of a more or less parallel arrangement of threads. The reticular or net-like arrangement is usually more nearly retained in the cytoplasm immediately about the nucleus, since here the stress of the outgrowing processes is less directly applied. In the cell-body of the spinal ganglion type of neurone, when no dendrites are given off, the net-like arrangement is apparent throughout the cytoplasm except in that region giving rise to the axone. On the other hand, in the typical so-called 'pyramidal cell' of the cerebral cortex, from which two chief processes, the axone and the apical dendrite, are given off from opposite poles, the more reticular arrangements about the nucleus if often practically obliterated by the opposing growth stress.

So manifest does the parallel appearance of the neurofibrillæ in the processes often become that it has been interpreted as a series of individual and independent fibrils. In the application of gold chloride and similar methods to the neurones of lower forms, the reduced reagent is often precipitated upon the fibrils in parallel, seemingly independent lines. And, assuming the existence of independent fibrils, it has been contended that the neurone is not the functional unit of the nervous system but is itself composed of numerous functional units, individual fibrils, each for the conduction of nerve impulses. More recent and trustworthy methods, however, show that the neurofibrillæ retain their original reticular form, the threads anastomosing in all planes, and that the meshes of the net may, in the processes, be so drawn in one direction that a parallel appearance predominates. Further, it is now held that the neuroplasm, or the more fluid substance in which the fibrils lie throughout, is capable, and probably fully as capable, of conducting impulses as the fibrils.

Of the **granules** in the cytoplasm, the most interesting are those first described in detail by Nissl. These are the most abundant of those in the cell-body and are known as *tigroid masses* or *Nissl bodies.* They consist of numerous basophilic granules collected into clumps or masses of varying size. They are known to disappear during fatigue of the nervous system and they are more abundant in animals after a period of rest. They are distributed throughout the cytoplasm of the cell-body with the interesting exception that they are not found in the axone nor in

the immediate vicinity of its place of origin from the cytoplasm, leaving a free region known as the *axone hillock*. As accumulated masses, they show characteristic shapes and arrangement which are interpreted as signifying the shapes and arrangement of the spaces or meshes they occupy in the reticulum of the neurofibrillæ. In cell-bodies of the varieties found in the ventral

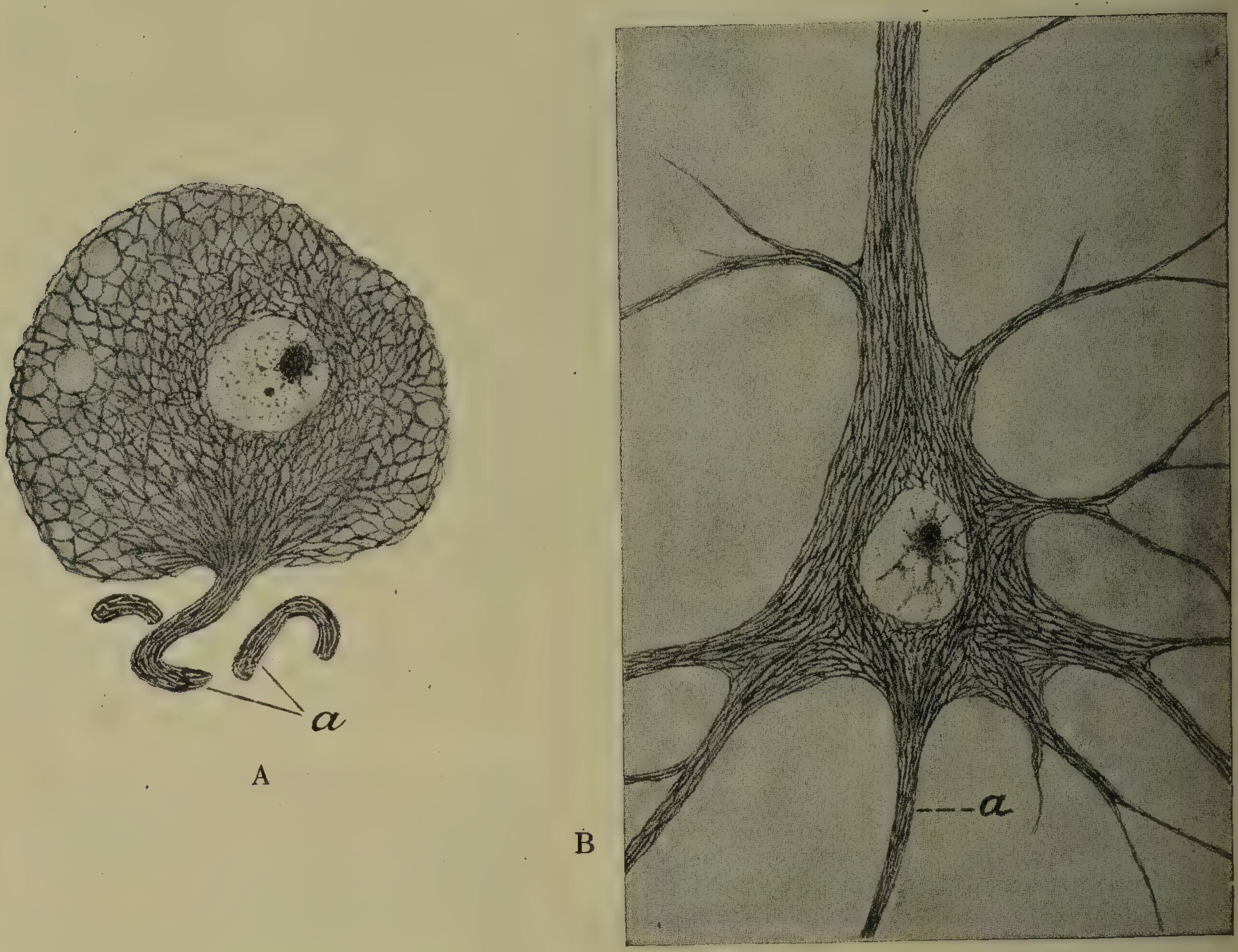


Fig. 687.—Two General Types of Arrangement of Neurofibrillæ in the Cell-bodies of Neurones.

A, cell-body of spinal-ganglion neurone. B, selected 'giant pyramidal cell' from cerebral cortex, human. a, axone.

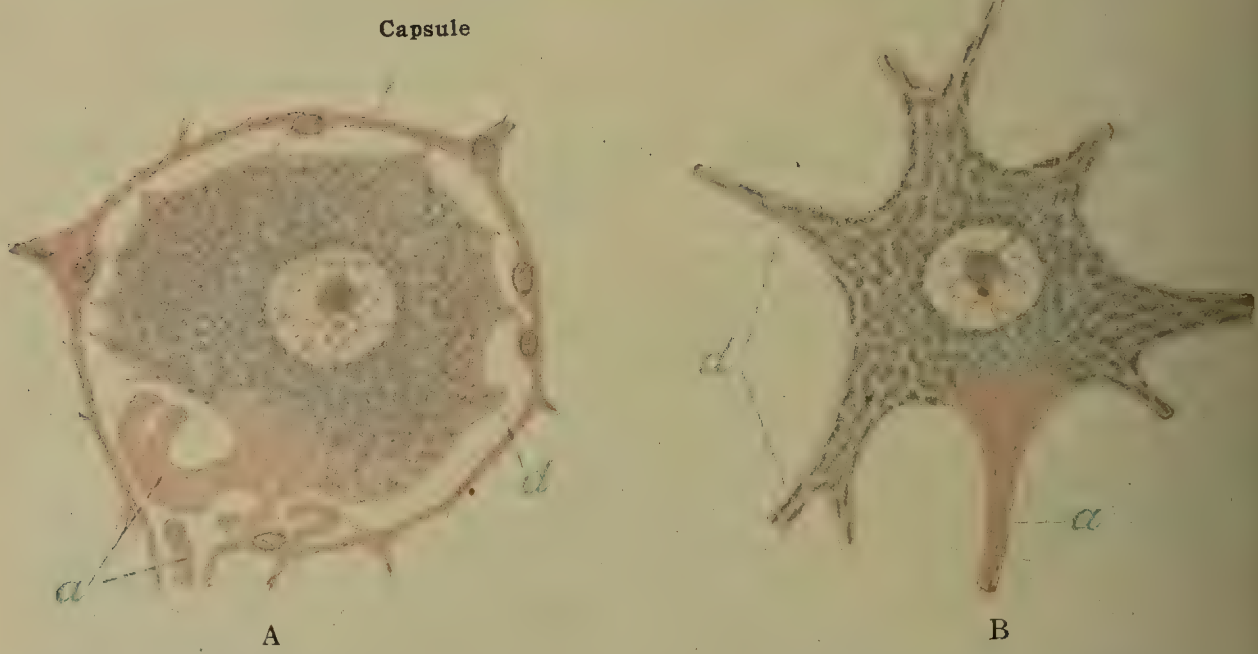


Fig. 688.—Drawings Illustrating the Abundance and General Arrangement of the Tigroid Masses (Nissl Granules) in Cell-bodies of Neurones in Resting Condition.

A, cell-body from spinal ganglion. B, large cell-body from ventral horn of spinal cord. a axone. d, dendrites.

horns of the spinal cord or in the cerebral and cerebellar cortex, for example, the masses situated immediately about the nucleus are smaller, more numerous and of irregular shape. Nearer and in the beginnings of the dendrites, they are larger and mostly of fusiform or diamond shape. Farther out in the dendrites, they become more and more thin and attenuated; and in the distant reaches of the dendrites they are invisible or absent. In the cell-body of the spinal ganglion they are of irregular shape, smaller and more numerous throughout the cytoplasm, being slightly

smaller and more thickly placed in the immediate vicinity of the nucleus. In all neurones several hours postmortem, they appear in fewer and larger masses and it was in this condition that Nissl originally described them in man. Closely examined, the masses of all sizes are found to be accumulations of finer granules. Functionally they are supposed to be of nutritive significance, substances in unstable chemical equilibrium, energy stored in the cytoplasm, capable at need of being split into simpler forms usable in the activities of the neurone. The fact that tigroid masses are absent from the axone hillock, the axone, and the distant reaches of the dendrites may signify that the substance is chiefly present here only in the split and usable form. Also, in the axone especially, the neurofibrillæ are so closely arranged that the meshes of their net here are too small to contain masses of appreciable size. Close examination of the axone hillock and longitudinal sections of the axone in deeply stained preparations usually discloses a few very minute basophilic granules.

A second form of granules described for the neurone is that included within the name, *mitochondria*. These granules are chemically different from the tigroid masses and are thought to be present in all protoplasm, animal and plant. They are considered composed of a phospholipin combined with a small amount of albumin, and, like tigroid masses, to represent a form of stored energy.

Pigment-granules also are found in nerve cells, probably representing an insoluble form of the waste products of the cell metabolism.

Sheaths of the axone.—The great majority of axones acquire sheaths about them which isolate and protect them in their course through other tissues or isolate them from other axones.

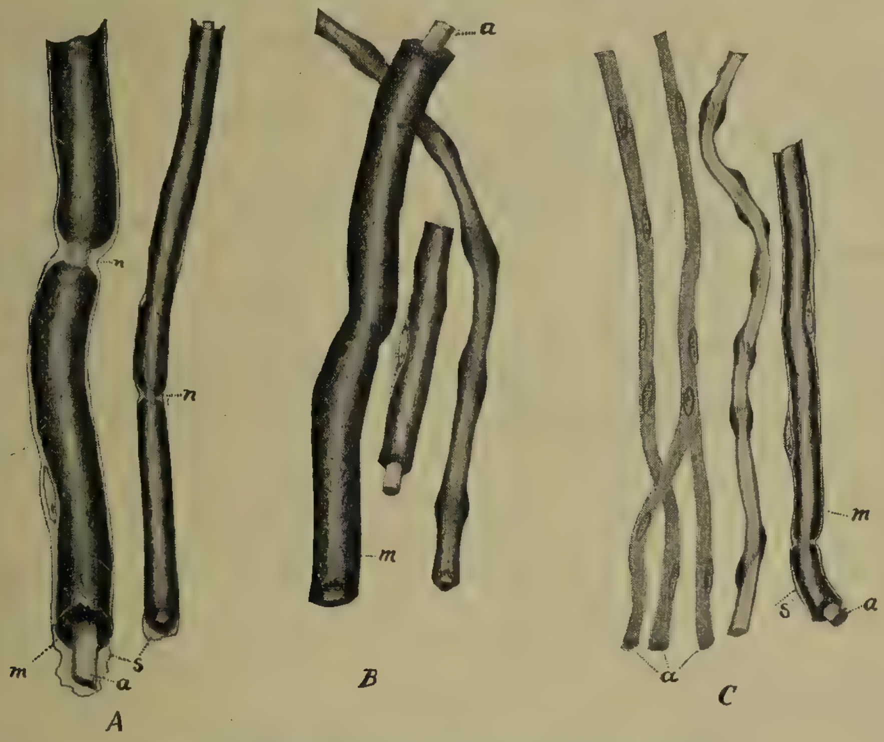


FIG. 689.—SHOWING PIECES OF AXONES.

A. From a craniospinal nerve. *B*. From the spinal cord. *C*. From the sympathetic. *a*. axones; *m*, medullary sheath; *n*, node of Ranvier; *s*, neurilemma or sheath of Schwann with occasional sheath-nuclei.

A *nerve-fiber* is an axone together with its sheaths. In transverse sections, the axone comprises the central portion of the nerve-fiber or its so-called 'axis-cylinder.' It is of course the essential portion of the fiber. As noted above in describing their development, nerve-fibers are classified according to the character of the sheaths. Those which possess sheaths of myelin, a peculiar form of fat, are known as *medullated fibers*, and those in which the sheaths are merely membranes of condensed fibrous tissue, void of myelin, are *non-medullated fibers*. A medullated fiber also possesses a fibrous membrane outside its myelin sheath, known as the *neurilemma* or sheath of Schwann. The neurilemma is of the same origin and general structure as the sheath of the non-medullated fiber, and both possess scattered nuclei of fibroblasts. Medullated fibers, at more or less regular intervals, show constrictions at which the myelin sheath ceases, but over which the neurilemma continues. These constrictions are the *nodes of Ranvier*. The myelin is in the form of an emulsion, whose fat droplets are supported in a fine fibrous reticulum (neurokeratin), while the neurilemma without serves to hold it in place. The neurilemma possesses from one to three or four sheath-nuclei between adjacent nodes of Ranvier.

There is no sharp line of separation between medullated and non-medullated fibers, for in any division of the nervous system there may be found axones in all degrees of medullation. Most of the fibers belonging to the sympathetic system (processes of sympathetic neurones) are non-medullated, but both partially medullated and completely medullated sympathetic fibers may be found. (See fig. 689.) The myelin sheaths of completely medullated sympathetic fibers are always thinner and less well developed than those of medullated craniospinal fibers. Most of the fibers belonging to the craniospinal nerves and to the central nervous system are medullated, but among the fibers belonging to either there are to be found numerous non-medullated fibers. As indicated in fig. 689, nodes of Ranvier are absent in the medullated fibers of the central system.

In all the higher vertebrates, the myelin sheath always begins on the axone a short distance from its parent cell-body. The neurilemma of the medullated and the fibrous membrane of

the non-medullated fiber are each faintly continuous with the fibrous connective tissue surrounding it, and, in the craniospinal and sympathetic ganglia, in which each cell-body of the neurone has a fibrous capsule about it, the fibrous membrane or the neurilemma, as the case may be, is directly continuous into the capsule of the cell-body. Upon approaching its final termination, in other tissues or upon the dendrites or cell-body of other neurones, the nerve fiber always loses its sheath, the telodendria of the axone always being bare when placed in contact with the other element. In losing the sheath, the myelin sheath, if present, always ceases and the fibrous membrane becomes continuous with the tissue investing the receiving element, whether the capsule of the ganglion cell, the sarcolemma of the skeletal muscle fiber, the corium of the skin, or the connective tissue capsule of the encapsulated terminal corpuscle.

The connective tissue of the nervous system is of two main varieties—*white fibrous connective tissue* and *neuroglia.* White fibrous tissue alone supports and binds together the peripheral system, and it is the chief supporting tissue of the central system. As connective tissues, these two varieties are quite similar in structure, each consisting of fine fibrillæ, either dispersed or in bundles, among which are distributed the nuclei of the parent syncytium. In both tissues nuclei of fibroblasts are frequently found possessing varying amounts of cytoplasm which has not yet been sacrificed in producing the essential fibrils.

In addition to its enveloping membranes, the three meninges, which are of white fibrous tissue, the white fibrous tissue supporting the central system within is quite abundant. It is all sent in from without, either as ingrowths of the developing pia mater, the innermost of the

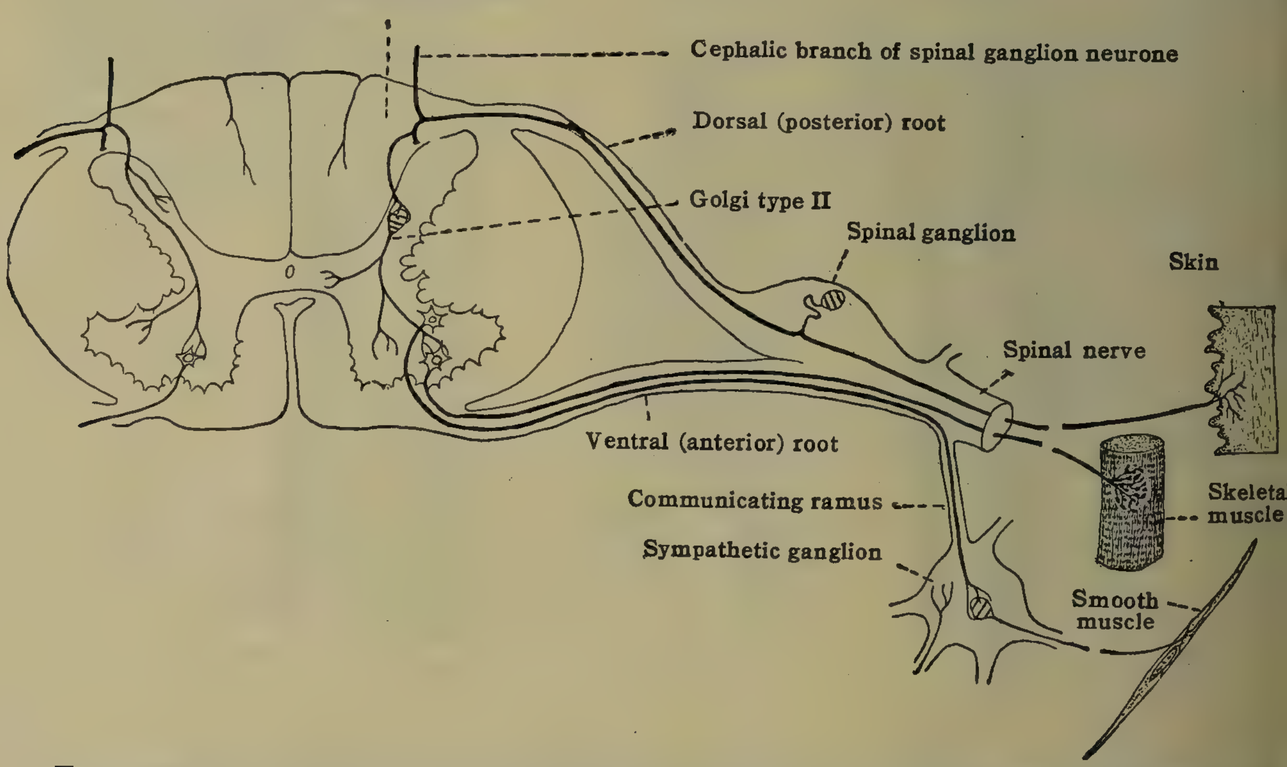


FIG. 690.—DIAGRAM OF TRANSVERSE SECTION OF SPINAL CORD WITH ROOTS OF SPINAL NERVE AND NEIGHBORING GANGLIA ATTACHED, ILLUSTRATING SIMPLEST FORMS OF NEURONE CHAINS. TWO VISCERAL EFFERENT FIBERS ARE SHOWN TERMINATING IN THE SYMPATHETIC GANGLION.

membranes, or is carried in with the blood-vessels, of the walls of which it is an abundant component (fig. 683). The neuroglia as a connective tissue differs from white fibrous tissue in origin and in its chemical or staining properties. Based upon the latter, there are methods of technique by which the two may be distinguished. The epithelioid lining the central canal of the spinal cord and the ventricles of the encephalon, with which the canal is continuous, is the remains of the mother tissue of the neuroglia, and in the adult is the only vestige representing its origin. The cells of this lining are known as *ependymal cells*, and they are usually classed as a variety of neuroglia. They retain in large part the original syncytial form.

Axones, with their medullated or non-medullated sheaths (nerve-fibers) comprise all nerves in the periphery and all nerve tracts in the central system.

White substance [substantia alba] ('white matter') consists of portions of nervous tissue in the central nervous system in which medullated fibers predominate. The myelin sheaths, being in the form of a fat emulsion, reflect the entire spectrum and thus appear white.

Gray substance [substantia grisea] ('gray matter') is an aggregation of nervous tissue in which medullated axones do not so predominate. Thus sympathetic ganglia and sympathetic nerves may be gray, though the term is usually applied to gray portions of the central system, such as the cerebral cortex, the gray column of the spinal cord, etc. Such gray regions contain more cell-bodies of neurones than other regions, though at least half of their volume may consist of neuroglia, white fibrous connective tissue, blood-vessels, and axones of both varieties.

Neurone chains.—As noted above, the numerous neurones comprising the nervous system are functionally and anatomically related to all the other tissues of the body and to each other. A functionally complete *nerve pathway* extends from the tissue in which the nerve impulse is aroused to the tissue in which a resultant reaction occurs. It is known that the simplest possible of such paths necessarily comprises at least two neurones. The great majority involve a greater number. The axone of one neurone bearing impulses from a peripheral tissue transfers the impulses to the dendrites or cell-body of another by synapsis, and the axone of this, in the same way, transfers them to another and so on till the final or efferent neurone receives the impulses and the telodendria of its axone transfer the impulse to the tissue element which reacts in response to the stimulus brought. Neurones are thus linked together in chains. A neurone chain may be defined, therefore, as a number of neurones associated with each other in series to form a functionally complete nerve pathway. Examples of the simplest forms of neurone chains as contained in the spinal cord are illustrated in fig. 690. An impulse aroused in the skin is borne by the spinal ganglion neurone to the spinal cord where, in the left half of the figure, telodendria of one of the terminal branches of its axone form synapses with a neurone in the ventral horn, and the axone of this bears the impulse out of the spinal cord to transmit it probably direct to skeletal muscle. This arrangement involves but two neurones and is supposed to be relatively rare. In the right half of the figure, a third neurone is seen interposed. This is a neurone, numerous in gray substance everywhere, whose axone is relatively short and branches frequently, making possible several synapses in the near neighborhood of its parent cell-body. Its type is referred to as the *Golgi neurone of type II*. This interposed, gives a chain of three neurones between the origin of the impulse in the periphery and the contraction of muscle in response. Simple chains like these can result only in reflex activities and such chains are often called *reflex arcs*. Another chain is indicated in the figure in which the reflex action involves involuntary or smooth muscle. This must involve at least one sympathetic neurone, and, should the Golgi neurone of type II form synapses with the ventral horn neurone involved, the chain is composed of four neurones. In the more extensive and complex neurone chains, such as those in which the impulse from the skin, as above, ascends to the cerebral cortex and the resultant muscular contraction is thrown under cerebral control, each of the several neurones or links in the series is not only referred to by name according to the position of its cell-body, but each is often called according to its order in the series, as 'neurone of first order,' 'second order,' 'third order,' etc.

A given axone may break into a considerable number of branches each of which forms synapses with a different second neurone, or, if peripheral, the telodendria of each branch may terminate upon a separate peripheral tissue element. Thus, a given impulse aroused in a peripheral tissue element may be transmitted to an ever increasing number of neurones, and the initial neurone may comprise the first link in a number of neurone chains. Such is quite general in the structural plan of the nervous system throughout. It is thought possible to consider each neurone interposed in a chain as a separate source of energy, a sort of relay in the nerve path; that the impulse passing through the axone is gradually weakened in overcoming resistance, but, when transferred to another neurone, it incites a splitting into usable form of the substance represented by the tigroid masses and mitochondria and thus a liberation of energy or a reinforcement of the impulse. Further, thus is made possible the economy of one neurone serving as a link in a number of neurone chains.

The axones (nerve-fibers) taking part in the various neurone chains course in bundles of varying size, the larger of which have names. In the central system there is a general tendency with axones of the same function, the same functional direction and the same origin to course in company with each other. A fiber bearing impulses from the peripheral tissues to the central system is an *afferent fiber* or sensory fiber. A fiber bearing impulses out of the central system to peripheral tissues is an *efferent fiber* or motor fiber. Efferent fibers which bear impulses to skeletal muscle are known as *somatic efferent fibers*, while those which terminate upon the cell-bodies of sympathetic neurones and thus bear impulses destined for smooth muscle, cardiac muscle and glands (secretory) are *visceral*, or *splanchnic*, *efferent fibers*.

A nerve is a closely associated aggregation of parallel nerve-fibers coursing in the *periphery*. It may be spinal, cranial or sympathetic according to its attachment or according to the origin of the majority of its fibers. It may contain several functional and structural varieties of fibers. The spinal nerves contain all structural varieties. **Nerve-roots** are those bundles of fibers which join to form a nerve. Most of the cranial nerves have but one root. Nerve-roots, in their turn, are formed by the junction of smaller *root-filaments*. *Nerve-branches* result from the divisions of the nerve, the separation of its component fibers into separate bundles. Some branches are of sufficient size and significance to be called nerves and given separate names. The smaller branches are called *rami*, twigs, etc.

In the *central system*, a given bundle of fibers of similar origin and functional direction is called a **fasciculus**, while two or more adjacent fasciculi coursing parallel with each other, but often of different origins and functional directions, comprise a **funiculus**, a bundle of bundles. The central nervous system is bilaterally symmetrical throughout its length. Bundles of fibers arising from cell-bodies situated on either side and crossing the mid-line transversely and within the level of their origin to terminate in the opposite side form a **commissure.** The commissures vary greatly in size and contain fibers crossing in both directions. Even scattered fibers which so cross the mid-line are called *commissural fibers*. In distinction, companion bundes of fibers of the same origin, functional direction and significance which arise and course one on either side of the mid-line and then cross the mid-line to terminate in levels different from the levels of their origin are said to *decussate* and their crossing is known as a **decussation.** In further distinction from commissures, the direction of the crossing in decussations usually is oblique rather than transverse. Fibers of varying length, arising from cell-bodies situated in one locality of the central system which do not cross the mid-line, but terminate in other localities of the same side, above and below the level of their origin or in a different region of the same level, form **association fasciculi.** The shortest association fasciculi, largely confined within the bounds of a given division of the central system, are known as **fasciculi proprii.**

The cell-bodies of neurones whose axones go to form certain nerve roots, fasciculi and certain commissures show a tendency to accumulation in localized masses. In the *peripheral* system, such an accumulation of cell-bodies is known as a ganglion; in the *central system* such is distinguished as a **nucleus.** Thus, there are the *sympathetic ganglia* which give rise to sympathetic nerves and sympathetic roots of nerves; and on the beginning of each spinal nerve there is a *spinal ganglion* which gives rise to the afferent fibers of its dorsal root and in its nerve trunk. There are *ganglia of* the *cranial nerves* which give rise to the afferent or sensory axones in them and which are of the same significance as the spinal ganglia. Every ganglion, therefore, has connected with it bundles of nerve-fibers. Some of these fibers bear impulses from the central system and transfer them to the cell-bodies of the ganglion; others arise from the cell-bodies in the ganglion and bear impulses to the central system or, in case of the sympathetic, to the tissues of the peripheral organs. Necessarily, the larger the ganglion, the larger will be the bundles of fibers connected with it.

Nuclei may be considered in two general classes: (1) Recipient nuclei or nuclei of termination, and (2) Nuclei of origin. (See fig. 691.)

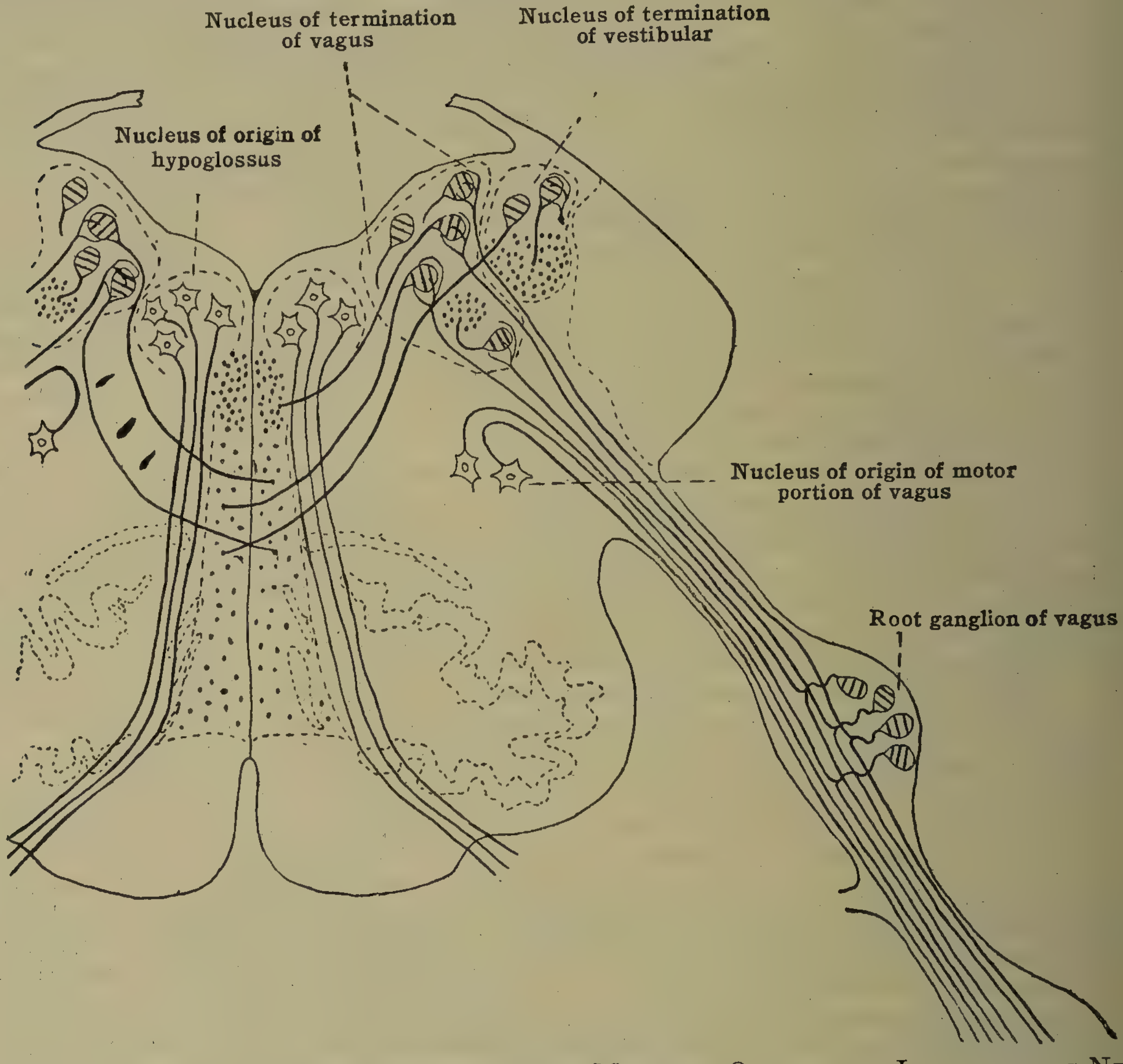


Fig. 691.—Diagram of Transverse Section of Medulla Oblongata, Illustrating Nuclei of Termination and Nuclei of Origin.

A nucleus of termination is an accumulation of cell-bodies in which the axones of a given fasciculus or of a nerve-root terminate, that is, cell-bodies which, by synapses, receive the impulses borne by the terminating axones. In most cases the impulses transferred to a nucleus so named are sensory in character. The nucleus may be considered as a defined region in which neurones of the next order are interpolated in a given nerve pathway or system of neurone chains. Fasciculi in the spinal cord which bear impulses to the brain have their terminal nuclei chiefly in the medulla oblongata and thalamus, and the sensory or afferent axones of the cranial nerves find their nuclei of termination upon entering the central system.

A nucleus of origin is an accumulation of cell-bodies of neurones which give origin to the axones going to form a given nerve-root or a fasciculus. Strictly speaking, a nucleus of termination for one nerve-tract is the nucleus of origin for another, the next link in the neurone chain. However, the term is commonly used to distinguish a group of cell-bodies giving rise to a motor nerve tract. Thus each motor cranial nerve has its nucleus of origin within the central system. The gray substance of the spinal cord is in the form of a column continuous throughout the length of the cord and so the cell-bodies in the ventral horns of this column which give rise to the motor or efferent roots of the spinal nerves are not considered as grouped into nuclei of origin, one for each of the motor roots.

The dorsal root of each spinal nerve is afferent or sensory in function and its axones arise as processes of cell-bodies comprising the spinal ganglion of the nerve. The afferent or sensory fibers of the cranial nerves arise as processes of cell-bodies comprising the ganglia of the cranial nerves, which ganglia are, in development and character, with the exception of the optic and olfactory, exactly homologous to the spinal ganglia.

The **ventral root** of each spinal nerve is efferent or motor in function and its fibers arise as processes of cell-bodies situated in the ventral horn of the gray substance of the spinal cord. The efferent or motor fibers of the cranial nerves arise as processes of cell-bodies accumulated as nuclei of origin in the gray substance of the encephalon, and homologous with those cell-bodies of the ventral horns of the spinal cord which give origin to the ventral-root fibers.

The general relation of the cerebrum (which includes the mesencephalon) to the remainder of the nervous system is a *crossed relation.* Neurone-chains from the general body to the cerebrum, via the spinal nerves and cord and via the cranial nerves and medulla oblongata and pons of one side, cross the mid-line to terminate in the opposite side of the cerebrum. Axones, and neurone chains, arising in response in one side of the cerebrum, likewise nearly always decussate in descending to terminate in the respective regions of the opposite side.

Many of the **names** given nervous structures, prior to 1850 especially, instead of suggesting something of their functional or anatomical significance, indicate nothing more than active imaginations for accidental resemblances between the various structures of the nervous system and objects in ordinary domestic environment. Also, quite often the name given a structure is merely the name of some anatomist associated with it. The much needed elimination of these old non-descriptive names is proving a very slow process. Attempts have often increased the difficulty by making necessary the use of several names for a given structure instead of one. The most recent and concerted attempt, the nomenclature known as the BNA (anatomical names chosen by a commission appointed for the purpose which convened in Basle in 1895), has been adopted by modern text-books. It is here used in the form of the English equivalents of the Latin terms, except in cases of those Latin terms which have become so commonly used as to be considered words incorporated into the English language. The BNA has retained many of the old names and, since a name should indicate something of the locality and significance of the structure to which it is applied, it is not yet wholly satisfactory throughout. In applying the names of a few fasciculi, the BNA in the following pages is slightly modified by so compounding the name that the first word in the compound indicates the locality of origin of the faciculus and the second, the locality of its termination. Thus, '*Dorsal spinocerebellar fasciculus*' indicates the more dorsally coursing of the fasciculi which arise from cell-bodies in the spinal cord and terminate in the cerebellum. This principle applies to many of the BNA names without change, as '*lateral cerebrospinal fasciculus.*' Some changes recommended by the NK are also indicated.

THE CENTRAL NERVOUS SYSTEM

The central nervous system [systema nervorum centrale], or organ, is an aggregation of nuclei, fasciculi and commissures—a large axis of gray and white substance—situated in the dorsal midline of the body, and the bundles of fibers connecting it with the tissues of other systems and with the peripheral ganglia are of necessity correspondingly large. So numerous are the axones connecting it and so intimately are its neurones associated that a disturbance affecting any one part of the system may extend by way of its neurone chains to influence all other parts. The enlarged cephalic extremity of this central axis, the brain or **encephalon,** is a special aggregation of nuclei and masses of gray and white substance, many of which are much larger than any found in the peripheral system.

In the study of the central nervous system its enveloping membranes or meninges are met with first, and logically should be considered first, but since a comprehensive description of these membranes involves a foreknowledge of the various structures with which they are related, it is more expedient to consider them after making a closer study of the entire system they envelop.

For convenience of study, the central nervous system is separated into the gross divisions, spinal cord and brain (encephalon) as illustrated in figure 691. Each of these divisions will be subdivided and considered with especial reference to its anatomical and functional relations to the other divisions and to the interrelations of its component parts.

I. THE SPINAL CORD

The spinal cord [medulla spinalis] is the lower (caudal) and most attenuated portion of the central nervous system. It is approximately cylindrical in form and terminates conically. Its average length in the adult is 45 cm. (18 in.) in the male and 42 cm. in the female. Divested of its outer meninges, it weighs from 26 to 28 grams or about 2 per cent. of the entire central nervous system.

After birth it grows more rapidly and for a longer period than the encephalon, increasing in weight more than sevenfold, while the brain increases less than half that amount. Its specific gravity is given as 1.038.

The line of division between the spinal cord and the medulla oblongata is arbitrary. The outer border of the foramen magnum is commonly given, or, better, a transverse line just below the decussation of the pyramids. Lying in the vertebral canal, the adult cord usually extends to the upper border of the body of the second lumbar vertebra. However, cases may

be found among taller individuals in which it extends no farther than the last thoracic vertebra. With increase in stature, its actual length increases, but the extent to which it may descend the vertebral canal decreases. Up to the third month of intrauterine life it occupies the entire length of the vertebral canal, but owing to the fact that the vertebral column lengthens more rapidly and for a longer period than does the spinal cord, the latter, being attached to the brain above, soon ceases to occupy the entire canal. At birth its average extent is to the caudal margin of the body of the second lumbar vertebra.

External Morphology of the Spinal Cord

In position in the body, the spinal cord conforms to the curvatures of the vertebral canal (fig. 681). In addition to the bony wall of the vertebral canal, it is enveloped and protected by its three membranes or meninges, which are continuous with the like membranes of the encephalon: first, the **pia mater,** which closely invests the cord and sends ingrowths into its substance, contributing to its support; second, the **arachnoid,** a loosely constructed, thin membrane, separated from the pia mater by a considerable **subarachnoid space**; third, the **dura mater,** the outermost and thickest of the membranes, separated from the arachnoid by merely a slit-like space, the **subdural space.**

The intimate association of the central system with all the peripheral organs is attained chiefly through the spinal cord, and this is accomplished by means of thirty-one pairs of spinal nerves, which are attached along its lateral aspects. The nerves of each pair are attached opposite each other at more or less equal intervals along its entire length, and in passing to the periphery they penetrate the meninges, which contribute to and are continuous with the connective tissue sheaths investing them. Each nerve is attached by two roots, an afferent or **dorsal root,** which enters the cord along its posterolateral sulcus, and an efferent or **ventral root,** which makes its exit along the ventrolateral aspect.

With its inequalities in thickness and its conical termination the spinal cord is subdivided into four parts or regions:—(1) The **cervical portion,** with eight pairs of cervical nerves; (2) the **thoracic portion,** with twelve pairs of thoracic nerves; (3) the **lumbar portion,** with five pairs of lumbar nerves; and (4) the **conus medullaris,** or sacral portion, with five pairs of sacral and one pair of coccygeal nerves. From the termination of the conus medullaris, the pia mater continues below in the subarachnoid space into the portion of the vertebral canal not occupied by the spinal cord, and forms the non-nervous, slender, thread-like terminus, the *filum terminale.* This becomes continuous with the dura mater at the lower extremity of the filum.

In the early fetus the spinal nerves pass from their attachment to the spinal cord outward through the intervertebral foramina at right angles to the long axis of the cord, but, owing to the fact that the vertebral column increases considerably in length after the spinal cord has practically ceased growing, the nerve-roots become drawn caudad from their points of attachment, and, as is necessarily the case, their respective foramina are displaced progressively downward as the termination of the cord is approached, until finally the roots of the lumbar and sacral nerves extend downward as a brush of parallel bundles considerably below the levels at which they are attached. This brush of nerve-roots is the **cauda equina.** The dura mater, being more closely related to the bony wall of the canal than to the spinal cord, extends with the vertebral column and thus envelops the cauda equina, undergoing a slightly bulbous, conical dilation which decreases rapidly and terminates in the attenuated canal of the coccyx as the coccygeal ligament [filum duræ matris spinalis] (fig. 692).

The enlargements.—Wherever there is a greater mass of tissue to be innervated, the region of the nervous system supplying such must of necessity contain a greater number of neurones. Therefore, the regions of the spinal cord associated with the skin and musculature of the regions of the superior and inferior limbs are thicker than the regions from which the neck or trunk alone are innervated. Thus in the lower cervical region the spinal cord becomes broadened into the *cervical enlargement,* and likewise in the lumbar region occurs the *lumbar enlargement.* The spinal nerves attached to these regions are of greater size than in other regions.

The **cervical enlargement** [intumescentia cervicalis] begins with the third cervical vertebra, acquires its greatest breadth (12 to 14 mm.) opposite the lower part of the fifth cervical vertebra (attachment of the sixth cervical nerves), and

extends to opposite the second thoracic vertebra. Unlike the lumbar enlargement, its lateral is noticeably greater than its dorsoventral diameter.

The **lumbar enlargement** [intumescentia lumbalis] begins gradually with the ninth or tenth thoracic vertebra, is most marked at the twelfth thoracic vertebra

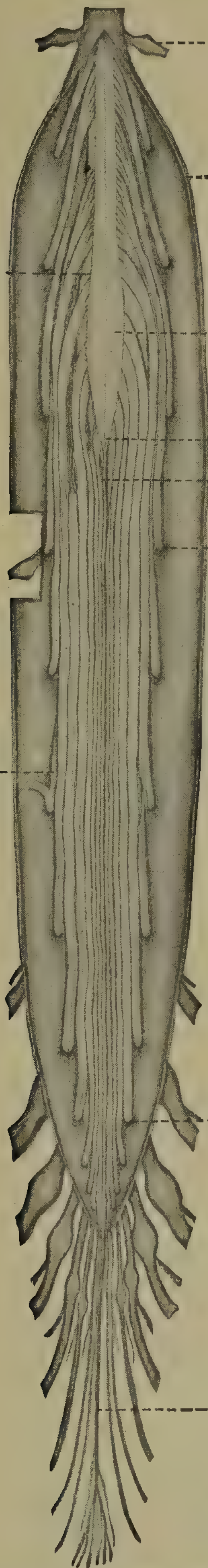


Fig. 692.—Drawing from Specimen Showing Cauda Equina, the Roots of Certain of the Spinal Nerves which Form it, and its Accompanying Dura Mater. (Dorsal aspect.)

(attachment of the fourth lumbar nerves), and rapidly diminishes into the conus medullaris.

Both the lumbar and thoracic regions are practically circular in transverse section. Neither diameter of the lumbar is ever so great as the lateral diameter of the cervical enlargement.

The thoracic part attains its smallest diameter opposite the fifth and sixth thoracic vertebra (attachment of the seventh and eighth thoracic nerves).

The enlargements occur with the development of the upper and lower limbs. In the embryo they are not evident until the limbs are formed. In the orang-utan and gorilla the cervical enlargement is greatly developed; the ostrich and emu have practically none at all.

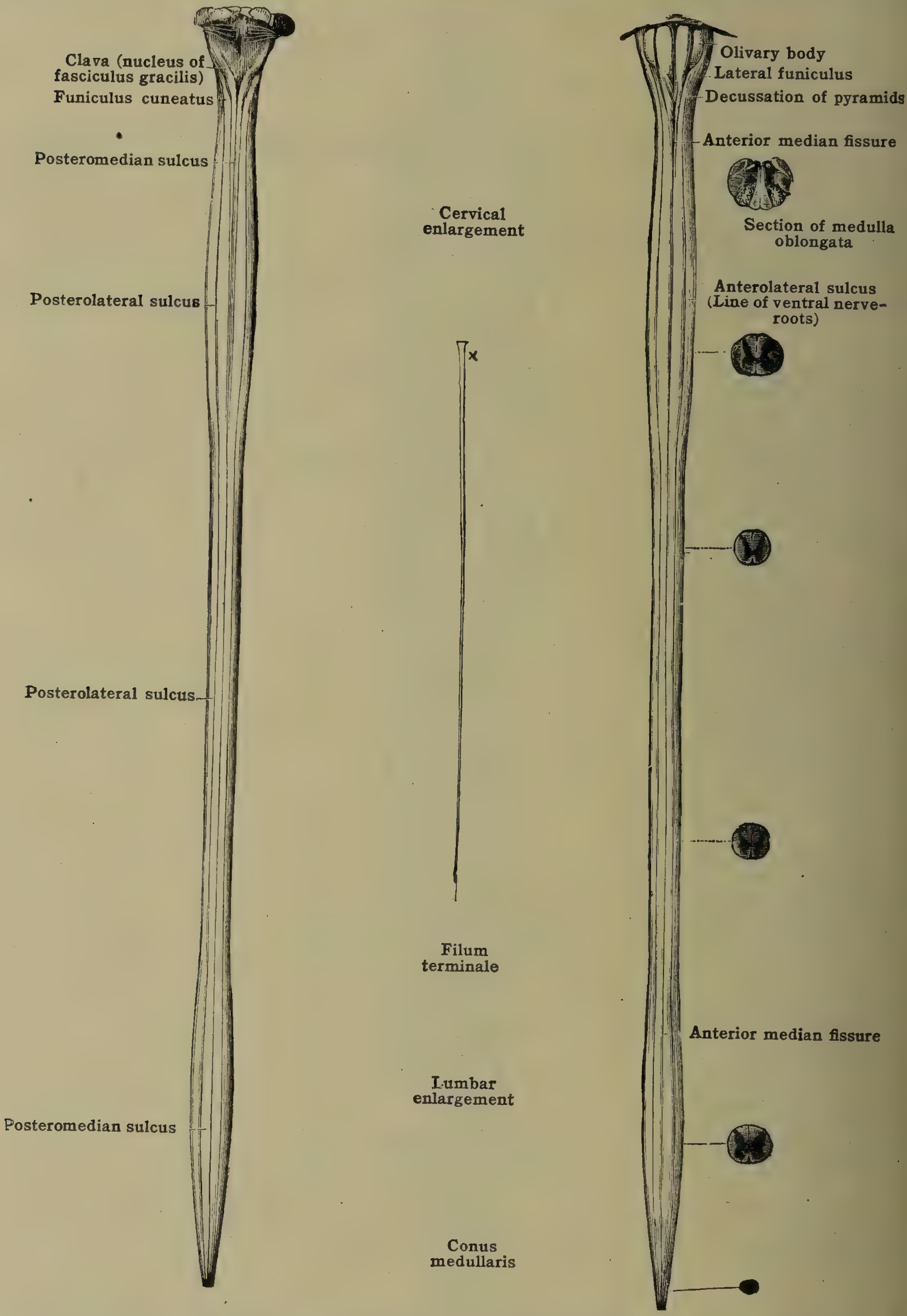


FIG. 693.—POSTERIOR AND ANTERIOR VIEWS OF THE SPINAL CORD. (Modified from Quain.)

Protection of the spinal cord.—The chief provisions for protection of the cord are the bony walls of the vertebral canal, the meninges of the cord, the curvatures of the vertebral column, and the fact that the vertebral canal in which the cord lies is of much greater diameter than the cord and is filled with a cushion of cerebrospinal fluid. The parts of the vertebral column most exposed to injury are the cervical and the lumbar regions—regions joining less mobile parts, the head and pelvis. The cervical region is especially affected by violence exerted on the

head and also the lumbar region because of the amount of leverage exerted on that part. The protective bony wall of the canal consists of a number of separate bones with joints which allow movement in all directions without serious weakening. The bones are of the spongy variety, allowing crushing of parts without fracture of the whole. The curvatures of the vertebral column, cervical, thoracic and lumbar, and the cushion structure of the intervertebral disks all serve to damp vibrations and absorb jars. The very tough dura mater with its subdural space filled with fluid holds the cord suspended in a voluminous sack which is firmly fixed in position (1) by fusion at the foramen magnum with the internal periosteum of the cranium, (2) by adherence along its ventral aspect to the internal periosteum of the vertebral canal, and (3) by being anchored caudally through the coccygeal ligament. Further the cord is slung laterally by the ligamenta denticulata, processes of the dura attached to the closely investing pia of the cord, and by the dural sheaths of its thirty-one pairs of spinal nerves, which sheaths also are continuous with the periosteum in the intervertebral foramina. (See meninges of the spinal cord.)

Surface of the spinal cord.—The cord is separated into nearly symmetrical right and left halves by the broad **anterior median fissure** into which the pia mater is duplicated, and opposite this, on the dorsal surface, by the **posterior**

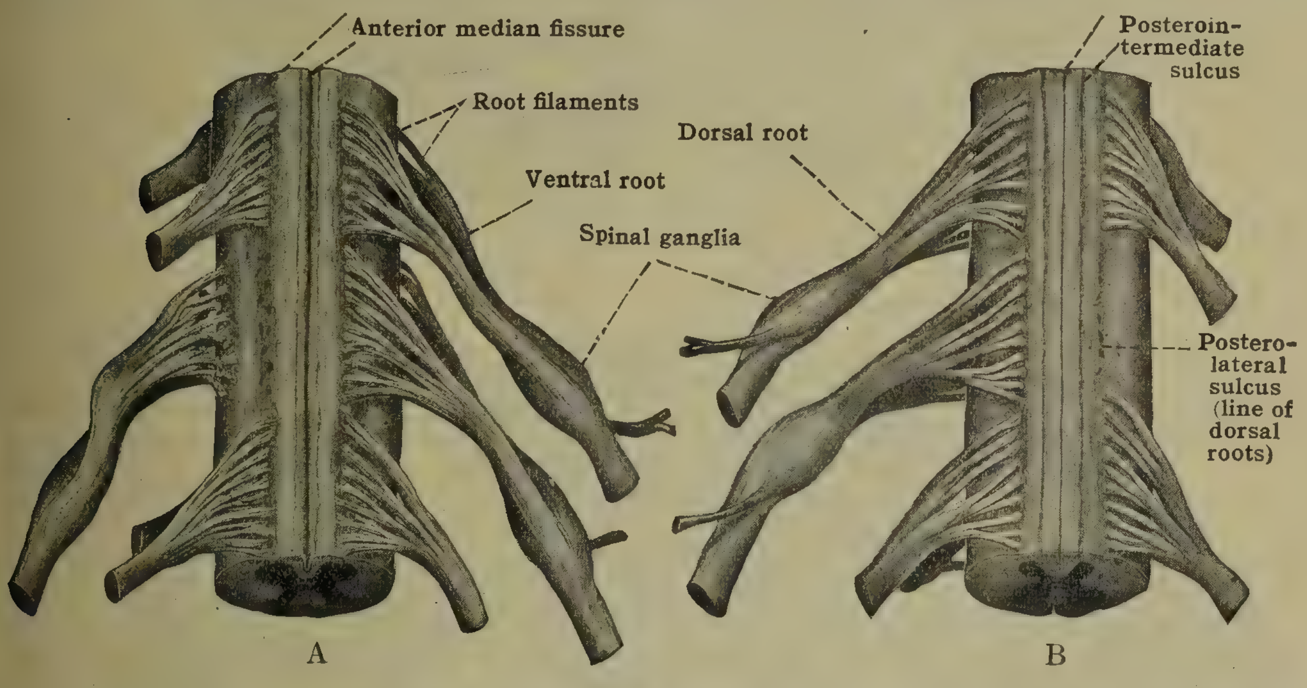
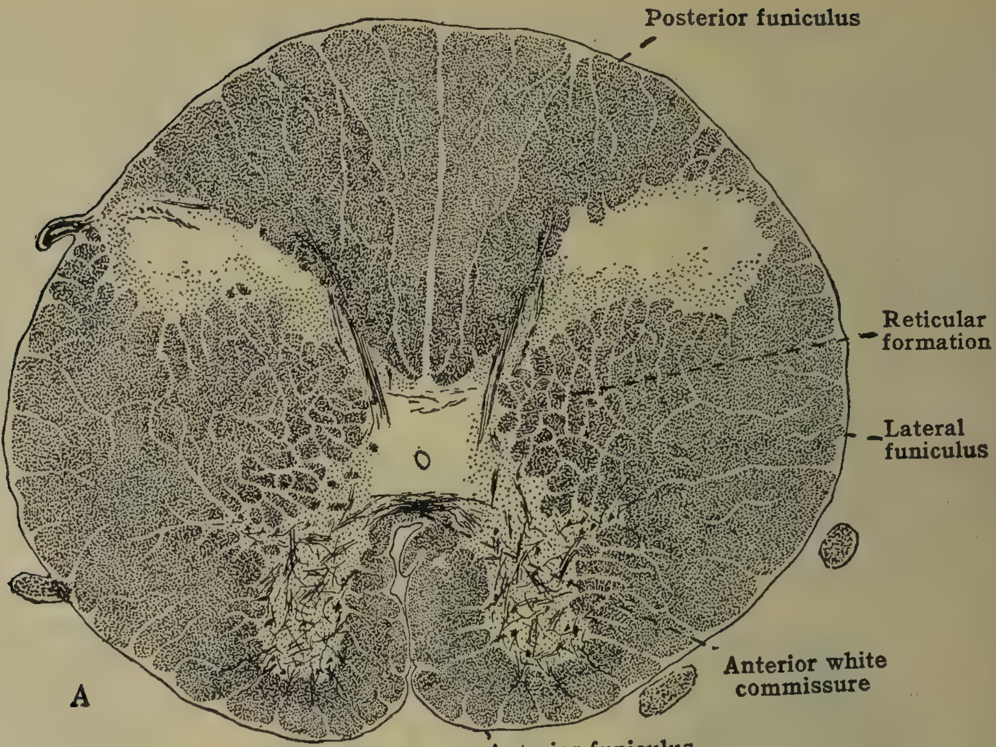


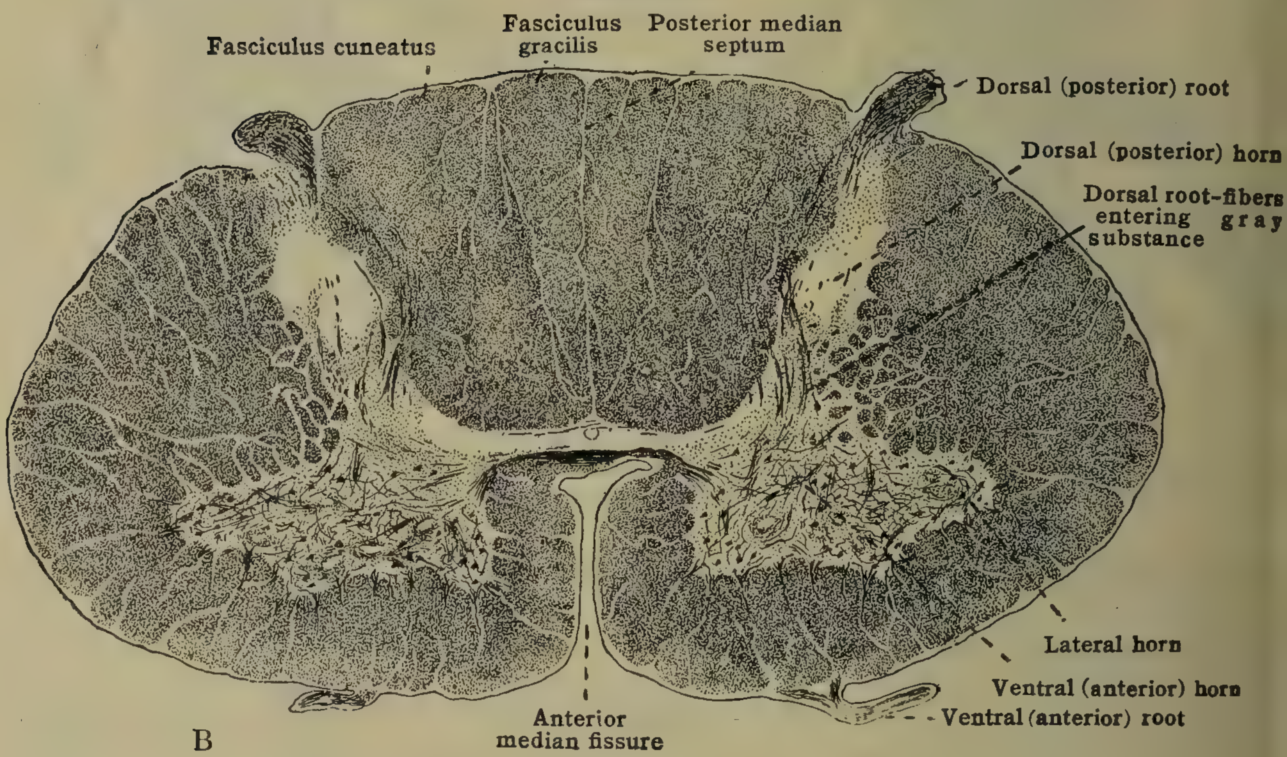
FIG. 694.—A, VENTRAL, AND B, DORSAL, VIEWS OF PORTION OF SPINAL CORD SHOWING MODES OF ATTACHMENT OF DORSAL AND VENTRAL ROOTS.

median sulcus. Along the lower two-thirds of the cord this sulcus is shallowed to little more than a line which marks the position of the posterior median septum; in the medulla oblongata it opens up and attains the character of a fissure. Each of the two lateral halves of the cord is marked off into posterior, lateral, and anterior divisions by two other longitudinal sulci. Of these,the **posterolateral sulcus** occurs as a slight groove 2 to 3½ mm. lateral from the posterior median sulcus, and is the groove in which the root filaments of the dorsal roots enter the cord in regular linear series. The ventral division is separated from the lateral by the **anterolateral sulcus.** This is an irregular, linear area rather than a sulcus. It is from 1 to 2 mm. broad, and represents the area along which the efferent fibers make their exit from the cord to be assembled into the respective ventral roots. This area varies in width according to the size of the nerve-roots, and, like the posterolateral sulcus, its distance from the midline varies according to locality, being greatest on the enlargements of the cord. In the cervical region, and along the cephalic part of the thoracic, the posterior division is subdivided by a delicate longitudinal groove, the **posterointermediate sulcus,** which becomes more evident toward the medulla oblongata and represents the line of demarcation between the fasciculus gracilis and the fasciculus cuneatus. Occasionally in the upper cervical region a similar line may be seen along the ventral aspect close to the anterior median fissure. This is the **anterointermediate sulcus,** forming the lateral boundary of the ventral cerebrospinal fasciculus.

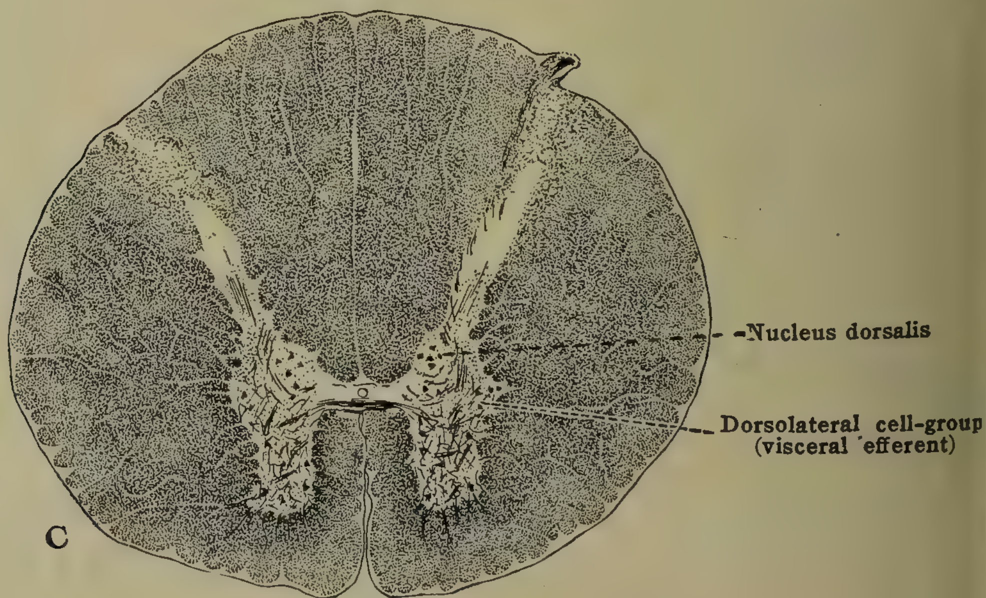
Collectively, the entire space between the posterior median sulcus and the line of attachment of the dorsal roots is occupied by the **posterior funiculus**; the lateral space between the line of attachment of the dorsal and that of the ventral roots, by the **lateral funiculus**; and the space between the line of attachment of



CERVICAL I



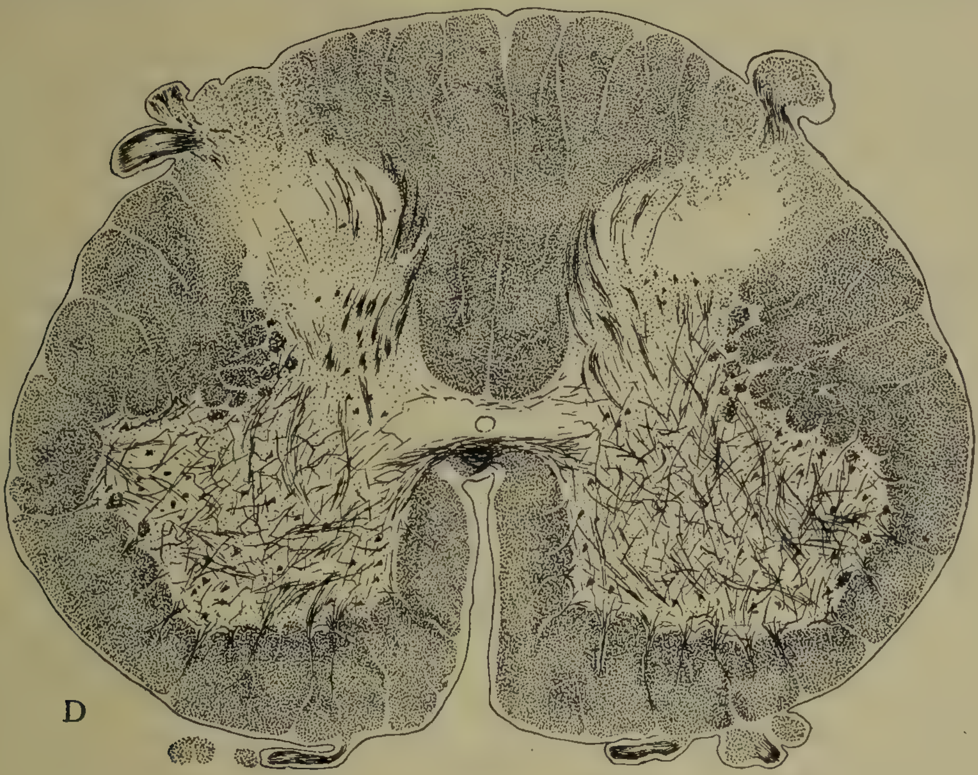
CERVICAL VI



THORACIC VIII

FIG. 695.—TRANSVERSE SECTIONS FROM DIFFERENT SEGMENTS OF THE SPINAL CORD, SHOWING SHAPE AND RELATIVE PROPORTIONS OF GRAY AND WHITE SUBSTANCE IN THE VARIOUS REGIONS.

INTERNAL STRUCTURE OF THE SPINAL CORD (FIG. 695 *Continued*)

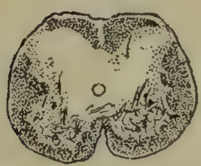


D

LUMBAR III

E

SACRAL IV



COCCYGEAL

the ventral roots and the anterior median fissure, by the **anterior funiculus.** Each of these funiculi is subdivided within into its component fasciculi.

The dorsal and ventral nerve-roots are not attached to the cord as such, but are first frayed out into numerous thread-like bundles of axones which are distributed along their lines of entrance and exit. These bundles are the **root-filaments** [fila radicularia] of the respective roots. The fila of the larger spinal nerves are fanned out to the extent of forming almost continuous lines of attachment, while in the thoracic nerves there are small intervals between the root-filaments belonging to adjacent roots. Throughout, the intervals are less between the fila of the ventral than between those of the dorsal roots.

By reflected light masses of medullated axones appear white when fresh, and such masses are known as **white substance.** The spinal cord consists of a continuous, centrally placed column of gray substance surrounded by a variously thickened tunic of white substance. The closely investing pia mater sends

numerous ingrowths into the cord, bearing blood-vessels and contributing to its internal supporting tissue. The volume of white and of gray substance varies both absolutely and relatively at different levels of the cord. The absolute amount of gray substance increases with the enlargements. The absolute amount of white substance also increases with the enlargements coincident with the greater amount of gray substance in those regions. The relative amount of white substance increases in passing from the conus medullaris to the medulla oblongata, as explained later.

The gray substance.—All the nerve-cells of the gray substance are derived from the cells forming the neural tube in the embryo, and in the adult the column of gray substance, though greatly modified in shape, still retains its position about the central canal. In transverse section the column appears as a gray figure of two laterally developed halves, connected across the mid-line by a more attenuated portion, the whole roughly resembling the letter H. The cross-bar of the H is known as the **gray commissure.** Naturally, it contains the **central canal** which is quite small and is either rounded or laterally or ventrally oval in section according to the level of the cord in which it is examined. The canal continues upward, and in the medulla oblongata opens out into the fourth ventricle. Downward, in the extremity of the conus medullaris, it widens slightly and forms the rhomboidal sinus or **terminal ventricle,** then is suddenly constricted into an extremely small canal extending a short distance into the filum terminale, and there ends blindly. The gray commissure always lies somewhat nearer the ventral than the dorsal surface of the cord, and itself contains a few medullated axones which vary in amount in the different regions of the cord. The medullated axones crossing the midline on the ventral side of the central canal form the ventral or **anterior white commissure;** those, usually much fewer in number, crossing on the dorsal side of the central canal, form the dorsal or **posterior white commissure.** These two commissures comprise fibers crossing in the gray substance as distinguished from others which cross in the white substance dorsal and ventral to them, namely, the **dorsal cornucommissural tract** and the **ventral commissural bundle.** The axones of these four commissures serve chiefly in functionally associating the two lateral halves of the gray column.

Each lateral half of the gray column presents a somewhat crescentic or comma-shaped appearance in transverse section, which also varies at the different levels of the cord. At all the levels each half presents two well-defined horns, themselves spoken of as columns of gray substance. The **dorsal horn** [columna posterior] extends posteriorly and somewhat laterally toward the surface of the cord along the line of the posterolateral sulcus. It is composed of an **apex** (crista columnæ dorsalis NK) and a **neck** [cervix columnæ posterioris].

In structure the apex is peculiar. The greater portion of it consists of a mass of small nerve-cells and neuroglia tissue, among which a gelatinous substance of questionable origin predominates, giving the horn a semi-translucent appearance. This is termed the **gelatinous substance of Rolando,** to distinguish it from a similar appearance immediately about the central canal, **the central gelatinous substance.** The apex of the dorsal horn is widest in the regions of the enlargements, especially the lumbar, and the gelatinous substance of Rolando is most marked high in the cervical region. In these regions the cervix shows a slight constriction of the dorsal horn between the apex and the line of the gray commissure. In the thoracic region, however, the base of the cervix is the thickest part of the dorsal horn. This thickness is due to the presence there of the **nucleus dorsalis,** or Clarke's column—a column of gray substance containing numerous nerve-cells of larger size than elsewhere in the dorsal horn, and extending between the seventh cervical and third lumbar segments of the cord. Tapering finely at its ends, this nucleus attains its height in the lower thoracic or first lumbar segment. About the ventrolateral periphery of the nucleus dorsalis are scattered nerve-cells of the same type as those contained in it. These cells are sometimes distinguished as **Stilling's nucleus,** though Clarke's column was also described by Stilling. They are more numerous about the lower extremity of the nucleus dorsalis, and they continue still more numerous in line with it below its termination in the lumbar region.

It must be noted that the dorsal horn throughout contains numerous cell-bodies of neurones, mostly of small size (nuclei of the dorsal horns). These are especially numerous in the margins of the horn where they are referred to as the *stratum zonale.* Their significance will be given below in connection with the nerve-tracts with which they are concerned (fig. 698).

The **ventral horn** [columna anterior] of each lateral half of the gray figure is directed ventrally toward the surface of the spinal cord, pointing toward the anterolateral sulcus. It contains the cell-bodies which give origin to the efferent or ventral root axones, and these axones make their emergence from the spinal cord along the anterolateral sulcus. The ventral horns vary markedly in shape

in the different regions. In certain segments each ventral horn is thickened laterally and thus presents its two component columns of gray substance: the **lateral horn** [columna lateralis], a triangular projection of gray substance into the surrounding white substance, in line with or a little ventral to the line of the gray commissure; and the **ventral horn proper** [columna anterior], projecting ventrally. In the midthoracic region the lateral horn is absent except its dorsolateral part, and the ventral horn is quite slender; in the cervical and lumbar enlargements both horns are considerably enlarged.

The gray substance is not sharply demarcated from the white. In the blending of the two there are often small fasciculi of white substance embedded in the gray, and likewise the gray substance sends fine processes among the axones composing the white substance. Such processes or gray trabeculæ are most marked along the lateral aspects of the gray figure and present there the appearance known as the **reticular formation.** The reticular formation of the spinal cord is most evident in the cervical region (fig. 695).

Minute structure.—The large cell-bodies of the ventral horn as a whole are divisible into four groups, only three of which are to be distinguished in the midthoracic region of the spinal cord:—(1) A *ventral group* of cells, sometimes separated into a ventrolateral and a ventromedial portion (see figs. 695, 698), occupies the ventral horn proper, is constant throughout the entire length of the cord, and contributes axones to the ventral root, most of which probably supply the muscles adjacent to the vertebral column; (2) a *dorsomedial group* of cells, situated in the medial part of the ventral horn, just below the level of the central canal, gives origin to axones some of which go to the ventral root of the same side, some of which cross the midline viâ the anterior white commissure, either to pass out in the ventral root of the opposite side or (mostly) to enter the white substance of that side and course upward or downward, associating with other levels of the cord. Some of its axones terminate among the cells of the ventral horn in the same level of the opposite side; (3) a *lateral group* of cells, which is separated into a dorsolateral and a ventrolateral portion, occupies the lateral column or horn, and is best differentiated in the cervical and lumbar enlargements. Most of the axones arising from its larger cells are contributed to the ventral root of the same side, and most of such axones supply the muscles of the extremities. Some of those from its ventral portion are distributed to the muscles of the body-wall. The dorsolateral portion is that part of the lateral column which persists throughout the cord, and is considered as supplying the visceral efferent ('autonomic') fibers in the ventral roots. It is usually referred to as the dorsolateral cell group of the ventral horn, the only lateral group in the midthoracic region. It is called the *intermediolateral* group when all the cell groups of both horns are collectively considered. (4) An *intermediate group*, occupying the middorsal portion of the ventral horn. Axones arising from its cells are in part contributed to the ventral root as visceral efferent fibers, but most of them course wholly within the central nervous system. Some pass to the opposite side of the cord, chiefly viâ the anterior and possibly the posterior white commissure, to terminate either in the same or different levels of the gray column. Others of longer course pass to the periphery of the cord, join one of the spinocerebellar fasciculi, and pass upward to the cerebellum.

Furthermore, there are scattered throughout the gray substance many small cell-bodies of neurones. These give rise to axones of shorter course, either **commissural** or **associational** proper. Of such axones many are quite short, coursing practically in the same level as that in which their cells of origin are located, and serve to associate the different parts of the gray substance of that level. Others course varying distances upward and downward for the association of different levels of the gray column.

It is evident from the above that in addition to the various nerve-cells it contains, there is also to be found a felt-work of axones in the gray substance. Many of these axones are medullated, though not in sufficient abundance to destroy the gray character of the substance The felt-work is composed of four general varieties of fibers:—(1) Axones arising from the cells of the spinal ganglia which enter the cord as dorsal root-fibers and form synapses with the cell-bodies of the gray substance; (2) The terminal branches of axones entering from the fasciculi of the white substance and forming end-brushes (synapses) about the various cell-bodies in the gray substance (partly medullated); (3) axones given off from the cells of the gray substance and which pass into the surrounding white substance either to enter the ventral roots or to join the ascending and descending fasciculi within the spinal cord (partly medullated); (4) axones of Golgi neurones of type II, which do not pass outside the confines of the gray substance (non-medullated). Some axones of any of these varieties may cross the midline and thus become commissural. In general all fibers of long course acquire medullary sheaths a short distance from their cells of origin, and lose them again just before termination. From the cell groups of the dorsal horn, especially the stratum zonale, arise fibers of long course which decussate in the ventral commissure and ascend to the brain in bundles known as the 'spinal lemniscus.'

The white substance of the spinal cord.—The great mass of the axones of the spinal cord course longitudinally and form the thick mantle surrounding the column of gray substance. This mantle is divided into right and left homolateral halves by the anterior median fissure along its ventral aspect, and along its dorsal aspect by the posterior median septum, which is for the most part a connective tissue partition derived from the pia mater along the line of the posterior median sulcus. The mantle is supported internally by interwoven

neuroglia and white fibrous connective tissue, the latter derived from the meso derm viâ the pia mater, closely investing it without.

The axones of the white substance belong to three general neurone systems:– (1) The *spinal association* and *commissural system* of axones which serve to cor relate the different levels and the two sides of the spinal cord and which ar proper to the spinal cord, i.e., they do not pass outside its confines. (2) Th *spinocerebral and cerebrospinal system*, which consists of axones of long cours one set ascending and another descending, forming links in the neurone chain between the cerebrum and the peripheral organs. The ascending axones of thi system collect the general bodily sensations which are conveyed through synapse to the cerebrum, the cerebral cells contributing axones which descend the cord conveying efferent or motor impulses in response. (3) The *spinocerebellar an cerebellospinal* system consists of conduction paths, one set ascending and anothe descending, which are links between cerebellar structures and the gray substanc of the spinal cord. To this might be added a fourth system of neurones (spinobul bar) connecting and correlating the spinal cord and the medulla oblongata.

The second, third and fourth systems increase in bulk as the cord is ascended The ascending axones of each system are contributed to the white substance o the cord along its length, and therefore accumulate upward; the axones descend ing from the encephalon are distributed to the different levels of the cord alon its length, and therefore diminish downward.

The mass of the first system of axones varies according to locality (figs. 695 701). Wherever there is a greater mass of neurones to be associated, as there i in the enlargements of the cord, a greater number of these axones is required Their cells of origin, being in the gray substance of the cord, contribute to it bulk and thus both the cells and the axones of this system serve to make th enlargements more marked. In the lumbar and sacral regions the greater mas of the entire white substance consists of axones belonging to this system. I forms a dense felt-work about the gray column throughout the cord. Neces sarily this system contains axones of various lengths. Some merely associat different levels within a single segment of the cord; others associate the differen segments with each other. Many of these axones cross the midline both in th gray and in the white substance to associate the neurones of the two sides. Fo purposes of distinction, such as cross the midline are called **commissural fibers**, while those which arise and course upward and downward on the same side are **association fibers.** Coursing in longitudinal bundles about the gray substance, the latter compose the **fasciculi proprii** or 'ground bundles' of the spinal cord. Naturally, these are mixed with fibers which have crossed the midline.

METHODS BY WHICH THE CONDUCTION PATHS HAVE BEEN DETERMINED

A purely anatomical examination of a normal adult cord, prepared by whatever means gives no indication of the fact that the mass of longitudinally coursing fibers of the white substance is composed of more or less definite bundles or fasciculi, each having a definite origin, course and termination and forming links (conduction paths) in a definite system of neurone chains. Present information as to the size, position, and connections of the various fasciculi is based upon evidence obtained by three different lines of investigation:—

(1) **Physiological investigation.**—(*a*) Direct stimulation of definite bundles or areas in section and carefully noting the resulting reactions which indicate the function and course of the axones stimulated. (*b*) Experimental section of fasciculi and observation of any impaired, function resulting. (*c*) 'Wallerian degeneration' and the application of such methods as that of Marchi. When an axone is severed, that portion of it which is separated from its parent cell-body degenerates. Likewise a bundle of axones severed from their cells of origin, whether by accident or design, will degenerate from the point of the lesion on to the locality of their termination in whichever direction this may be. This phenomenon was noted by Waller in 1852 and is known as **Wallerian degeneration.** By the application of a staining technique which is differential for these degenerating axones and a study of serial sections containing the axones in question, their course and distribution may be determined. The locality of their cells of origin, if unknown, may be determined by repeated experiment till a point of lesion is found not followed by degeneration of the axones under investigation. (*d*) The axonic reaction or 'reaction from a distance.' Cell-bodies whose axones have been severed undergo chemical change and stain differently from those whose axones are intact. Thus cell-bodies giving origin to a bundle of severed axones may be located in appropriately stained sections of the region containing them.

(2) **Embryological evidence.**—In the first stages of their development axones of the cerebrospinal nervous system are non-medullated. They acquire their sheaths of myelin later. Axone pathways forming different chains become medullated at different periods. Based upon this fact a method of investigation originated by Flechsig is employed, by which the posi-

tion and course of various pathways may be determined. A staining method differential for medullated axones alone is applied to the nervous systems of fetuses of different ages, and pathways medullated at given stages may be followed from the locality of their origin to their termination. In the later stages, when most of the pathways are medullated and therefore stain alike, the less precocious pathways may be followed by their absence of medullation.

(3) **Direct anatomical evidence.**—(*a*) Stains differential for axones alone are applied to a given locality to determine the fact that the axones of a given bundle actually arise from the cell-bodies there, or that axones traced to a given locality actually terminate about the cell-bodies of that locality. For example, it may be proved anatomically that the axones of a dorsal root arise from the cells of the corresponding spinal ganglion, and then these axones may be traced into the spinal cord and the terminations noted either of their collateral or terminal twigs, or the fasciculus they join in their cephalic course may be determined. (*b*) The staining properties and the size and distribution of the tigroid masses in the cell-bodies of sensory neurones differ from those in the motor neurones, and recently Malone has claimed that, in the central

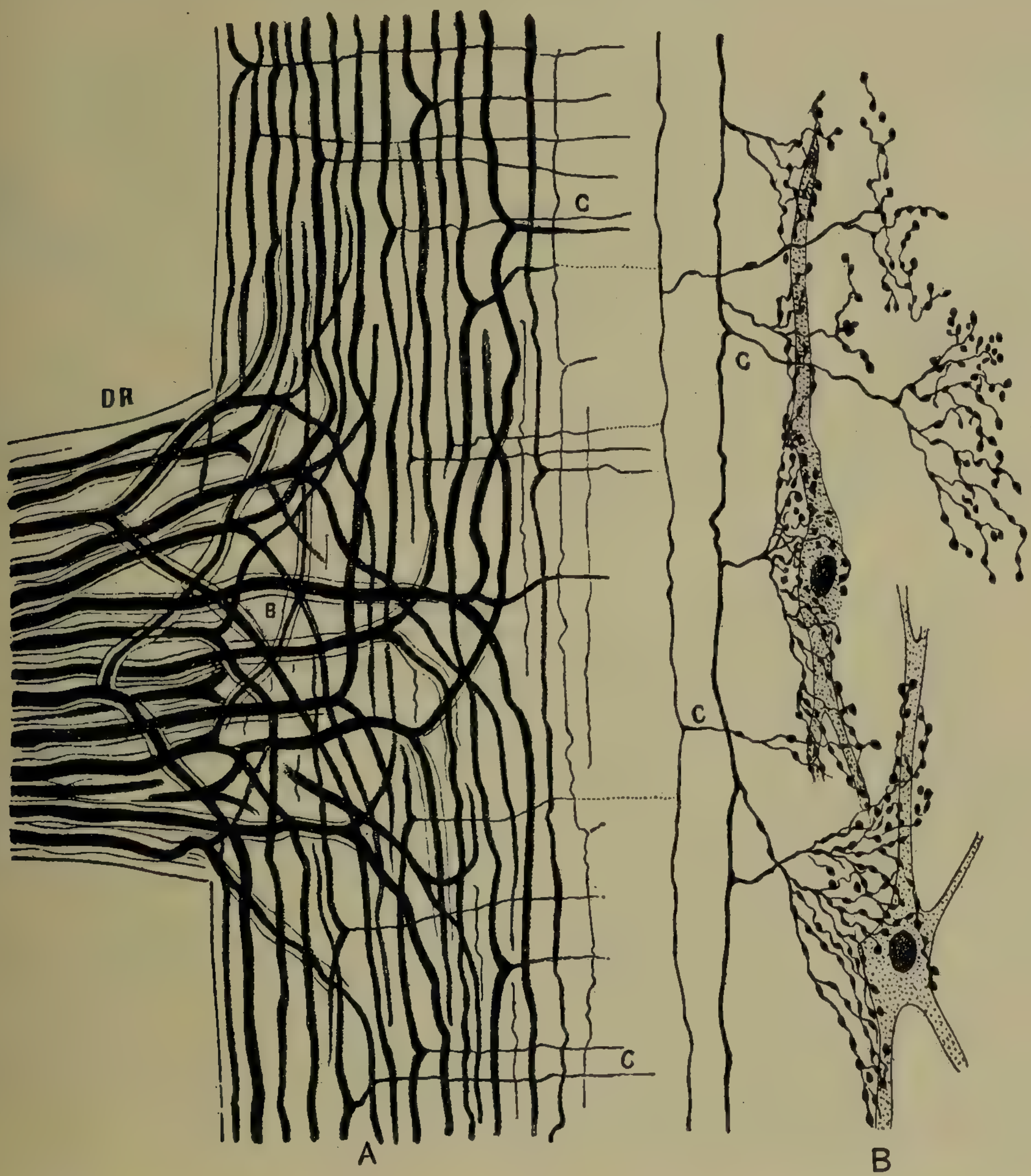


FIG. 696.—SHOWING DISPOSITION OF THE DORSAL ROOT FIBERS UPON ENTERING THE SPINAL CORD. (From Edinger after Cajal.)

A shows dorsal root axones DR, entering the spinal cord, bifurcating at B, and giving off collaterals C to the neurones of the cord. B shows the telodendria of these axones or of their collaterals forming synapses with cell-bodies of the gray substance of the cord.

system, the cell-bodies in the nuclei of sensory neurone-chains, those chains ascending toward the cerebral cortex, may be distinguished from the cell-bodies of the motor or descending chains by the arrangement and size of their tigroid masses. He claims further that in the same way, the cell-bodies of the somatic efferent neurones may be distinguished from those of the visceral efferent neurones. In this way the locality of origin of certain physiologically known paths may be determined. (*c*) Direct dissection in case of the larger bundles in the brain.

(4) The so-called **pathologic-anatomical method** is based upon the same general principles as is the physiological (or experimental) method. A pathological lesion, a local infection or a tumor for example, may destroy a nucleus of cell-bodies or sever a bundle of axones, and the resulting degeneration of the axones may be followed through serial sections suitably prepared. The locality of the lesion known, the path may be followed to determine the locality of its termination; its locality of termination known from the symptoms resulting, the path may be followed to its cells of origin, or to the locality of the lesion.

Funiculi.—In order that the various fasciculi may be referred to with greater ease, the white substance of the spinal cord in transverse section is divided into three areas known as funiculi or columns and which correspond to the funiculi already mentioned as evident upon the surface of the cord when intact. The funiculi are outlined wholly upon the basis of their position in the cord and with reference to the median line and the contour of the column of gray substance; their component fasciculi are defined upon the basis of function. (1) The *posterior funiculus* or column is bounded by the posterior median septum and the line of the dorsal horn; (2) the *lateral funiculus* or column is bounded by the lateral concavity of the gray column and the lines of entrance and exit of the dorsal and ventral roots; (3) the *ventral funiculus* or column is bounded by the line of exit of the ventral roots, and by the anterior median fissure. (See figs. 695, 698.)

The posterior funiculus or column [funiculus posterior].—This funiculus is composed of two general varieties of axones arranged in five fasciculi. First, and constituting the predominant type in all the higher segments of the cord, are the afferent or general sensory axones, which arise in the spinal ganglia, enter the cord as the dorsal roots, assume their distribution to the neurones of the cord, and then (some of them) take their ascending course toward the encephalon. The axone of the spinal ganglion neurone undergoes a T-shaped division a short distance from the cell-body, one limb of this division terminating in the peripheral organs and the other going to form the dorsal root. Upon entering the cord the dorsal root-axones undergo a Y-shaped bifurcation in the neighborhood of the dorsal horn, one branch ascending and the other descending (fig. 696). The longest of the ascending branches form the **fasciculus gracilis** (Goll's column) and the **fasciculus cuneatus** (Burdach's column). These fasciculi are the largest ascending or sensory spinocerebral connections, the direct main sensory path to the brain. Their neurones represent the first links in the neurone chains between the periphery of the general body and the cerebral and cerebellar cortex.

In threading their way toward the brain, these sensory axones of long course tend to work toward the midline. Therefore those of longest course are to be found nearer the posterior septum, in the upper segments of the cord, than those axones which enter the cord by the dorsal roots of the upper segments. Thus it is that the fasciculus gracilis, the medial of the two fasciculi, contains the axones which arise in the spinal ganglia of the sacral, lumbar and lower thoracic segments (S., L. and T. 12 to 6). In other words, it is the fasciculus bearing sensory impulses from the lower limbs to the brain, while the fasciculus cuneatus, the lateral of the two, is the corresponding pathway for the higher levels (T. 6 to 1 and C.). Naturally, there is no fasciculus cuneatus as such in the lower segments of the spinal cord. The axones being much blended at first, it is only in the upper thoracic and cervical region that there is any anatomical demarcation between the two fasciculi. In this region the two become so distinct that there is in some cases a distinct connective tissue septum between them, continuing inward from the posterointermediate sulcus—the surface indication of the line of their junction (fig. 695).

Upon reaching the medulla oblongata the fibers of the fasciculus gracilis and the fasciculus cuneatus terminate about cells grouped to form the nuclei of termination of these fasciculi. The nucleus of termination of the fasciculus gracilis is situated medially and begins just below the point at which the central canal opens into the fourth ventricle; that of the fasciculus cuneatus is placed laterally and extends somewhat higher than the other nucleus. The neurones whose cell-bodies compose these nuclei constitute the second links in the neurone chains conveying sensory impulses from the periphery to the cerebral and cerebellar cortex.

The descending or *caudal branches* of the dorsal root-axones are concerned wholly with the neurones of the spinal cord. They descend varying distances, some of them as much as four segments of the cord, and give off numerous collaterals on their way to the cells of the gray column. Those terminating about cell-bodies of the ventral horn, which give rise to the ventral or motor root-fibers, are responsible for certain of the so-called '*reflex activities*' and thus contribute to the simplest of the **reflex arcs.** In descending they serve to associate different levels of the gray substance of the cord with impulses entering by way of a single dorsal root. Some of their collaterals cross the midline in the posterior white commissure, and thus transfer impulses to neurones of the opposite side. The caudal branches of longer course are scattered throughout the ventral portion of the fasciculus cuneatus (*middle root zone*), and the longest show a tendency to collect along the border-line between the fasciculus cuneatus and the fasciculus gracilis, and thus contribute largely to the **comma-shaped fasciculus** (*fasciculus interfascicularis.*) Also a few of the longest of them in the lower levels course in the *oval bundle of Flechsig* or septomarginal root zone.

The ascending branches of the dorsal-root axones also give off collaterals to the gray substance of the cord, thus extending the area of distribution of a given dorsal nerve-root to levels of the cord above the region at which the root enters.

The greater number of the terminations of dorsal root-axones within the spinal cord form synapses with neurones other than those directly contributing ventral root-fibers. The greater mass of the neurones concerned are those of the Golgi type II and those contributing the **fasciculi proprii** or **ground bundles** of the spinal

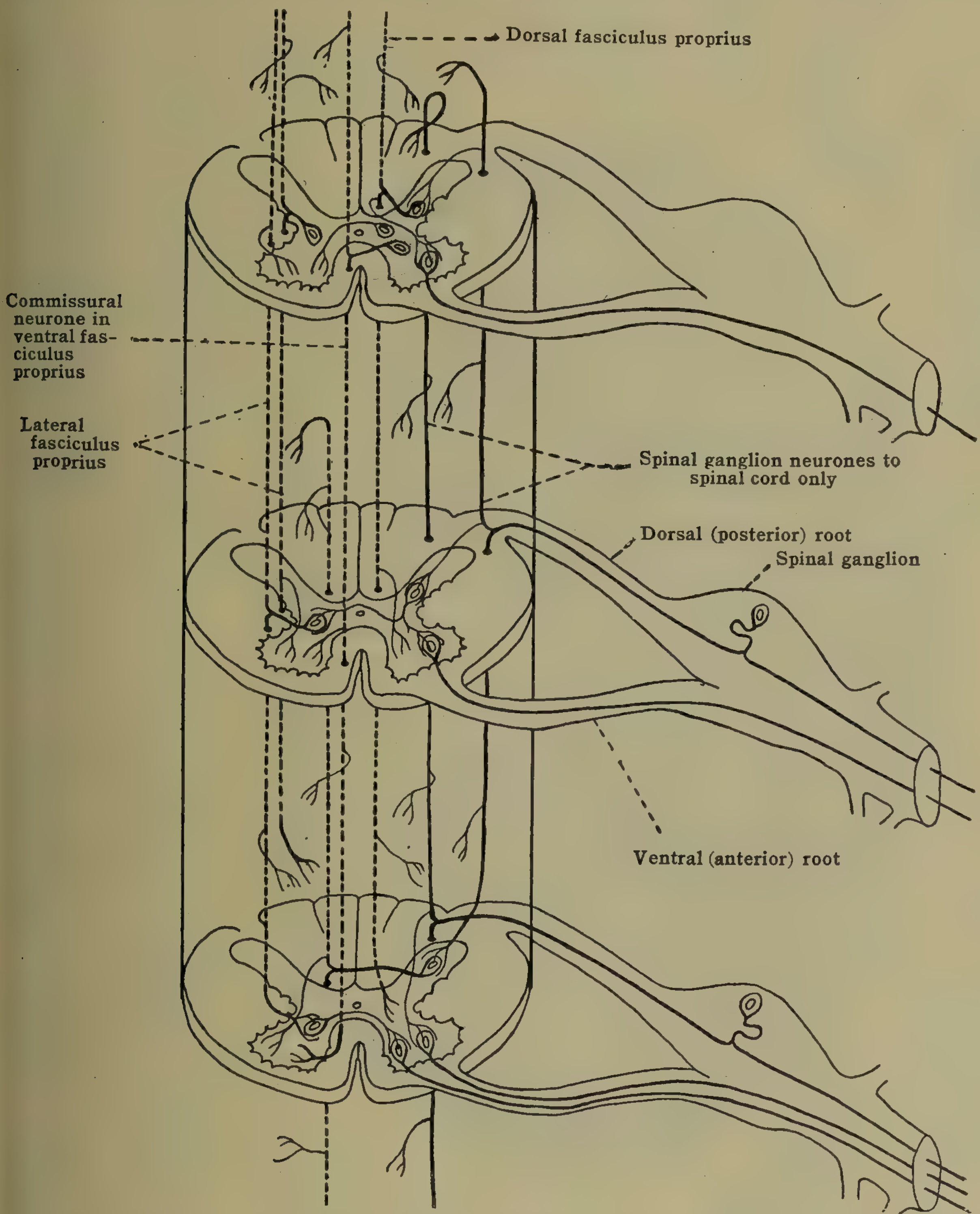


FIG. 697.—DIAGRAM ILLUSTRATING THE FORMATION OF THE FASCICULI PROPRII (ASSOCIATION FASCICULI) AND COMMISSURAL FIBERS OF THE SPINAL CORD, AND THE GENERAL ARCHITECTURE OF THE CORD AS A MECHANISM FOR REFLEX ACTIVITIES.

The ventral fasciculus proprius is omitted and the lateral is shown on one side only. The lower spinal ganglion neurone shown illustrates the type whose ascending branch is of much longer extent than that of the upper one. Reflex arcs involving the sympathetic are not included.

cord, or the second variety of axones composing the posterior funiculus. The latter fasciculi arise from the smaller cells of the gray column (figs. 697, 698).

These axones pass from the gray substance to enter the surrounding white substance, bifurcate into ascending and descending branches, which in their turn give off numerous collaterals to the cells of the gray substance of the levels through which they pass. The cell-bodies giving origin to such axones are so numerous that the entire column of gray substance is surrounded by a continuous felt-work of fasciculi proprii.

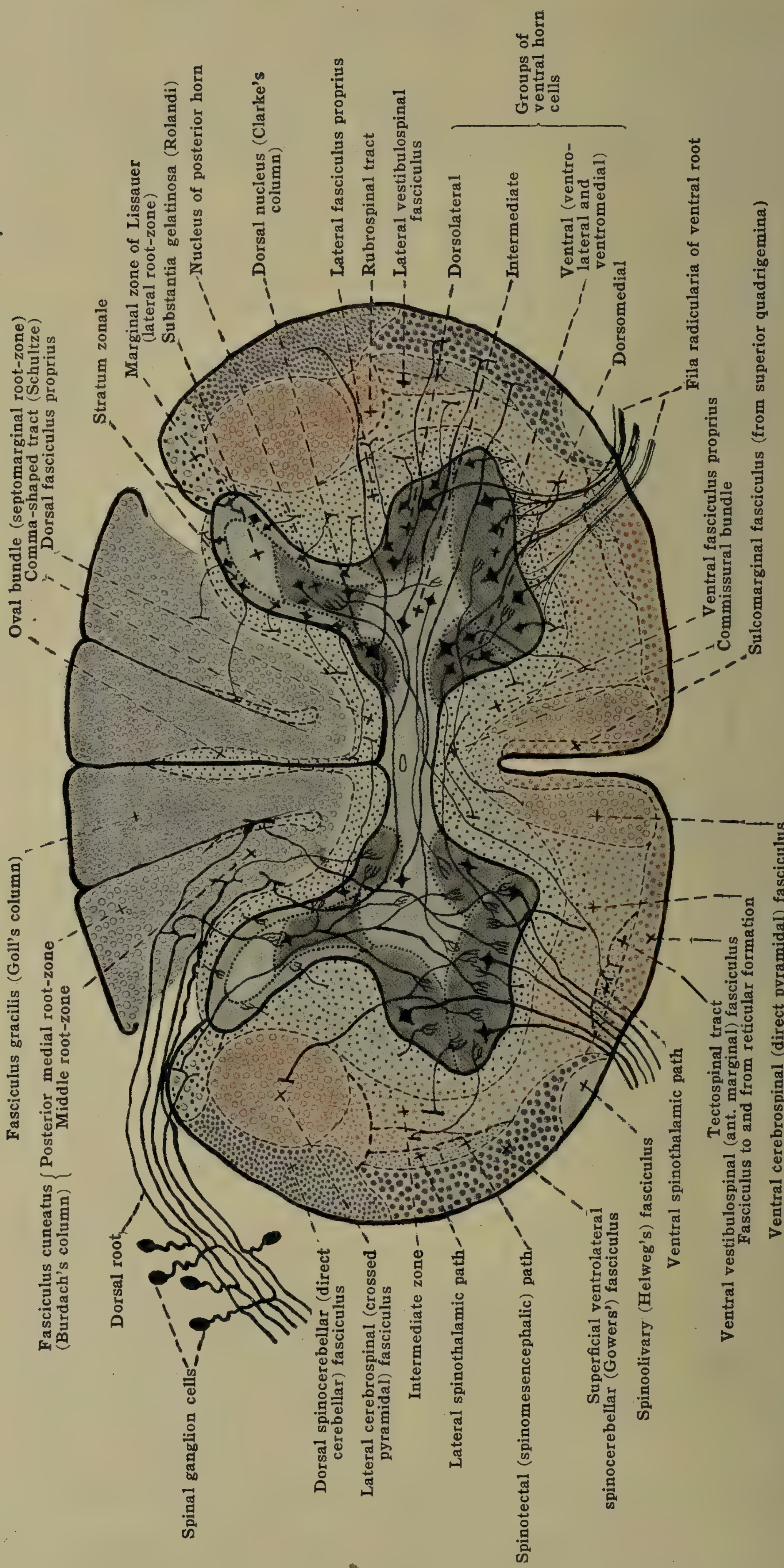


FIG. 698.—SCHEMATIC REPRESENTATION OF THE SHAPE AND POSITION OF THE VARIOUS FASCICULI OR CONDUCTION PATHS OF THE SPINAL CORD AND THE GROUPING AND SIGNIFICANCE OF THE CELL-BODIES OF THE GRAY SUBSTANCE.

The **dorsal fasciculus proprius** (anterior zone of posterior column) arises chiefly from cells situated in the dorsal horn (*stratum zonale*). Coincident with the ingrowth and arrangement of the fasciculi gracilis and cuneatus many of the longer fibers of the dorsal fasciculus proprius go to form both the oval bundle and the comma-shaped fasciculus. Thus these two bundles are mixed, being fasciculi proprii which also contain caudal branches of dorsal root-axones. The association fibers in the oval bundle are the longest of any belonging to the dorsal fasciculus proprius. The cephalic and caudal branches of some, combined, are said to extend more than half the length of the cord and it has been claimed that some even associate the conus medullaris with the cervical region. Based upon this claim, Obersteiner has called the oval bundle the 'dorsomedial sacral field' and Edinger has referred to the most dorsal part of it as the '*tractus cervicolumbalis dorsalis*.' Since this dorsal part is evident as a bundle only in the upper segments, a better name for it is *lumbosacral tract*, for, to become so removed from the gray substance, it must arise in the lower segments of the cord. As a tract it courses just under the pia, one on each side of the dorsal edge of the dorsal septum. When spread laterally there, it has been called *the dorsal peripheral band*. Hoche has described an oval bundle, minus this dorsal part, in the lower lumbar segments, shown in degenerations resulting from a destructive compression of the middle thoracic region. This indicates a lumbar composition of the oval bundle to be caudal branches of association neurones descending from the middle thoracic region and above it. The '*median triangle*', is formed by the continuation of the dorsal fasciculi proprii with the oval or septomarginal fasciculus. Some of the axones of the dorsal fasciculus proprius cross the midline to distribute impulses to the neurones of the opposite side. These commissural axones, together with certain collaterals of the dorsal root-axones, which cross the midline outside the dorsal white commissure, compose the so-called **cornucommissural tract** at the ventral edge of the posterior septum.

Only a minor proportion of the axones of the posterior or dorsal nerve-roots extend to the encephalon. Estimation shows that the sum of all the dorsal roots is greatly in excess of the sum contained in the fasciculi cuneatus and gracilis just before these enter their nuclei of termination. Therefore most of the ascending branches are concerned wholly with spinal cord relations.

The lateral and ventral funiculi or columns.—The region of the passage of the ventral root-fibers from the ventral horn is considered the line of demarcation between the lateral and ventral funiculi. In that it is much less definite than the demarcation between the lateral and dorsal funiculi and because it is so broad as to involve in it certain of the tracts to be considered, some extending through the line, the fasciculi comprising the lateral and ventral funiculi will be considered together.

The **marginal zone of Lissauer,** situated along the lateral margin of the posterolateral sulcus, is composed largely of dorsal root-axones which bifurcate lateral instead of medial to their line of entrance. Many of these finally work across the line of entrance into the posterior funiculus. Many of the dorsal root-fibers which do not reach the brain occur in Lissauer's zone. Lissauer's zone also contains fibers arising from the small cells of the dorsal horn, and to this extent corresponds to a fasciculus proprius. Ranson has found that large numbers of the non-medullated dorsal root-axones which enter the cord are contributed to Lissauer's zone. The lateral half of the zone consists very largely of the fibers arising in the gray substance of the cord (endogenous fibers). It has been suggested (Ranson), that one of the functions of the fibers of the zone as a whole has to do with pain and temperature sensations. Thus they would comprise a division of the spinal lemniscus, discussed below.

The **lateral and ventral fasciculi proprii** (ground or basis-bundles).—The lateral fasciculus proprius is situated in the lateral concavity of the gray column and is continuous with the other fasciculi proprii both dorsal and ventral. Except that it probably contains fewer commissural axones, it is of the same general significance as the others. It is the largest of the three and is more or less divided throughout into small bundles by the reticular formation (see fig. 695A, B).

The ventral fasciculus proprius is continuous around the ventral horn with the lateral, is bounded medially by the fasciculi bounding the ventral median fissure and is continuous under the floor of this fissure with its fellow of the opposite side. More commissural fibers traverse it than traverse either of the other two. The neurones represented in it serve especially to associate the different levels of the ventral horn, and it is known to contain some association-fibers of extra long course—extending between the brain and cord.

The lateral cerebrospinal fasciculus (crossed pyramidal tract).—In contrast to the sensory fibers passing through the spinal cord and conveying impulses destined to reach the cerebral cortex, axones are given off from the pyramidal cells of the cortex, which descend to terminate about the cells of the gray substance of the spinal cord, chiefly about the cells which give origin to the ventral root-fibers.

Upon reaching the medulla oblongata in their descent, these axones are accumulated into two well-defined, ventrally placed bundles, the **pyramids,** one from each cerebral hemisphere. In passing through the brain stem the pyramids contribute many fibers which cross the midline to terminate in the motor nuclei of the cranial nerves of the opposite side (cortico-medullary fibers), and thus here they decrease appreciably in bulk. According to the estimate of Thompson only about 160,000 of the pyramidal fibers are destined to enter the spinal cord.

Upon reaching the lower part of the medulla, the greater mass of the fibers of each pyramid, which are destined to enter the cord, suddenly cross the midline in the 'decussation of the pyramids.' The remainder retain their ventral position in their descent, decussating gradually

in the cord itself. The pyramidal fibers which cross in the medulla course in the lateral column ventral to Lissauer's zone, and lateral to the lateral fasciculus proprius, and form the *lateral cerebrospinal fasciculus* (crossed pyramidal tract). It is a large fasciculus, oval-shaped in transection, and since its axones terminate in the gray column of the cord all along its length, it decreases in bulk as the cord is descended.

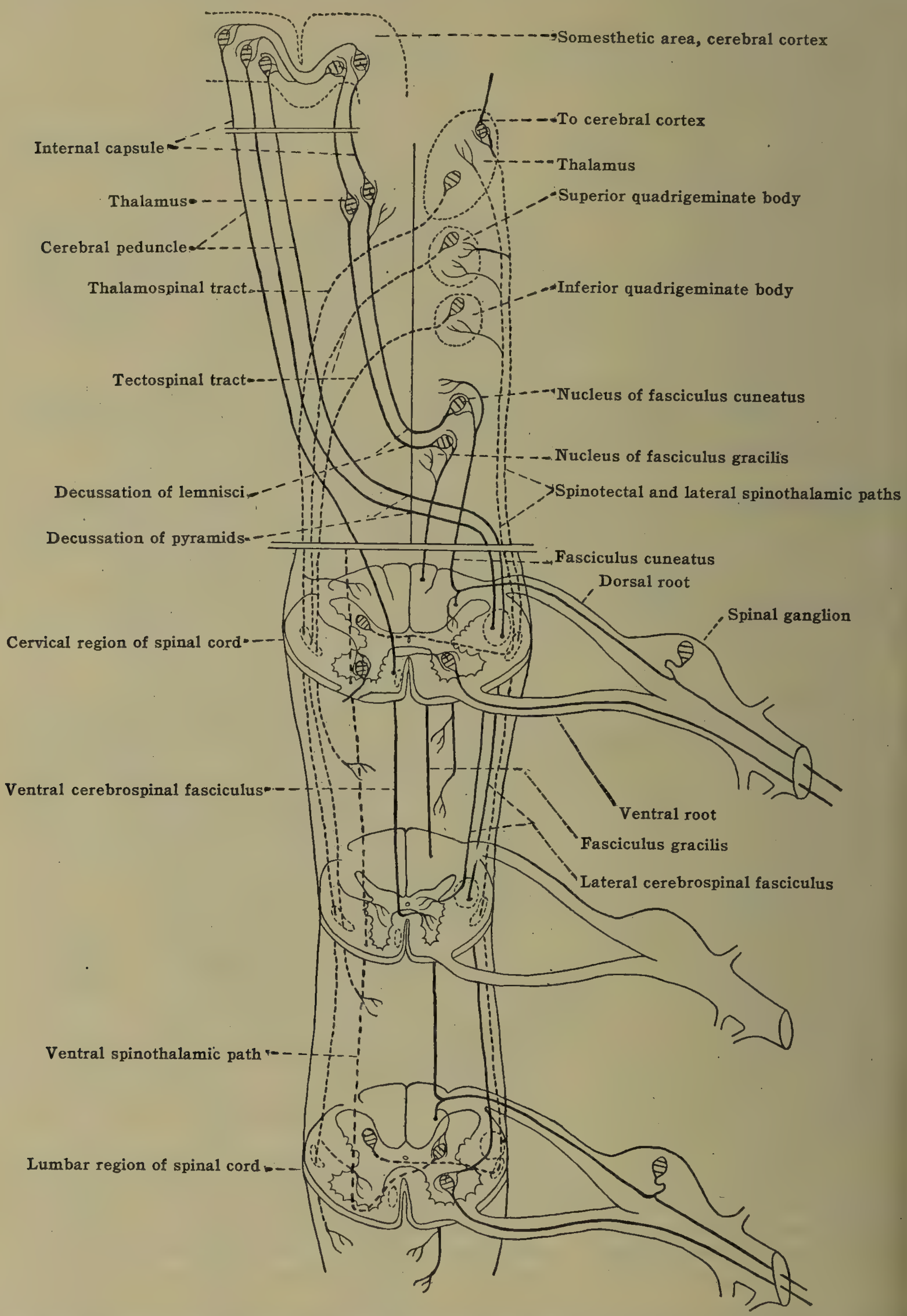


Fig. 699.—Diagram of Spinal Cord Illustrating the Two Chief Varieties of Spino-cerebral and Cerebrospinal Neurone Chains. The ventral tectospinal (sulco-marginal) fasciculus, fibers descending from the superior quadrigeminate bodies, and the rubrospinal path are not filled in.

The **ventral cerebrospinal fasciculus** (anterior or direct pyramidal tract), as stated above, is the uncrossed portion of the descending cerebrospinal system of neurones. It is a small, oblong bundle, situated mesially in the anterior funiculus,

parallel with the anterior median fissure. Like the lateral cerebrospinal fasciculus (crossed pyramidal tract), its axones arise from the large pyramidal cells of the motor area of the cerebral cortex, and transmit their impulses to the neurones of the ventral horns of the gray substance of the spinal cord, and almost entirely to those neurones which give origin to the ventral or motor root-fibers

It represents merely a delayed decussation of the pyramidal fibers, for instead of crossing to the opposite side in the lower portion of the medulla oblongata, as do the fibers of the lateral fasciculus, its fibers decussate all along its course, crossing in the ventral white commissure and in the *commissural bundle* of the cord to terminate about the ventral horn cells of the opposite side. Hoche, employing Marchi's method, found that a few of its fibers terminate in the ventral horn of the same side. This conforms to the pathological and experimental evidence that there may be a few homolateral or uncrossed fibers in the crossed pyramidal tracts also. Like the crossed tract, the ventral pyramidal tract diminishes rapidly in volume as it descends the cord. Its loss is greatest in the cervical enlargement, and it is entirely exhausted in the upper half of the thoracic cord, its fibers for the most part having decussated. With the exception of the anthropoid apes and certain monkeys, none of the mammalia below man, which have been investigated, possess this ventral pyramidal tract, the decussation being completed in the medulla above.

There is also a group of cerebrospinal paths known collectively as the 'extrapyramidal system.' Instead of arising from the cerebral cortex as do the regular pyramidal fasciculi, these extrapyramidal fibers arise in the basal ganglia (corpus striatum) of the cerebrum, and some of them from the thalamus and red nucleus. There is evidence that they descend to transfer impulses to ventral horn cells of the cord and thereby mediate a control and coordination of the muscular activities induced by the regular pyramidal fibers. (See extrapyramidal system, p. 965.)

In addition to the dispositions of the dorsal root-axones given above, certain of them, either by collaterals or terminal twigs, form synapses with the cells of the dorsal nucleus (Clarke's column), which nucleus, tapering in its two ends, extends from about the seventh cervical to the third lumbar segment of the cord. The axones given off by these cells pass to the dorsolateral periphery of the lateral funiculus and there collect to form the **dorsal spinocerebellar fasciculus** (direct cerebellar tract of Flechsig). As such they ascend without interruption, and in the upper level of the medulla oblongata pass into the cerebellum by way of the inferior cerebellar peduncle or restiform body. Necessarily, this fasciculus is not evident in levels below the extent of the nucleus dorsalis.

Also situated superficially in the lateral funiculus is another ascending conduction path, and, like the dorsal spinocerebellar fasciculus, to which it is adjacent, it is also in great part at least a cerebellar connection. Its position suggests its name, **superficial ventrolateral spinocerebellar fasciculus** (**Gowers' tract**).

This tract at present does not include as great an area in transverse section as when originally described. The more internal portion of the original Gowers' tract is now given a separate significance, and will be considered separately. While the exact location in the gray column of all the cell-bodies giving origin to the superficial ventrolateral spinocerebellar fasciculus is uncertain, it is known that certain ventral horn cells contribute their axones to it. Many of its cells of origin are scattered in the area immediately ventral to the nucleus dorsalis, others in the intermediate group and mesial portion of the lateral group of ventral horn cells. In the lumbar region these cells increase in line with the position of the nucleus dorsalis above and are quite numerous; therefore, the fasciculus arises for the most part at a lower level in the spinal cord than does the direct cerebellar tract and from cells analogous to those of the nucleus dorsalis. In degenerations it becomes visible in the upper segments of the lumbar region, and has been proved to increase notably in volume as the cord is ascended. Its axones arise for the most part directly from cell-bodies of the same side of the cord, though it has been shown by several investigators that many of its axones come from the gray substance of the opposite side by way of the ventral white commissure. Terminal twigs and collaterals of the dorsal root-fibers, mostly of the same side, but occasionally from the opposite side, transfer sensory impulses to its cells of origin. At one time Gowers' tract was considered an entity, but now, even in the more limited area it occupies, it must be considered a mixture of axones of several terminal destinations or distinct neurone systems. The destination of some of its axones has not been determined with certainty. The spinocerebellar fibers proper go to the cerebellum, and there have been traced to the cortex of the superior vermis. Most of these reach the cerebellum not by way of the restiform body, as does the dorsal spinocerebellar tract, but pass on in the brain-stem to the level of the inferior corpora quadrigemina, and there turn back to join the brachium conjunctivum or superior cerebellar peduncle. Only a few of its axones leave the fasciculus lower down in the medulla, to enter the cerebellum by way of the restiform body, in company with the dorsal spinocerebellar tract. (Rossolimo, Tschermak.) Another portion of its axones are thought to reach the cerebrum, probably the nucleus lentiformis, though it has not been positively traced further than the superior corpora quadrigemina. Many axones in Gowers' tract of the cord correspond to those of the fasciculi proprii, and merely run varying distances in the cord, to turn again into its gray substance. Schaeffer followed some of these from the lumbar region up to the level of the second cervical nerve.

In the ventromesial border of Gowers' tract and immediately upon the periphery, near the anterolateral sulcus (exit of ventral nerve-roots), there is found in the higher segments of the cord a small oval bundle, the **spino-olivary fasciculus** or **Helweg's** (Bechterew's) **bundle.** The functional direction of its fibers has not been settled.

The bundle was at first thought to arise wholly within the olive in the medulla oblongata and to terminate in the cord. More recent claims assert that it arises from cell-bodies in the cord and thus is spino-olivary. By some observers it has been traced as far down as the mid-thoracic region; by others, however, only as far as the third cervical segment. Goldstein suggests that spino-olivary fibers arise from the entire length of the cord. Others hold that the fasciculus contains both spino-olivary and olivospinal fibers, the latter having the shorter extent. The olives being nuclei largely concerned with cerebellar connections, Helweg's fasciculus is probably an indirect cerebellar association with the cervical spinal cord neurones. It is composed of axones of relatively very small diameter, and it is one of the last fasciculi of the spinal cord to become medullated.

Considering Helweg's bundle as spinocerebellar, it may be noted that there are three spinocerebellar fasciculi, one for the cervical region, one for the thoracic and one for the lumbosacral region of the cord, the origin of each considerably overlapping that of the succeeding.

Situated between the lateral and ventral fasciculi proprii and the superficially placed fasciculi is an area which, in transverse sections, may be, by position, referred to collectively as the **intermediate zone.** So intermingled are the axones comprising it that it has been called the **mixed zone.** It extends through both the lateral and ventral funiculi and it contains fibers of the following functional varieties:

1. Fibers ascending and descending, belonging to the lateral and ventral fasciculus proprius, which are of longer extent and gradually course farther away from the gray substance of the cord and as such mix into the intermediate zone. It is said to contain fibers descending from the cerebellum to synapse with the neurones of spinal cord, probably directly with the ventral root or motor neurones. However, it is doubtful that there are present in the cord any fibers arising directly from cell-bodies situated in the cerebellum. None are indicated by anatomical evidence through degenerations. Some may occur as a downward continuation of the *tractus cerebellotegmentalis bulbi* claimed by some authors. It is thought that the cortical cerebrospinal (pyramidal) and rubrospinal fasciculi serve for descending impulses in responses to the several paths conveying sensory impulses from the body into the cerebellum.

2. **The rubrospinal fasciculus.**—This arises from cell-bodies in the red nucleus of the tegmentum (in the mesencephalon) and is a crossed fasciculus. Axones arising from the red nucleus of one side cross the midline in the mesencephalon (ventral tegmental decussation) and descend the medulla, ventral to the nucleus of termination of the trigeminus, into the lateral funiculus of the cord to terminate gradually about cell-bodies of the ventral horn, both those which give rise of ventral root fibers and those which contribute to the fasciculi proprii. In passing it gives off fibers to the pons and medulla. Its fibers are more thickly bundled in a crescentic area fitting onto the ventral side of the lateral cerebrospinal fasciculus, and some are said to mix into the area of this latter.

3. **The lateral vestibulospinal fasciculus** is a much smaller tract than one of similar significance in the ventral funiculus of the cord. It arises from some of the cell-bodies comprising Deiters' nucleus, the lateral nucleus of termination of the vestibular nerve, and from some of those of the spinal nucleus (nucleus of the descending root) of this nerve, all of which are in the medulla. It descends the cord, uncrossed, to terminate gradually about ventral horn cells, thus comprising a part of the apparatus for the equilibration of the body. Its fibers are thought to be more closely collected in the area immediately ventral to the rubrospinal fasciculus, but of course commingle with the latter.

4. *The corpora-quadrigemina-thalamus paths.* In the lateral, ventrolateral and medial portions of the intermediate zone are small tracts, both ascending and descending, which connect the spinal cord with the thalamus (diencephalon) and the quadrigeminate bodies of the mesencephalon. These are crossed paths. The ascending fibers arise from cell-bodies situated in the dorsal horns and carry sensory impulses received by direct synapses made by collaterals and terminal twigs of the dorsal root-fibers invading the dorsal horns. Of the descending components, fibers arising in the quadrigeminate bodies are best established. For description, the components of the paths are named as follows:

(a). **The spinal lemniscus.**—The *ascending* components of the corpora-quadrigemina-thalamus paths are known collectively as the spinal lemniscus, not because of any 'band-like' shape assumed by the tracts but because, like the well-known lemniscus in the rhombencephalon, they carry sensory impulses from the general body, received from spinal ganglion neurones, to the cerebrum. As distinguished from the former, the spinal lemniscus is claimed to carry impulses which are interpreted by the brain as sensations of pain, temperature and the finer touch sensations. They are described as ascending in three paths:

The spinotectal (spinomesencephalic) path arises from cell-bodies in the dorsal horn of one side, crosses in the commissures of the cord (chiefly the ventral), turns cephalad and accumulates into a bundle in the lateral part of the intermediate zone, medial to Gowers' tract. It terminates in the gray substance of the quadrigeminate bodies or tectum of the mesencephalon. These bodies likewise receive visual and auditory impulses for transmission to the nuclei of origin of the oculomotor and trochlear nerves. Therefore, by this path, general body-sensations may induce eye movements.

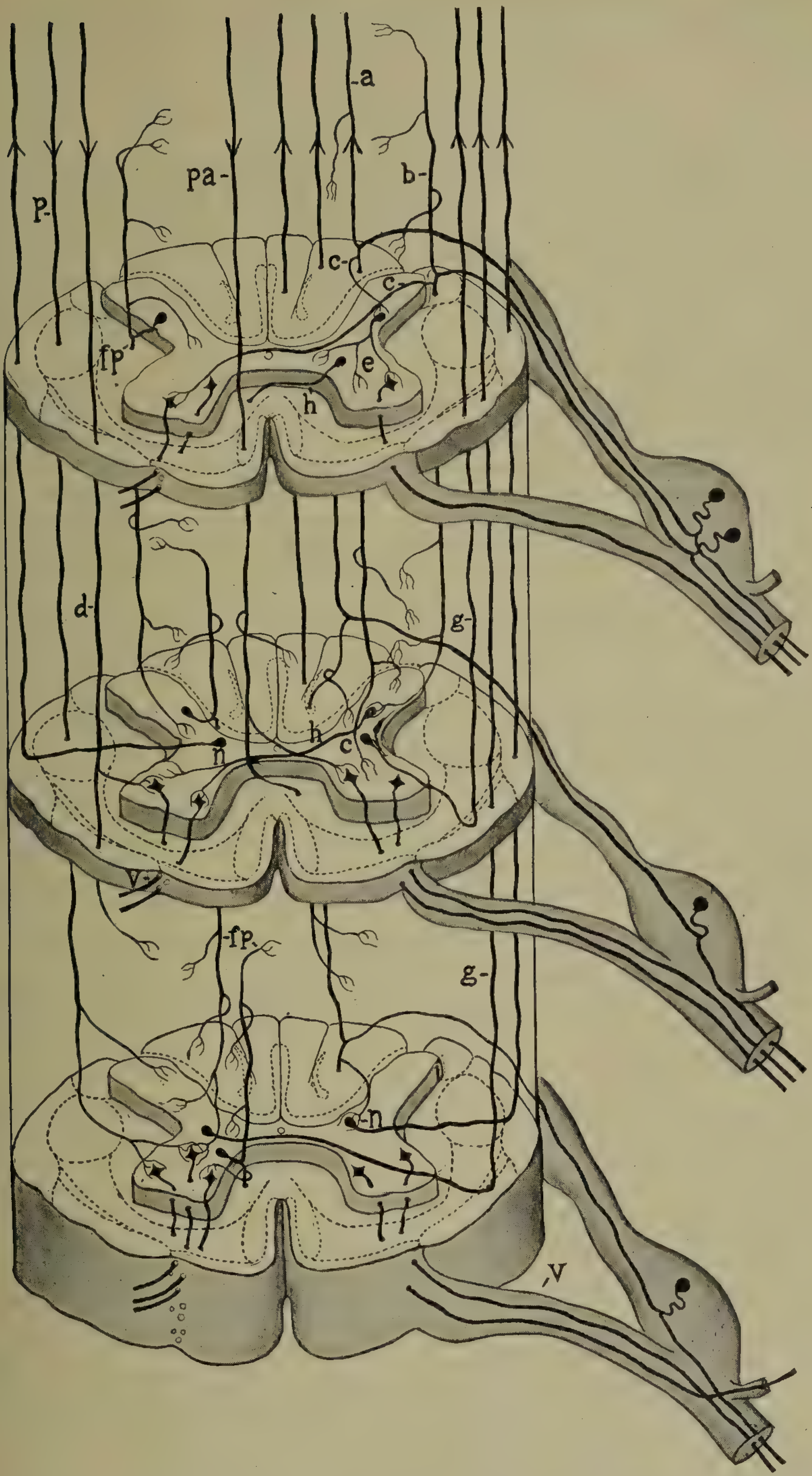


FIG. 700.—SCHEMATIC REPRESENTATION OF THE MORE IMPORTANT ARCHITECTURAL RELATIONS OF NEURONES IN THE SPINAL CORD, OMITTING THOSE INVOLVING THE MESENCEPHALON AND THALAMUS.

a, afferent (spinal ganglion) axone of spinocerebral chain with bifurcation and caudal branch; b, afferent axone coursing in Lissauer's zone, and distributed wholly within the cord; c, collaterals of a and b disposed in three ways; p, pyramidal axone in lateral (crossed) cerebrospinal fasciculus distributed to levels of grey substance; pa, axone in ventral cerebrospinal fasciculus decussating before termination; v, ventral root or motor neurones; n, nucleus dorsalis giving axone to dorsal spinocerebellar fasciculus; g, ascending neurones of Gowers' tract; d, descending axone from cerebellum (uncertain); fp, neurones of fasciculi proprii, association proper; h, commissural neurones; e, Golgi cell of type II.

The lateral and ventral spinothalamic paths both arise from cell-bodies in the dorsal horn o one side and both cross in the ventral commissures of the cord to ascend in the intermediat zone of the opposite side. The lateral ascends medial to Gowers' tract in dorsal company wit the spinotectal tract. The ventral one ascends in the ventral funciculus of the cord, medial t the spino-olivary tract and in the dorsolateral extension of the ventral vestibulospinal fasci ulus. Both terminate in the inferior and lateral nuclei of the thalamus, which nuclei in the turn give fibers which terminate in the cerebral cortex.

(b). The *descending* components of the corpora-quadrigemina-thalamus paths are as follow

The tectospinal tract (lateral tectospinal tract of Löwenthal) which arises from the fou corpora quadrigemina (but especially from the inferior pair) of the mesencephalon, decussate there in the 'fountain decussation' and descends the medulla oblongata and the spinal cord i company with the ascending fibers of the ventral spinothalamic tract. It probably distribute its impulses to the ventral horn neurones throughout the cord. Since the superior and inferio pairs of the quadrigeminate bodies receive impulses of sight and hearing respectively, it may b assumed that this tract correlates these sensations with bodily movements. (See also th extrapyramidal system.)

The sulcomarginal fasciculus, is a ventral tectospinal path. As its name implies, it des cends in the margin of the ventral median fissure of the cord, medial to the ventral cerebrospina fasciculus where this is present. It is continuous into the cord with the median longitudinal fascic ulus, one of the long association-tracts of the brain, but it chiefly contains fibers which arise fron the cell-bodies of the superior quadrigeminate body and which form part of the 'optic-acoustic reflex path' of the mesencephalon, cross the midline in the fountain decussation and descend t distribute impulses to the ventral horn of the opposite side of the cord, supposedly along it entire length. Since the superior quadrigemina have to do with sight, the sulcomarginalfascic ulus forms the chief path by which general bodily movements may be induced in response t visual impulses.

In addition to the above components of the intermediate zone, the studies of Flechsig, vo Bechterew and others suggest that the medial portion of the zone also contains fibers both ascend ing and descending, probably uncrossed, which associate the gray substance of the spinal cord with the reticular formation of the medulla oblongata. Among the regions to which it is claimed they have been traced are the nuclei of origin of the facial and eye-moving nerves and in the medulla such fibers are known to arise from the nuclei of termination of the vagus, glosso-pharyngeal, vestibular, cochlear and trigeminal nerves. All of the intermediate zone grades into the lateral and ventral fasciculi proprii. The fasciculi proprii proper, the axones nearest the gray substance, serve for the intersegmental association of the cord itself, while the inter-mediate zone may be considered as carrying axones which serve to associate more distant levels of the axis, i.e., the gray substance of the cord with that of its upward continuation into the medulla, pons, mesencephalon and thalami. In general terms, the relation of the cord to the cerebrum is a crossed relation, while its relation to the medulla, cerebellum and pons is uncrossed.

The **anterior marginal fasciculus or ventral vestibulospinal tract** forms the superficial boundary of the medial portion of the intermediate zone. It is a narrow band, on the surface of the cord, and extends medially from the medial extremity of Gowers' tract (from Helweg's bundle) to the beginning of the anterior median fissure.

The axones properly belonging to it are descending from the recipient nuclei of the vestib-ular nerve. Of these nuclei it has been held by some investigators that only Deiters' nucleus (the lateral nucleus of termination in the upper extremity of the medulla oblongata) gives origin to the axones of the anterior marginal fasciculus. Others agree with Tschermak that the superior and more laterally situated Bechterew's nucleus of the vestibular nerve also contributes axones to it, and quite logically it is held that the nucleus of the spinal root of the vestibular adds further axones. Still other investigations have suggested that a part at least of the fasciculus comes from the nucleus fastigius (roof nucleus) of the cerebellum. Since many axones from both Deiters' and Bechterew's nucleus terminate in the nucleus fastigius, the ven-tral vestibulospinal fasciculus is, in any case, a conduction path from the nerve for equilibration to the gray substance of the spinal cord. The fasciculus is said to extend as far as the sacral region of the cord, its axones terminating about the cells of the ventral horns. The greatest number of its axones terminate in the ventral horn of the lumbar and cervical enlargements. This should be since it is mainly a path from the organ of equilibration. The term 'ventral' is added to its name to distinguish it from the vestibulospinal tract described above as coursing in the lateral funiculus. It is considered an uncrossed pathway. Since to some extent the vestibular and cochlear nerves share each other's nuclei of termination, it may also distribute to the cord impulses aroused in the organ of hearing.

The **commissural bundle** is situated about the floor of the anterior median fissure, and is the most dorsal tract of the anterior funiculus. It contains decus-sating or commissural axones of four varieties.

(1) It contains the decussating axones of the ventral cerebrospinal fasciculus throughout the extent of that fasciculus; (2) it is chiefly composed of the axones of the ventral fasciculus proprius which arise in the gray substance (ventral horn) of one side, cross the midline as com-missural fibers, and course both upward and downward to be distributed to the neurones of different levels of the gray substance of the opposite side; (3) it contains decussating axones which arise from cell-bodies in the gray substance of one side and cross the midline to terminate about cell-bodies in practically the same level of the opposite side. The latter are merely axones belonging to the ventral white commissure which course without the confines of the grey

figure. (4) It carries most of the decussating fibers of the spinothalamic and spinotectal tracts, the spinal lemniscus. The commissural bundle is present throughout the length of the spinal cord, and is largest in the enlargements, i. e., where the association and commissural neurones occur in greater number generally.

SUMMARY OF THE SPINAL CORD

The spinal cord contains two general classes of axones arranged into three general systems. It contains axones which—(a) enter it from cell-bodies situated outside its boundaries, i. e., in the spinal ganglia and in the encephalon, and (b) axones which arise from cell-bodies situated within its own gray substance, some of which axones pass outside its boundaries both to the periphery and into the encephalon; some of which remain wholly within it. Its axones comprise—(1) a system for the intersegmental association of its gray substance, both ascending and descending, association proper and commissural; (2) a spinocerebral and cerebrospinal system, ascending and descending; and (3) a spinorhombencephalic (spinocerebellar and spinobulbar) and a rhombencephalospinal system, descending (bulbospinal and including rubrospinal). In general terms the relation of the cord to the cerebrum is a crossed relation, while its relation to the medulla, cerebellum and pons is uncrossed.

For these relations the gray substance of the cord contains three general classes of nerve-cells: those which give rise to the peripheral efferent or motor axones of the ventral roots; those which give rise to central axones of long course, going to the encephalon; and those which supply its central axones of short course, the association and commissural systems.

The three systems: (1) Association and commissural.—Axones of spinal ganglion (afferent) neurones bifurcate within the cord into cephalic and caudal branches which extend varying distances upward and downward and terminate, (*a*) about cell-bodies whose axones are short and terminate within the gray substance of the same side and in the same level as their cell-bodies (*Golgi neurones of type II*); (*b*) about cell-bodies whose axones pass without the gray substance, bifurcate into cephalic and caudal branches to terminate in the gray substance of the same side but in various levels above and below (association fibers in the *dorsal*, *lateral* and *ventral fasciculi proprii*); (*c*) about cell-bodies whose axones cross the midline to terminate either in the same level of the gray substance of the opposite side, or bifurcate and the cephalic and caudal branches pass in the fasciculi proprii to terminate in various levels of the gray substance of the opposite side. The longer cephalic branches of (*b*) and (*c*) may terminate in the medulla oblongata. Synapses of any of the above axones with efferent ventral root neurones complete the neurone-chains for the so-called *reflex activities*.

(2) **The cerebral system.**—(*a*) The cephalic branches of certain spinal ganglion neurones *ascend* beyond the bounds of the spinal cord to terminate within the medulla. Those ascending from the spinal ganglia of lower thoracic and lumbosacral segments accumulate medially to form the *fasciculus gracilis* which terminates in the nucleus of this fasciculus; those arising from the upper thoracic and cervical segments accumulate more laterally in the posterior funiculus to form the *fasciculus cuneatus* which terminates in the nucleus of the fasciculus cuneatus. (*b*) The impulses transferred to the neurones of these nuclei are borne across the midline and finally reach the sensory-motor area of the cerebral cortex, and cell-bodies here give rise to axones which *descend*, some decussating in the medulla to form the *lateral cerebrospinal fasciculus*, others form the uncrossed *ventral cerebrospinal fasciculus* which crosses the midline as it descends the cord, practically all crossing in the cervical region. Both of these fasciculi transfer their impulses either directly to efferent ventral horn neurones, or to association neurones and these to the efferent neurones, thus completing chains for activities of cortical control. (*c*) The cephalic and caudal branches of spinal ganglion neurones terminate about cell-bodies in the dorsal horns of the cord whose axones cross the mid-line and *ascend* laterally to terminate either in the quadrigeminate bodies (*spinotectal tract*), or in the thalamus (*spinothalamic pnths*). (*d*) Cell-bodies in the superior quadrigeminate bodies (receiving optic impulses) and in the inferior quadrigeminate bodies (mediating auditory impulses), give axones which cross the midline in the mesencephalon and *descend*, forming the *tectospinal tracts*, to terminate in contact with the efferent neurones of the cord. Axones from both sources descend in the lateral funiculus, (lateral tectospinal fasciculus) while from the superior quadrigeminate body, a separate bundle descends in the ventral funiculus as the *sulcomarginal* (*ventral tectospinal*) *fasciculus*. (*e*) The *rubrospinal tract* arises from cell-bodies in the red nucleus (in the mesencephalon), crosses the midline in the ventral tegmental decussation and descends in the lateral funiculus to transfer (probably cerebellar) impulses to the efferent neurones of the spinal cord. (*f*) The extrapyramidal fibers arise in the striate body in addition to arising in the thalamus and red nucleus and terminate in the cord to mediate control and coordination of the muscular activities induced by the regular cerebrospinal (pyramidal) fasciculi.

(3) **The rhombencephalic system.**—(*a*) The cephalic and caudal branches of spinal ganglion neurones give telodendria about the cell-bodies forming the *dorsal nucleus* of the cord (Clarke's column) and about cell-bodies situated in grey substances ventral to the dorsal nucleus and in line with it in the lumbar and sacral regions. Axones arising from the cells of the dorsal nucleus pass laterally to form the *dorsal spinocerebellar fasciculus* which *ascends* into the cerebellum by way of its inferior peduncle of the same side and terminates about cell-bodies of its cortex and its nuclei. Axones arising from near and in line with the dorsal nucleus, of both the *same*

and *opposite sides* of the cord, accumulate to form the *superficial ventrolateral spinocerebella* *fasciculus*, which *ascends* to enter the cerebellum by way of its superior peduncle and terminate about the cells of the cerebellum. (*b*) Possibly a few axones arising in the roof nucleus of th cerebellum *descend* in the *anterior marginal fasciculus* in company with the *ventral vestibulospina tract* to terminate upon the efferent neurones of the cord. (*c*) The inferior olivary nucleus, in th medulla, is a cerebellar relay and its cell-bodies are associated with the neurones of the uppe portion of the same side of the spinal cord. Whether the axones arise in the olivary nucleus o in the gray substance of the cord is uncertain, but the more usual supposition favors the cor and thus the name *spino-olivary fasciculus* is given them. (*d*) Among its other function the cerebellum is concerned with muscular tone and equilibration. The vestibular nerve is th chief afferent pathway of equilibration and a large mass of the axones arising from its nuclei o termination terminate in the cerebellum, in the roof nuclei especially. Axones arising fron cell-bodies in Deiters' nucleus (its lateral nucleus of termination) and in the nucleus of it descending root *descend* the cord in the lateral funiculus to form the *lateral vestibulospinal tract* and also in the *anterior marginal fasciculus* to form *ventral vestibulospinal tract.* Impulses born by these axones reach the efferent or motor root neurones. The rubrospinal fasciculus, mentione above, also is considered as belonging to the cerebellar system. (*e*) The fasciculi propri contain ascending and descending association-fibers between the spinal cord and the medull oblongata.

Sympathetic relations.—The cell-bodies of the efferent neurones in the ventral horns ar of two general varieties: (*a*) those whose axones terminate upon skeletal muscle (somati efferent), and (*b*) those whose axones terminate in contact with cell-bodies of sympatheti neurones, *preganglionic* or *visceral efferent neurones.* The axones of the sympathetic neurones in their turn, terminate upon cardiac and smooth muscle (motor) and in glands (secretory) Like the somatic, the visceral efferent neurones receive impulses within the ventral horn (*a*) from the cephalic and caudal branches of spinal ganglion neurones, (*b*) the descending cere brospinal fasciculi, including the extrapyramidal fibers, and (*c*) from either, by way of the fasciculi proprii and Golgi neurones of type II. Their cell-bodies are situated for the most part in the dorsal portion of the lateral horn (dorsolateral or intermediolateral group of cells), which is the only portion of the lateral horn present in the thoracic region of the cord. Many of the visceral efferent fibers leave the spinal nerves distal to the spinal ganglia, mostly in the white communicating rami, thus going to the nearest sympathetic ganglia; many pass over these ganglia and on in the sympathetic nerves, or on in the trunk of the spinal nerve and its branches, to terminate in more distant sympathetic ganglia. Some axones arising in symphatic ganglia enter the spinal cord by either the dorsal or ventral roots of the spinal nerves or by separate roots (meningeal rami) to supply the muscle of the blood vessels of the cord (fig. 818).

Functionally, the peripheral afferent (spinal ganglion) neurones have been referred to as *receptors* and the efferent or peripheral motor neurones as *effectors.* According to the tissues and organs innervated, they are grouped into (1) somatic receptors and effectors and (2) visceral receptors and effectors. The somatic tissues are the skin, including its appendages and the epithelium of the organs of special sense, the subcutaneous fascia, membranes of joints, tendons and skeletal muscle; the visceral tissues are all glands and glandular epithelium, cardiac muscle and all smooth muscle, including that of blood-vessels and hair-follicles. A somatic afferent neurone may give some of its branches in the cord for synapsis with visceral efferent neurones.

Sherrington, Head and others who hold specific or separate afferent neurones for the different sensations experienced suggest three groups of receptor neurones:

1. *An exteroceptive group*, comprising those spinal ganglion neurones whose peripheral processes collect impulses from the skin and its appendages especially (impulses aroused by stimuli outside the body), but doubtless from any or all the somatic tissues and even the visceral tissues also, and which, in the cord, transfer these impulses to those cell-bodies in the dorsal horn whose axones cross the midline to form the two spinothalamic tracts of the opposite side. The lateral of these tracts is claimed to carry sensations of pain and heat and cold, while to the ventral are given sensations of touch and pressure and both are included within the so called *spinal lemniscus.* These tracts terminate in the ventral and lateral nuclei of the thalamus. In passing, each may give collaterals which form synapses with the nuclei of origin of the motor cranial nerves. The inferior and lateral nuclei of the thalamus send axones to the cerebral cortex and the corticospinal impulses aroused in response may descend the cord by way of the cerebrospinal fasciculi. The functions of the neurone chains of this group are classed within 'conscious phenomena.' The neurones of the eye and cochlea are included among the exteroceptive neurones of the cranial nerves.

(2) *A proprioceptive group.* This group is subdivided into two classes: (*a*) spinal ganglion neurones which collect impulses from the somatic tissues (skin, tendons, joints, skeletal muscle, etc.) and whose cephalic branches within the cord form the fasciculus gracilis and fasciculus cuneatus. The nuclei of termination of these fasciculi in the medulla give rise to the medial lemniscus of the opposite side and this transfers the impulses to the ventral thalamic gray substance, whose cell-bodies in turn send axones to the cerebral cortex. Corticospinal impulses, which descend in response, are distributed to the cord by the cerebrospinal fasciculi. The neurone chains included are claimed to mediate tactile sensations of position and spatial relations and to make possible motor control, aiding also in regulating reactions mediated through the exteroceptive group. Most of the functions of this class are likewise within consciousness. (*b*) spinal ganglion neurones which collect impulses from the somatic tissues, especially from tendons, joints, skeletal muscle and muscle-fasciæ, and which in the spinal cord give collaterals and terminal twigs to the cell-bodies giving origin to the dorsolateral and superficial ventrolateral spinocerebellar fasciculi. The chief functions of the cerebellum are coördination of muscular contractions and maintenance of muscular tone. Impulses from it are distributed to the cord by way of the rubrospinal and cerebrospinal fasciculi. The functions of the neurones of this class are considered unconscious. The neurones of the vestibular nerve (supplying the membranous laybrinth, exclusive of cochlea) are considered proprioceptive.

3. *An interoceptive group* (visceral receptors), comprising those spinal ganglion neurones which collect impulses from the visceral tissues (the epithelium of the digestive canal, including the infoldings of the skin continuous with it, from all glands, from the mesothelium lining the cavities of the body, from blood-vessels and probably from both smooth and cardiac muscle), and which in the cord give collaterals and terminal twigs for synapses with the dorsolateral (visceral efferent) cell-group of the ventral horn. These cell-bodies give rise to ventral root preganglionic axones which form synapses in the sympathetic ganglia, the cells of which in turn give off sympathetic or postganglionic axones for the secretory and motor innervation of glands and smooth muscle (visceral effectors). These afferent or visceral receptors also give branches which form synapses with the neurones of the fasciculi proprii of the cord, the longer of which may transfer impulses to visceral efferent or preganglionic neurones in the cranial nerves. Certain of the cranial nerves, the vagus especially, are very rich in both visceral receptors and visceral effectors. The central control, largely inhibitory, of the muscle of the heart and of many of the blood-vessels of the body, of the lungs, esophagus, stomach and intestine is mediated chiefly by the vagus. (See figs. 815 and 818.)

It must be remembered that the above three general groups of neurones functionally and anatomically overlap each other. An afferent neurone of either the exteroceptive or proprioceptive group may, in the cord, give some of its many terminals to form synapses with visceral efferent neurones, and a visceral receptor may give a branch in the cord whose synapsis will make it a chain from the peripheral structures to the cerebral cortex, bringing sensations aroused in the visceral organs into the domain of consciousness, as sensations of pain, pressure, temperature, etc. Also, the contention for a specific afferent neurone for conveying each of the many varieties of sensation, verbally indicated by man, is not satisfactorily supported. There are peculiar anatomical differentiations of peripheral tissue-elements (sense organs) of such character and arrangement as to be especially acted upon, specifically irritated, each by a cer-

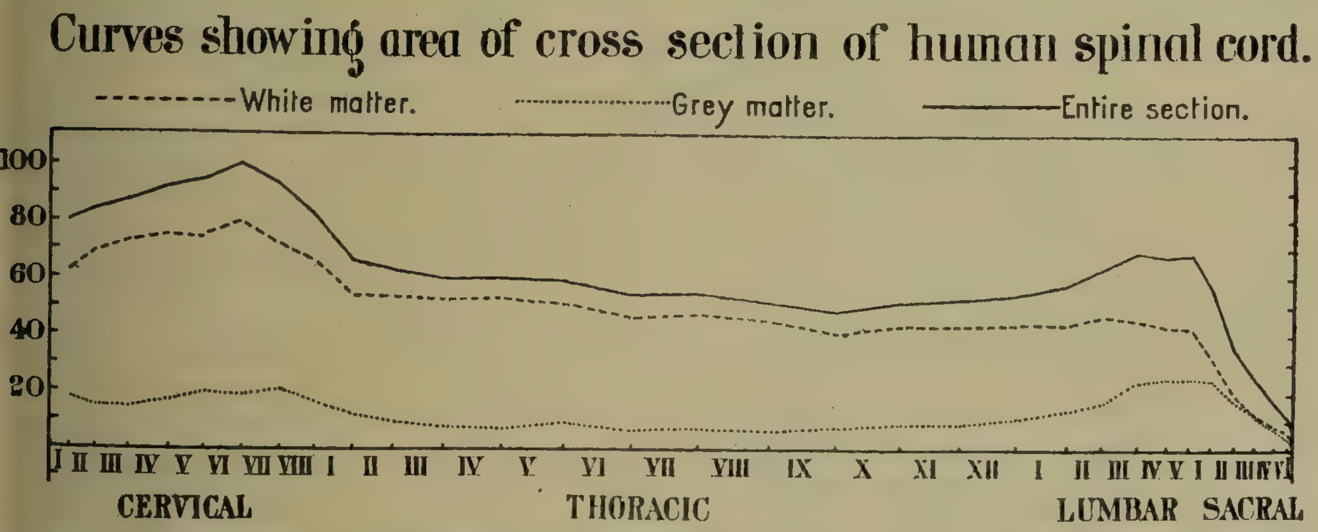


Fig. 701.—Graphic Representation of the Varying Amounts of Gray and White Substance and of the Variations in Area of Entire Sections of the Different Segments of the Spinal Cord. (From Donaldson and Davis.)

(Based upon measurements from several adult human spinal cords.)

tain form of stimuli. It is probable that impulses may be aroused in any spinal ganglion neurone by any form of stimulus. These impulses, reaching the cerebral cortex or entering 'consciousness', are analyzed and interpreted there according to the character, quality and intensity of the stimulus applied and according to the locality of its application. Certain tracts in the cord carry impulses destined for certain areas of the cerebral cortex especially devoted to the analysis of certain forms of stimuli.

In transverse sections of the spinal cord (figs. 695, 701), the relative area of white substance as compared with that of gray increases as the cord is ascended. The gray substance predominates in the conus medullaris and lower lumbar segments. The white substance begins to predominate in the upper lumbar segments, not because of the increased presence of ascending and descending cerebral and cerebellar axones, but because of the increased volume of the fasciculi proprii coincident with the greater mass of gray substance to be intersegmentally associated in this region. In the thoracic region the greatly predominating white substance is composed mostly of the axones of long course. The absolute area of each substance varies locally, both being greatest in the enlargements. The greatly increased absolute amount of white substance in the cervical region is due both to the greater accumulation of cerebral and cerebellar axones in this region and to the increased volume of the fasciculi proprii necessary for the increased amount of gray substance of the cervical enlargement.

ORDER OF MEDULLATION OF THE FASCICULI OF THE CORD

The axones of the spinal cord begin to acquire their myelin sheaths during the fifth month of intrauterine life and myelinization is not fully completed till between the fifteenth and twentieth

years. In general, axones which have the same origin and the same locality of termination– the same function—acquire their sheaths at the same time. While it has been proved that th medullary sheath does not necessarily precede the functioning of an axone, it may be said tha those fasciculi which first attain complete and definite functional ability are the first to becom medullated. At birth all the fasciculi of the spinal cord are largely medullated except the spino olivary fasciculus, and occasionally the lateral and ventral cerebrospinal tracts. The latte tracts vary considerably and in general may be said to become distinguishably medullate between the ninth month (just before birth) and the second year. As indicated by thei medullation, those axones by which the cord is enabled to function as an organ *per se*, that is the axones making possible the simpler reflex activities, complete their development befor those axones which involve the brain with the activities of the cord.

According to Flechsig and van Gehuchten, and investigators succeeding them, the followin is the order in which the axones of the cord become medullated:

(1) The afferent and efferent nerve-roots and commissural fibers of the gray substanc

(2) The fasciculi proprii, first the ventral, then the lateral, and last the dorsal fasciculu proprius.

(3) The fasciculus cuneatus (Burdach's column) and Lissauer's zone—the area of thos ascending spinocerebral fibers which run the shorter course and which convey impulses fro the upper limbs, neck and thorax (including chains for the earlier respiratory reflexes).

(4) Fasciculus gracilis (Goll's column).

(5) The dorsal spinocerebellar fasciculus (direct cerebellar tract).

(6) The superficial ventrolateral spinocerebellar fasciculus (Gowers' tract).

(7) The lateral cerebrospinal fasciculus (crossed pyramidal) and the ventral cerebrospina fasciculus (direct pyramidal tract).

(8) The spino-olivary fasciculus.

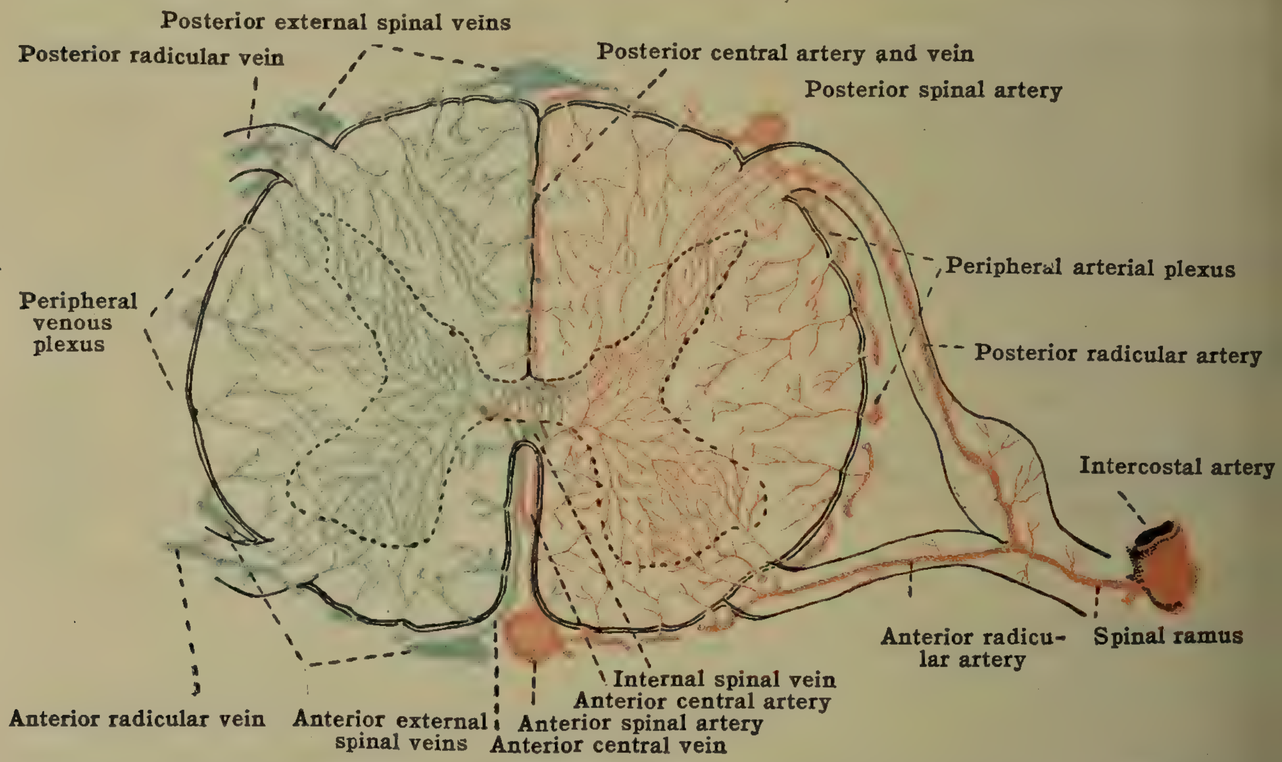


FIG. 702.—SEMI-DIAGRAMMATIC REPRESENTATION OF THE BLOOD-SUPPLY OF THE SPINAL CORD.

The remaining fasciculi are so mixed with other axones that it is difficult to determine th sequence of their medullation. The fasciculi containing them also contain axones of the variety in the fasciculi proprii and so show medullation early.

BLOOD-SUPPLY OF THE SPINAL CORD

The **spinal rami** of the sacral, lumbar, intercostal, or vertebral arteries, as the case may be, accompany the spinal nerves through the intervertebral foramina, traverse the dura mate and arachnoid, and each divides into a **dorsal** and a **ventral radicular artery.** These accompany the nerve-roots to the surface of the cord, and there break up into an anastomosing plexus in the pia mater. From this superficial plexus are derived three tortuously coursing longitudinal arteries and numerous independent central branches, which latter penetrate the cord directly. Of the longitudinal arteries, the **anterior spinal artery** zigzags along the anterior median fissure and gives off the anterior central branches, which pass into the fissure and penetrate the cord. These branches give off a few twigs to the white substance in passing, but their most partial distribution is to the ventral portion of the gray substance. The two **posterior spinal arteries**, one on each side, course near the lines of entrance of the dorsal root-fibers. They each branch and anastomose, so that often two or more posterior arteries may appear in section upon either side of the dorsal root. These give off transverse or central twigs to the white substance, but especially to the gray substance of the dorsal horns. Of the remaining central branches many enter the cord along the efferent fibers of the ventral roots, and are distributed chiefly to the grey substance; others from the superficial plexus throughout penetrate the cord and break up into capillaries within the white substance. Some of the terminal twigs of these also enter the gray substance. The blood-supply of the gray substance is so much more abundant than that

of the white substance that in injected preparations the outline of the gray figure may be easily distinguished by its greater abundance of capillaries alone. The central branches are of the terminal variety. In the white substance the capillaries run for the most part longitudinally, or parallel with the axones. The radicular arteries in passing give twigs supplying the spinal ganglia and the nerve-roots. The anterior spinal artery anastomoses with the vertebral arteries on the ventral surface of the medulla oblongata, making continuous the sources of blood for cord and brain (fig. 536).

The *venous system* is quite similar to the arterial. The blood of the central arteries is collected into corresponding central venous branches which converge into a superficial venous plexus in which there are six main longitudinal channels, one along the posterior median sulcus, one along the anterior median fissure, and one along each of the four lines of the nerve-roots. These comprise the **posterior and anterior external spinal veins** (fig. 702).

The **internal spinal veins** course along the ventral surface of the gray commissure, and arise from the convergence of certain of the twigs flowing into the *anterior central veins*. The *posterior central vein* courses along the posterior median septum in company with the posterior central artery, and empties into the *median dorsal vein*. The venous system communicates with the coarser extradural or internal vertebral plexus chiefly by way of the **radicular veins**.

II. THE BRAIN OR ENCEPHALON

The brain is that greatly modified and enlarged portion of the central nervous system which is enclosed within the cranial cavity. It is surrounded and supported by continuation over it of the same three membranes (meninges) that envelop the spinal cord. While there is a considerable subarachnoid space, the brain more nearly fills its cavity than does the spinal cord.

The average length of the brain is about 165 mm. and its greatest transverse diameter about 140 mm. It averages longer in the male than in the female. Exclusive of its dura mater, the normal brain weighs from 1100 to 1700 gm. (40–60 oz.), varying in weight with the stature of the individual or with the bulk of the tissues to be innervated. Its average weight is 1360 gm. (48 oz.) in males and 1250 gm. (44 oz.) in females. It averages about fifty times heavier than the spinal cord, or about 98 per cent. of the entire central nervous system. Owing to its precocious growth it is at birth relatively much larger than at maturity. At birth it comprises about 13 per cent. of the total body-weight, while at maturity it averages only about 2 per cent. of the weight of the body. Its specific gravity averages 1.036. In proportion to the body-weight the brain-weight averages somewhat higher in smaller men and women. Some very small dogs and monkeys and some mice have brains heavier in proportion to body-weight than does man.

The minimal weight of the adult brain compatible with human intelligence may be placed at from 950 to 1000 grams. Above the minimal, there is only a general relation between the degree of intelligence and the weight of the brain, owing to the fact that several factors (large statue, congenital defects, disease) may be coincident with large brains. It may be said in general, however, that the average brain-weight of eminent men is above the general average. Some men judged eminent have had brains weighing less than the general average. Of the records generally accepted, the greatest brain-weight for eminent men is 2012 grams, recorded for the poet and novelist, IvanTourgenieff. The trustworthiness of this weighing is doubted by some authorities. From the undisputed records the following may be taken: Cuvier, 1830 grams; John Abercrombie, 1786 grams; Thackeray, 1658 grams; Kant, 1600 grams; Spurzheim, 1559 grams; Daniel Webster, 1518 grams; Louis Agassiz, 1495 grams; Dante, 1420 grams; Helmholtz, 1440 gram; Goltz, 1395 grain; Liebig, 1352 grams; Walt Whitman, 1282 grams; Gall, 1198 grams. In the average brain-weights for the races that for the Caucasian stands highest, the Chinese next, then the Malay, followed by the Negro, with the Australian lowest. Size or volume of the cranium is but a general index for the size of the brain. The shape and thickness of the skull and of the subarachnoid space vary. Todd found that of two heads of the same size, one may carry a brain with a volume as much as 200 cc. greater than the other.

The differences between the meninges of the brain and those of the spinal cord occur chiefly in the dura mater. The cranial *dura mater* is about double the thickness of the spinal dura, and consists of two closely adhering layers, the outermost of which is the internal periosteum of the cranial bones, while that of the cord is entirely separate from the periosteum lining the vertebral canal. The semilunar ganglion and the hypophysis cerebri are pocketed between the two layers of the cranial dura. The inner layer is duplicated in places into strong partitions which extend between the great natural divisions of the encephalon. Of these, the sickle-shaped *falx cerebri* extends between the hemispheres of the cerebrum, the crescentic *tentorium cerebelli* extends between the cerebellum and the overlapping posterior portion of the cerebrum, and the smaller *falx cerebelli* occupies the notch between the hemispheres of the cerebellum. Contained within these partitions of the dura mater are the great collecting venous sinuses of the brain. These will be considered in the more detailed description of the cranial meninges.

General topography.—In its superior aspect or **convex surface** the encephalon is oval in contour, with its **frontal pole** usually narrower than its **occipital pole.** Viewed from above, the **cerebrum** comprises almost the entire dorsal aspect, the occipital lobes overlapping the **cerebellum** to such an extent that only the lateral and lower margins of the cerebellar hemispheres are visible. The **great longitudinal fissure** of the cerebrum separates the cerebral hemispheres.

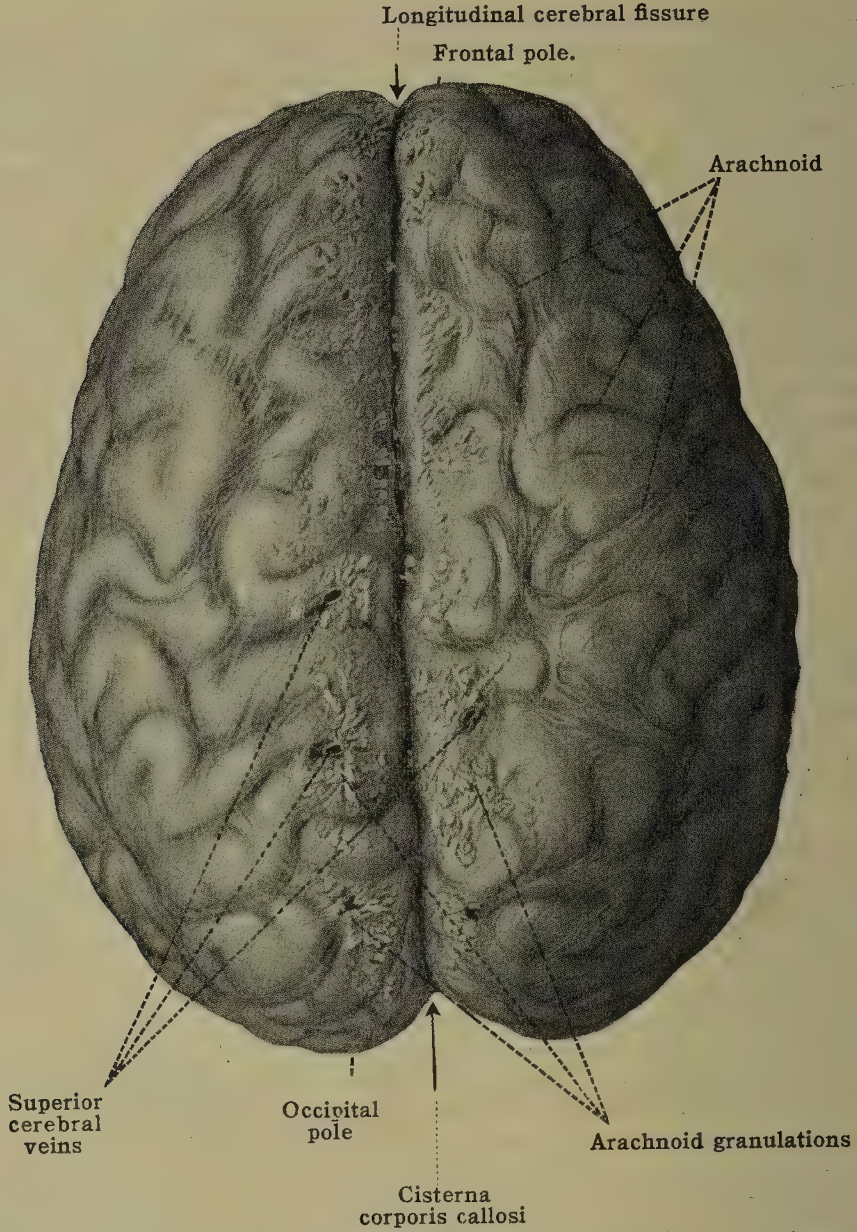


Fig. 703.—Superior View of the Cerebrum, Showing the Cranial Arachnoid. (From Sobotta-McMurrich, Atlas of Human Anatomy.)

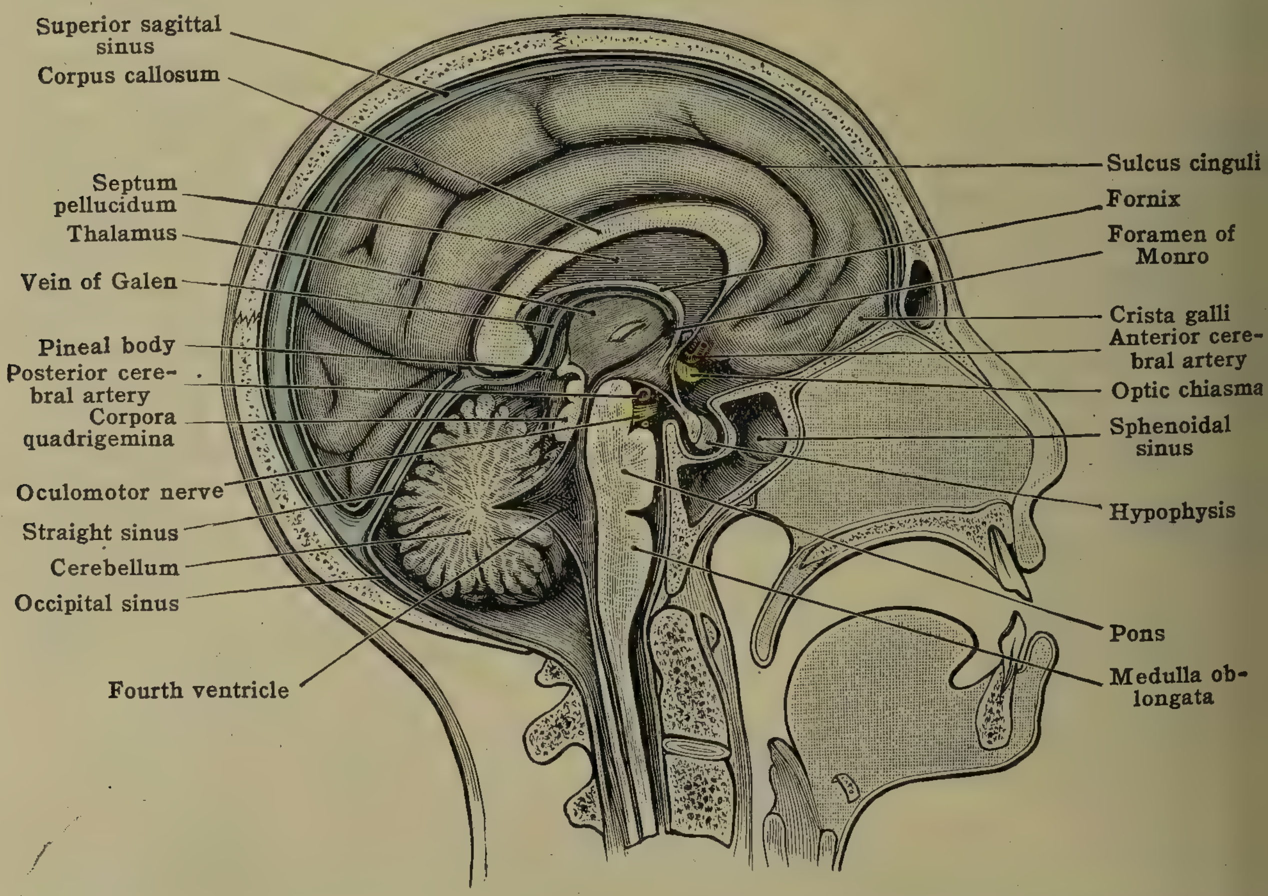


Fig. 704.—Diagram of Median Section of Head of Female of Thirty-five Years

Laterally the **temporal lobes,** with their rounded anterior extremities, the **temporal poles,** are each separated from the frontal and **parietal lobes** above by the **lateral cerebral fissure** (fissure of Sylvius). In the depths of this fissure and overlapped by the temporal lobe is situated the **insula, or island of Reil** (central lobe).

The surface of each cerebral hemisphere is thrown into numerous folds or curved elevations, the **gyri cerebri** or convolutions, which are separated from each other by slit-like fissures, the **sulci cerebri.** The gyri (and sulci) vary greatly in length, in depth, and in their degrees of curvature. The larger and deeper of them are similar in the two hemispheres; most of them are individually variable, but each gyrus of one hemisphere is homologous with that of the like region of the other hemisphere. By gently pressing open the great longitudinal fissure, the **corpus callosum,** the chief commissural pathway between the cerebral hemispheres, may be seen. The occipital margin of this large transverse band of white substance is rounded and thickened into the **splenium** of the corpus callosum, while its frontal margin arches downward to form its **genu** and continues downward and backward to form its **rostrum.**

The **base of the encephalon** (fig. 705) is more irregular than the convex surface, and consists of a greater variety of structures. In the midline between the frontal lobes appears the anterior and inferior extension of the great longitudinal fissure. When the margins of this are separated, the outer aspect of the **rostrum** of the *corpus callosum,* the downward continuation of the curve of the genu, is exposed.

The inferior surface of each frontal lobe is concave, due to its compression upon the superior wall of the orbit. The *orbital gyri* with their respective *orbital sulci* occupy this concave area.

The cranial nerves [nervi cerebrales].—Along the mesial border of each orbital area, and parallel with the great longitudinal fissure, lie the **olfactory bulbs,** continued into the **olfactory tracts.** Each olfactory bulb is the first central connection or the 'nucleus of termination' of the **olfactory nerve,** the first of the cranial nerves. A few fine filaments of this nerve may often be discerned penetrating the ventral surface of the bulb. The olfactory bulb and tract lie in the *olfactory sulcus,* which forms the lateral boundary of the *gyrus rectus,* the most medial gyrus of the inferior surface of the frontal lobe. Upon reaching the parolfactory area of Broca, or the region about the posterior extremity of the gyrus rectus, each olfactory tract undergoes a slight expansion, the **olfactory tubercle,** and then divides into three roots or **olfactory striæ**—a medial, an intermediate, and a lateral, which comprise the **olfactory trigone.** The striæ begin their respective courses upon the **anterior perforated substance,** an area which contains numerous small foramina through which the anterolateral group of central cerebral arteries enters the brain. This region forms the anterior boundary of that area of the base of the encephalon in which the substance of the brain becomes continuous across the midline.

At the posterior boundary of the anterior perforated substance the **optic nerves** come together and fuse to form the **optic chiasma.** Thence the **optic tracts** disappear under the poles of the temporal lobes in their backward course to the *thalami,* the geniculate bodies and superior quadrigeminate bodies.

Immediately behind the optic chiasma occurs that diverticulum from the floor of the third ventricle known as the **tuber cinereum.** It is continuous by its tubular stalk, the **infundibulum,** with the **hypophysis** or pituitary body, which occupies its special depression (sella turcica) in the floor of the cranium and is usually torn from the encephalon in the process of its removal. Behind the tuber cinereum are the two **mammillary bodies** (corpora albicantia), each of which is connected with the fornix, one of the larger association fasciculi of the cerebrum. The **peduncles of the cerebrum** (crura cerebri) are the two great funiculi which associate the cerebral hemispheres with all the structures below them. They diverge from the anterior border of the **pons** (Varoli) and, one for each hemisphere, disappear under the poles of the temporal lobes. The pons (with the brachia pontis or middle cerebellar peduncles) is chiefly a bridge of white substance or a commissure between the cerebellar hemispheres.

The **oculomotor** or third pair of cranial nerves make their exit from the **posterior perforated substance** in the **interpeduncular fossa** just behind the corpora mammillaria.

The **trochlear nerves** come to view on the basal surface around the lateral aspects of the cerebral peduncles along the anterior border of the pons. They

actually emerge from the dorsal surface just inferior to the posterior quadrigeminate bodies and decussate while approaching this surface. The trochlear is the smallest of the cranial nerves, and the only pair arising from the dorsal aspect of the brain and the only pair thus decussating.

The **trigeminus,** or fifth cranial nerve, is the largest. It penetrates the pons to find its terminal nuclei in the depths of the brain-stem. It is a purely sensory nerve, but it is accompanied by the much smaller **masticator nerve** which is motor and is usually referred to as the motor root of the trigeminus.

Five pairs of cranial nerves are attached to the brain-stem along the inferior border of the pons: the **abducens** nerve, which is motor, emerges near the midline; the **facial,** motor, emerges from the more lateral aspect of the brain-stem; the **glossopalatine** or the intermediate nerve of Wrisberg, largely sensory, is attached in company with the facial; and entering the extreme lateral aspect of the stem are the **cochlear** and **vestibular** nerves. These latter two, when taken together as one, are known as the **acoustic** (auditory) or eighth cranial nerve.

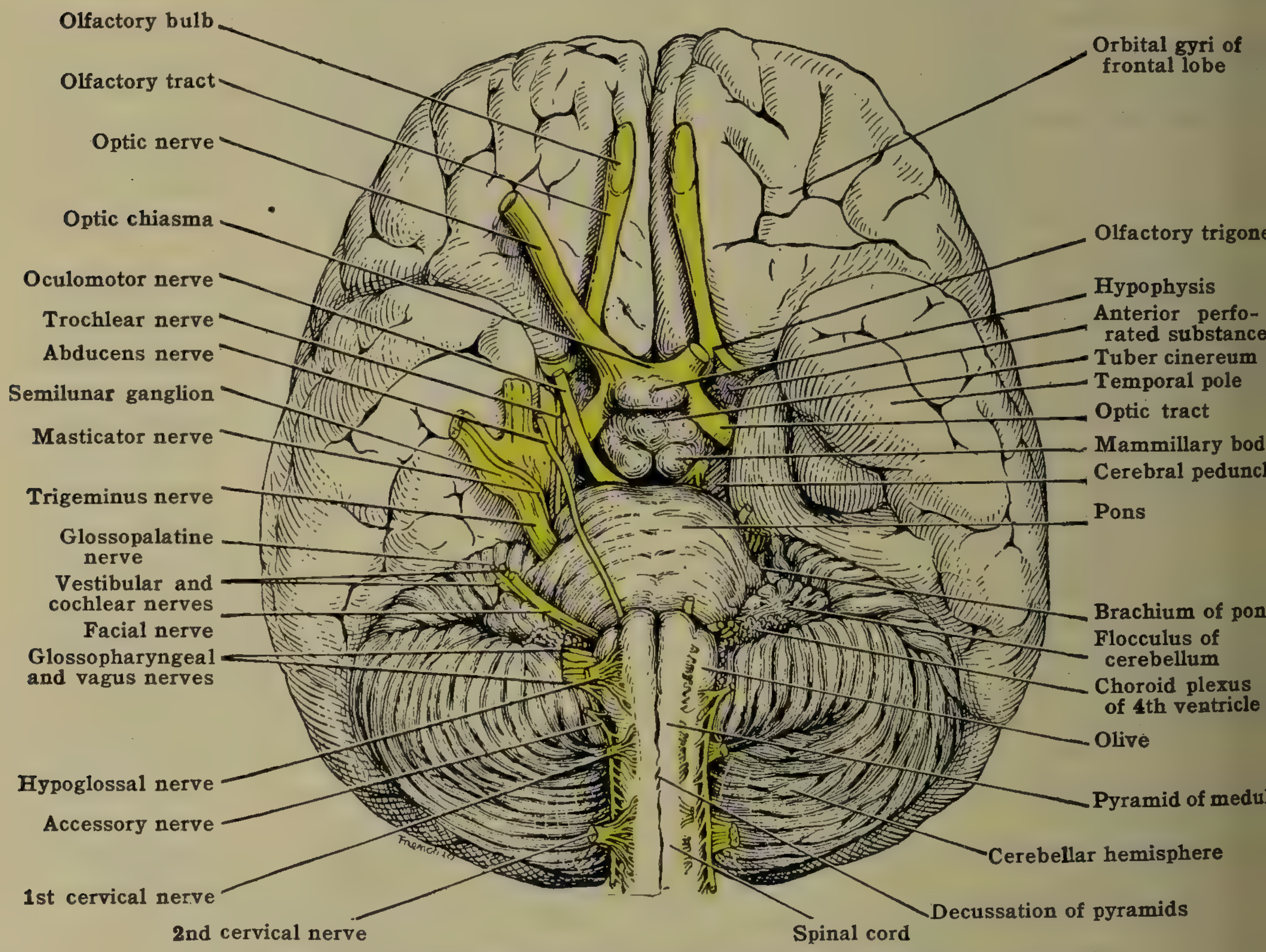


Fig. 705.—View of the Base of the Brain. (Spalteholz's Atlas.)

They are both purely sensory. The cochlear nerve courses for the most part laterally and dorsally around the *inferior cerebellar peduncle,* giving to the latter the ropelike appearance from which it derives its name, **'restiform body.'**

The remaining four pairs of the cranial nerves are attached directly to the **medulla oblongata.** This comprises that portion of the brain-stem beginning at the inferior border of the pons above, and continuous into the first segment of the spinal cord below. On its ventral surface the **pyramids** and the **olives** (olivary nuclei) are the two most prominent structures. The pyramids, which are continuous below into the pyramidal (cerebrospinal) tracts of the spinal cord, form the two tapering prominences along either side of the anterior median fissure; the olives are the oblong oval elevations situated between the pyramids and the restiform bodies, and each is the superficial indication of the inferior olivary nucleus.

The **glossopharyngeal,** the **vagus** (pneumogastric), and the **spinal accessory** nerves are attached along the lateral aspect of the medulla oblongata in line with the facial nerve and between the olive and the restiform body. The spinal accessory, purely motor, is assembled from a series of rootlets which emerge from the lateral aspect of the first three or four cervical segments of the spinal

cord, as well as from the medulla. It becomes fully formed before reaching the level of the olive, and passes lateralward in company with the vagus and further on joins the latter in part. The root-filaments of the vagus and glossopharyngeal are arranged in a continuous series, and, if severed near the surface of the medulla, those belonging to the one nerve are difficult to distinguish from those belonging to the other. Both of these are mixed motor and sensory.

The **hypoglossal**, purely motor, emerges as a series of rootlets between the pyramid and the olive. Thus it arises nearer the midline, and in line with the abducens, trochlear, and oculomotor.

If the occipital lobes be lifted from the superior surface of the cerebellum, the tentorium cerebelli removed, the **quadrigeminate bodies** of the mesencephalon may be observed. These are situated above the cerebral peduncles, at the level of the ventral appearance of the oculomotor and trochlear nerves. Resting upon the superior pair of the quadrigeminate bodies [colliculi superiores] is the **pineal body** (epiphysis), and just anterior to this is the cavity of the third ventricle, bounded laterally by the thalami and roofed over by the **tela chorioidea of the third ventricle** (velum interpositum).

By separating the inferior margin of the cerebellum from the dorsal surface of the medulla oblongata the lower portion of the **fourth ventricle** (rhomboid fossa) may be seen. The **cisterna cerebellomedullaris,** the locally enlarged subarachnoid space in this region, is occupied in part by a thickening of the arachnoid. This is continuous with the tela chorioidea and the choroid plexus of the fourth ventricle. The former roofs over the lower portion of the fourth ventricle, and passing through it in the medial line is the passage, the **foramen of Magendie,** by which the cavity of the fourth ventricle communicates with the subarachnoid space. Also there are two lateral apertures into the ventricle, one on either side. The fourth ventricle, as it becomes continuous with the central canal of the spinal cord terminates in a point, the **calamus scriptorius.** From the inferior surface, the cerebellar hemispheres are more definitely demarcated, and between them is the **vermis** or central lobe of the cerebellum.

Divisions of the Encephalon

The encephalon as a whole is developed from a series of expansions, flexures, and thickenings of the wall of the cephalic portion of the primitive neural tube, the three primary brain vesicles. Being continuous with the spinal cord, it is arbitrarily considered as beginning just below the level of the decussation of the pyramids, or at a line drawn transversely between the decussation of the pyramids and the level of the first pair of cervical nerves.

In its general conformation four natural divisions of the brain are apparent; the two most enlarged portions—(1) the cerebral hemispheres and (2) the cerebellum; (3) the midbrain (mesencephalon) between the cerebral hemispheres and the cerebellum, and (4) the medulla oblongata, the portion below the pons and above the spinal cord (fig. 681). However, the most logical and advantageous arrangement of the divisions and subdivisions of the encephalon is on the basis of their development from the embryonic brain vesicles. (See figs. 677, 706, 707.) On this basis, for example, both the medulla oblongata and the cerebellum with its pons are derived from the posterior of the primary vesicles, and are, therefore, included in a single gross division of the encephalon, viz., the *rhombencephalon.* In the outline on p. 874 the anatomical components of the encephalon are arranged with reference to the three primary vesicles from the walls of which they are derived, and the primary flexures and thickenings of the walls of which they are elaborations.

During the early growth of the neural tube its basal or ventral portion and the lateral portions acquire a greater thickness than the roof of the tube, and thus the tube is longitudinally divided into a basal or **ventral zone** and an alar or **dorsal zone.** This is especially marked in the brain-vesicles. Structures arising from the dorsal zone begin as localized thickenings of the roof. For example, in the rhombencephalon the greater part of the medulla oblongata and of the pons region is derived from the ventral zone, while the cerebellum is derived from the superior part of the dorsal zone of the posterior vesicle. The first of the flexures occurs in the region of the future mesencephalon, and is known as the **cephalic flexure;** next occurs the **cervical flexure,** at the junction with the spinal cord; third, the **pontine flexure,** in the region of the future fourth ventricle. Both the cervical and pontine flexures, while having a significance in the growth processes, are almost entirely obliterated in the later growth of the encephalon.

OUTLINE OF THE DIVISIONS OF THE ENCEPHALON

(The numerals refer to like numerals in figs. 706, 707 and 708.)

- Encephalon (Brain)
  - Cerebrum.
    - Prosencephalon (Forebrain) — Anterior primary vesicle.
      - Telencephalon (Endbrain)
        - Optic portion of hypothalamus, VI_1 (Hypophysis),
        - Optic nerves and retinæ. VI,
        - *Anterior portion of third ventricle.*
        - Cerebral hemispheres
          - Corpus striatum, VI_2,
          - Olfactory bulb and tract, VI_3,
          - Cerebral cortex (pallium), VI_4,
          - *Lateral ventricles.*
      - Diencephalon (Interbrain)
        - Thalamencephalon
          - Thalamus, V_2,
          - Metathalamus, V_3 (Geniculate bodies),
          - Epithalamus, V_4 (Epiphysis or pineal body).
        - Mammillary portion of hypothalamus, V_1,
        - *Posterior portion of third ventricle.*
    - Mesencephalon (Midbrain) — Middle primary vesicle.
      - Quadrigeminate bodies (colliculi), IV_2,
      - Cerebral peduncles (crura), IV_1,
      - Posterior perforated substance, IV,
      - *Aquæductus cerebri (Sylvii).*
  - Rhombencephalon — Posterior primary vesicle.
    - Isthmus rhombencephali — III.
      - Superior cerebellar peduncles,
      - Anterior medullary velum,
      - Cerebral peduncles,
      - *Superior part of fourth ventricle.*
    - Metencephalon (Hindbrain)
      - Cerebellum, II_2,
      - Pons (Varoli), II_1,
      - *Middle part of fourth ventricle.*
    - Medulla oblongata—myelencephalon, I. (Afterbrain) *Inferior part of fourth ventricle.*

The location of the development of the various parts of the encephalon may be determined, and their elaboration and changes in shape and position may be traced by comparing the accompanying figs. 706, 707, 708. The reference numbers in the last three figures correspond with the like numerals after the names of the parts on p. 874 in the outline of the divisions of the encephalon. The more detailed subdivisions of the parts will be met with in their individual descriptions.

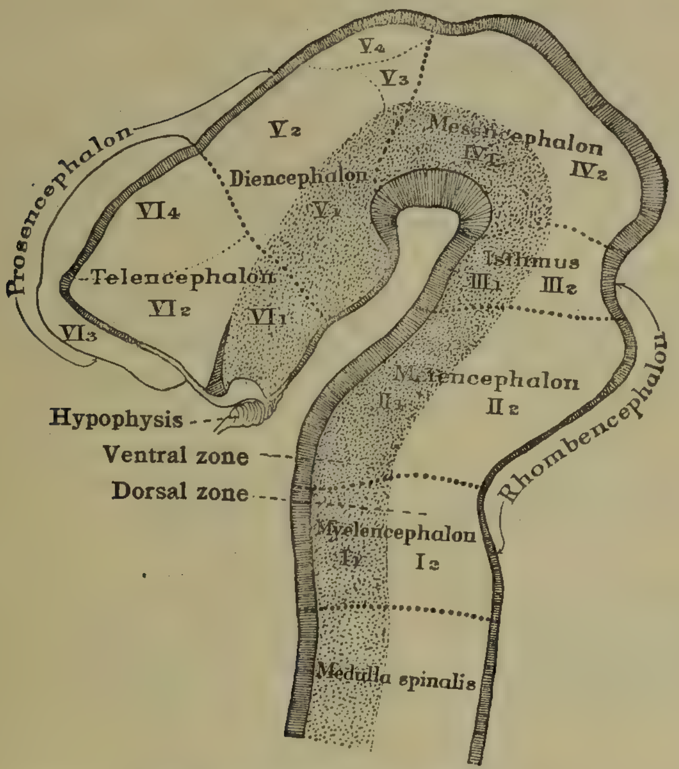


FIG. 706.—MEDIAN SAGITTAL SECTION THROUGH EMBRYONIC HUMAN BRAIN AT END OF FIRST MONTH. (After His.)

(Showing the localities of origin of the derivatives of the vesicles named in outline on p. 874.)

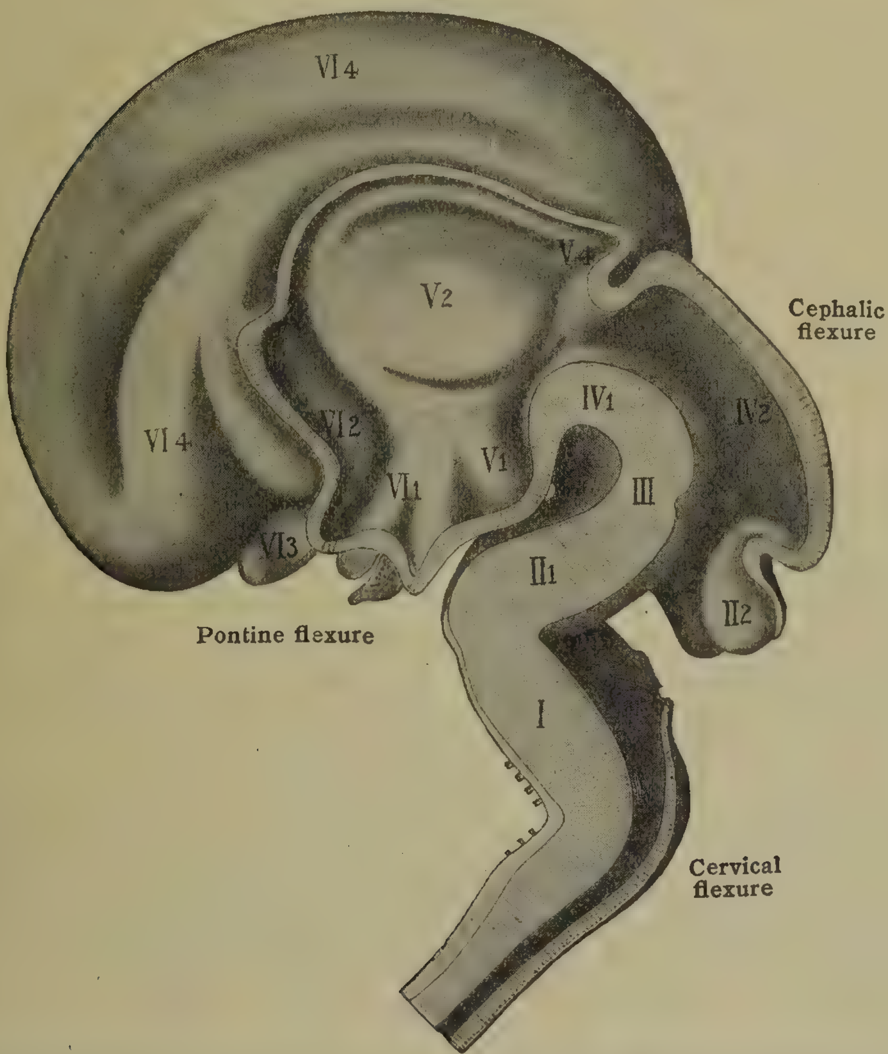


FIG. 707.—SAGITTAL SECTION OF BRAIN OF HUMAN FETUS OF THE THIRD MONTH. (After His.)

(Reference numerals correspond with those of fig. 706 and those after names of parts in outline on p. 874.)

THE RHOMBENCEPHALON

1. THE MEDULLA OBLONGATA

The **medulla oblongata** [myelencephalon] is the upward continuation of the spinal cord. It is only about 25 mm. long, extending from just above the first cervical nerve (beginning of the first cervical segment of the spinal cord) to the inferior border of the pons. It lies almost wholly within the cranial cavity, resting upon the superior surface of the basal portion of the occipital bone, with its lower extremity in the foramen magnum. Its weight is from 6 to 7 gm. or about one-half of 1 per cent. of the central nervous system. It is a continuation of the spinal cord, and more. It contains structures continuous with and homologous to the structures of the spinal cord, and in addition it contains structures which have no homologues in the spinal cord. Due in part to these additional structures, the medulla, as it approaches the pons, rapidly expands in its dorsoventral and especially in its lateral diameter. With it are associated nine of the pairs of cranial nerves.

On its **ventral aspect** (figs. 705, 747) the continuation of the anterior median fissure of the spinal cord becomes broader and deeper because of the great height attained by the **pyramids.** At the level at which the pyramids emerge from the pons, the region in which they are largest, the fissure terminates in a

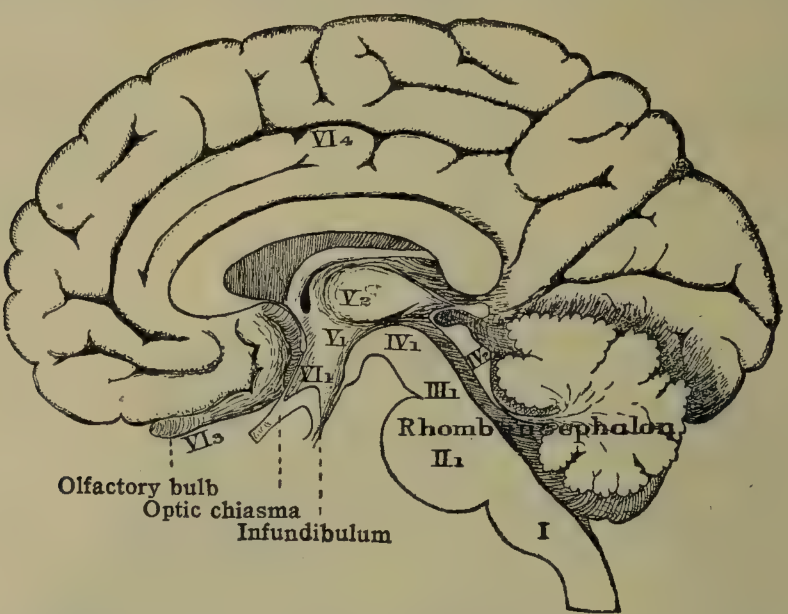


Fig. 708.—Median Sagittal Section of Adult Human Brain. (Drawing of model by His.) (Reference numerals same as in figs. 706 and 707.)

triangular recess so deep as to merit the name **foramen cecum.** The pyramids are the great descending cerebral or motor funiculi. In the medulla oblongata they decrease in bulk in passing toward the spinal cord, for the reason that many of the pyramidal axones are contributed to structures of the medulla, chiefly after crossing the midline. At the lower end of the medulla occurs the **decussation of the pyramids,** by which the anterior median fissure is almost obliterated for about 6 mm., and which, upon removal of the pia mater, may be easily observed as bundles of fibers interdigitating obliquely across the midline.

Not all the pyramidal fibers cross to the opposite side at this level in man, but a portion of those coursing in the lateral portion of the pyramid maintain their ventromedial position and continue directly into the spinal cord, to form there the ventral cerebrospinal fasciculus or direct pyramidal tract. However, most of such fibers finally cross the midline during their course in the cervical region of the spinal cord. The exact proportion of the direct fibers is variable, but always the greater mass of each pyramid crosses to the opposite side at the level of the decussation of the pyramids, and descends the cord as the lateral cerebrospinal fasciculus or crossed pyramidal tract. Both of these pyramidal tracts are described in the discussion of the fasciculi of the cord.

Each pyramid is bounded laterally by the **anterolateral sulcus,** also continuous with that of the same name in the spinal cord. Toward the pons this sulcus separates the pyramid from the **olive** [oliva] (inferior olivary nucleus), and in the region of the olive there emerge along this sulcus the root-filaments of the hypoglossal nerve. The olives, as their name implies, are oblong oval eminences about 1.2 cm. in length. They extend to the border of the pons, and are somewhat

thicker at their upper ends. Their surfaces are usually smooth, except at their lower ends, where they frequently appear ribbed, owing to bundles of the **external arcuate fibers** passing across them to and from the *restiform* body, which occupies the extreme lateral portion of the medulla. Along the line between the restiform body and the olive are attached the root-filaments of the *vagus, glossopharyngeal,* and *spinal accessory nerves.* Both the *abducens* and the *facial* nerves emerge along the inferior border of the pons, the facial in line with the glossopharyngeal, but the abducens in line with the hypoglossal.

Dorsal aspect.—The increased lateral diameter of the medulla oblongata is contributed to a great extent by the **restiform bodies.** These are the inferior cerebellar peduncles and contain the majority of the ascending fibers, which associate the cerebellum with the structures below it.

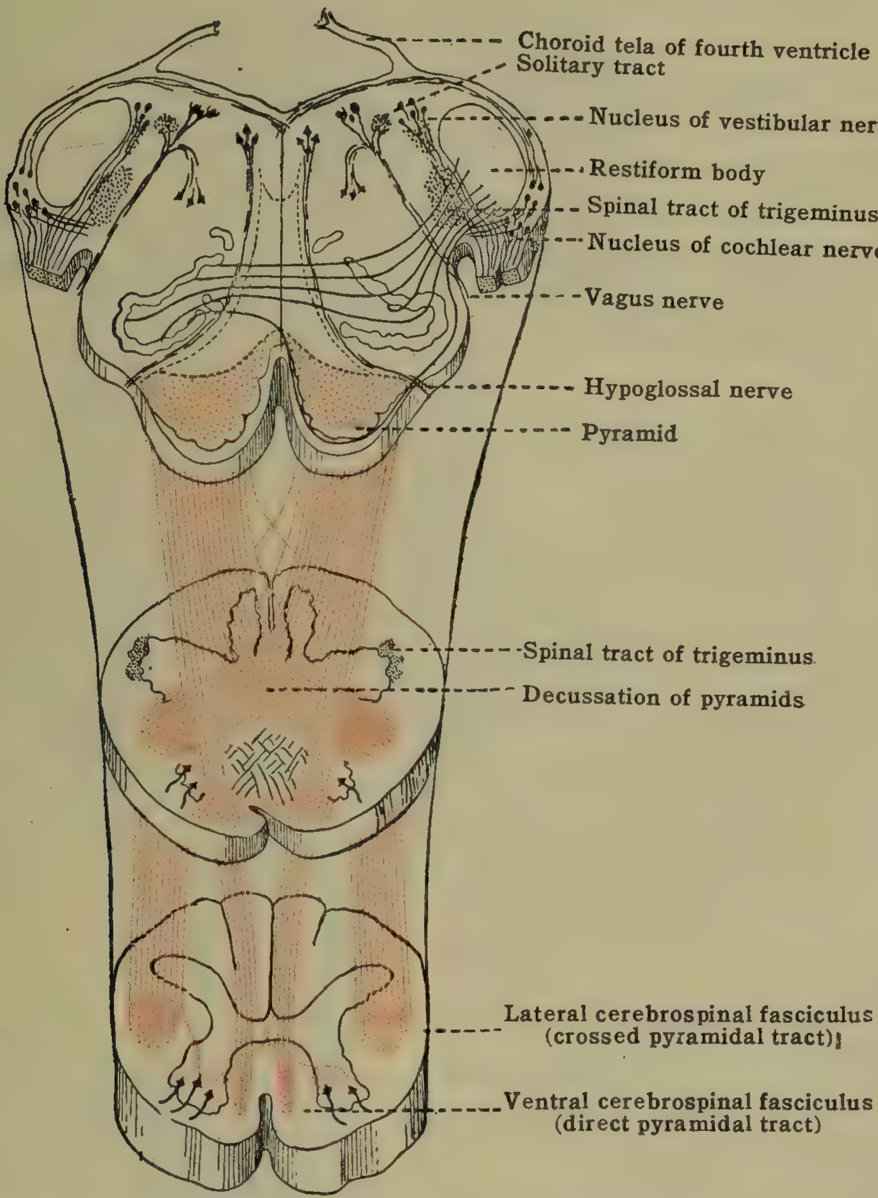


Fig. 709.—Diagram Showing the Decussation of the Pyramids.
The uppermost level represented is near the inferior border of the pons.

In toto, the restiform bodies are much larger than could be formed by the combined cerebellar fasciculi of the spinal cord, their great size being due to their receiving numerous axones coursing in both directions, which connect the cerebellum with structures contained in the medulla oblongata alone, so that in the medulla they increase as they approach the cerebellum. Their mesial borders form the lateral boundaries of the fourth ventricle. Their name (*restiform,* meaning rope-like) was suggested from the appearance frequently given them by the fibers of the cochlear nerve, which course around their lateral periphery to become in part the *striæ medullares* in the floor of the fourth ventricle. (Corpus restiforme or crus medullocerebellare NK.)

Upon removal of the cerebellum it may be seen that below the *calamus scriptorius* (inferior terminus of the fourth ventricle) the structures manifest in the dorsal surface of the medulla are directly continuous with those of the spinal cord. The fasciculus gracilis (Goll's column) of the spinal cord acquires a greater height and volume and becomes the **funiculus gracilis** of the medulla, and because of this increased height the posterior median sulcus of the cord becomes deepened into the **posterior median fissure.** The posterior intermediate sulcus is also accentuated

by the fasciculus cuneatus (Burdach's column) likewise now enlarged into the **funiculus cuneatus** of the medulla. The lateral funiculus of the medulla, of course, does not contain the lateral or crossed pyramidal tract present in the spinal cord.

At the border of the calamus scriptorius the funiculus gracilis terminates in a slight elevation, the **clava,** which is the superficial indication of the (terminal) **nucleus of the fasciculus gracilis.** Beginning somewhat more superiorly, and

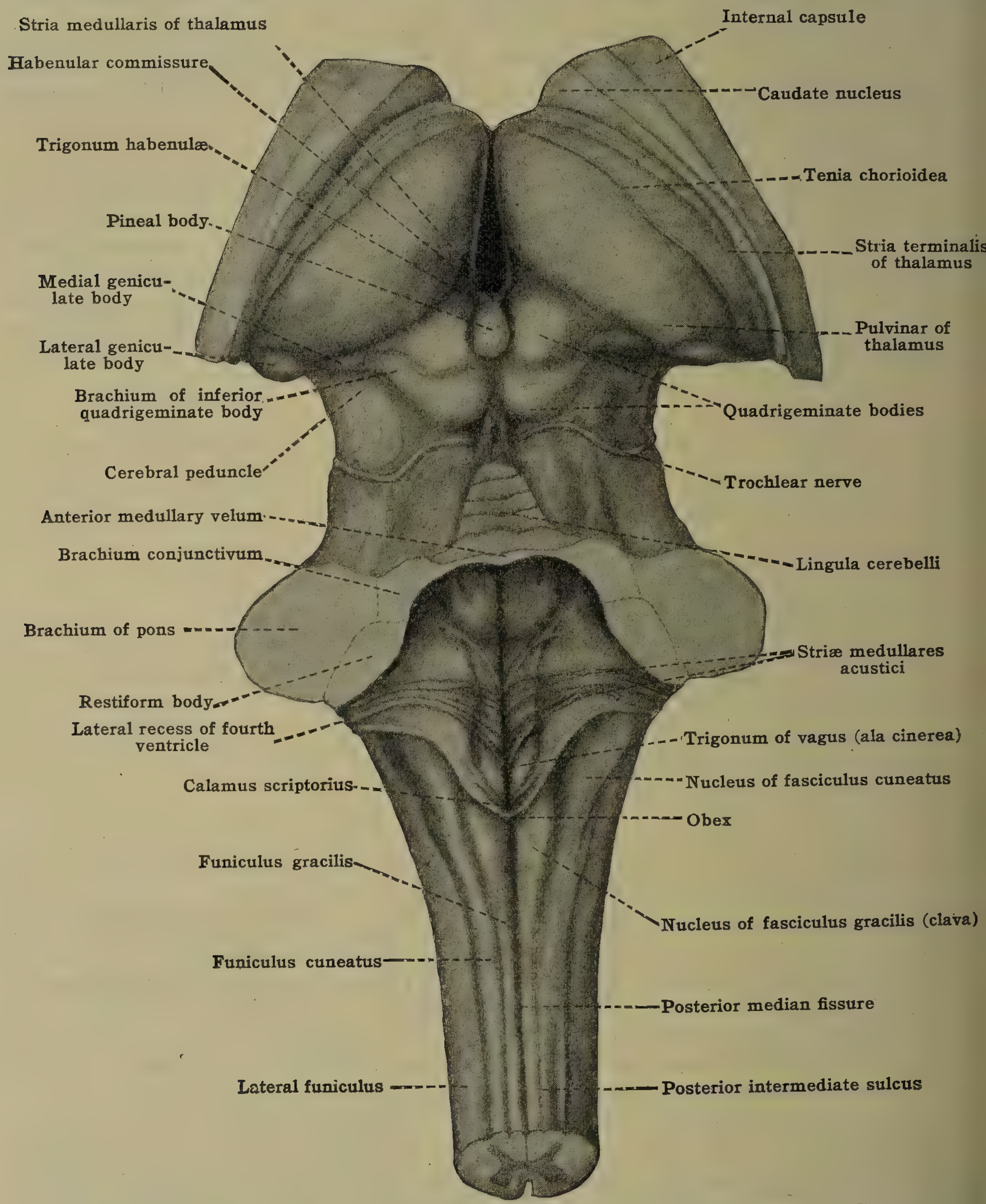


Fig. 710.—Dorsal Aspect of Medulla Oblongata and Mesencephalon, Showing the Floor of the Fourth Ventricle (Rhomboid Fossa). (Modified from Spalteholz.)

having a somewhat greater length, is a similar enlargement of the funiculus cuneatus, the **tuberculum cuneatum** or **nucleus of the fasciculus cuneatus.**

These nuclei are the groups of nerve cell-bodies about which the ascending or sensory axones of the respective fasciculi terminate or where the sensory impulses are transferred to a second neurone in their course to the structures of the encephalon. These cell-bodies in their turn give off axones which immediately cross the midline and assume a more ventral position, contributing largely to the *lemniscus* or fillet of the opposite side. Thus such axones are the encephalic continuation of the central sensory ('proprioceptive')pathway conveying impulses from the periphery of one side of the body to the opposite side of the cerebrum. These axones comprise one of the components of the *internal arcuate fibers* and their crossing is known as the *decussation of the lemnisci.*

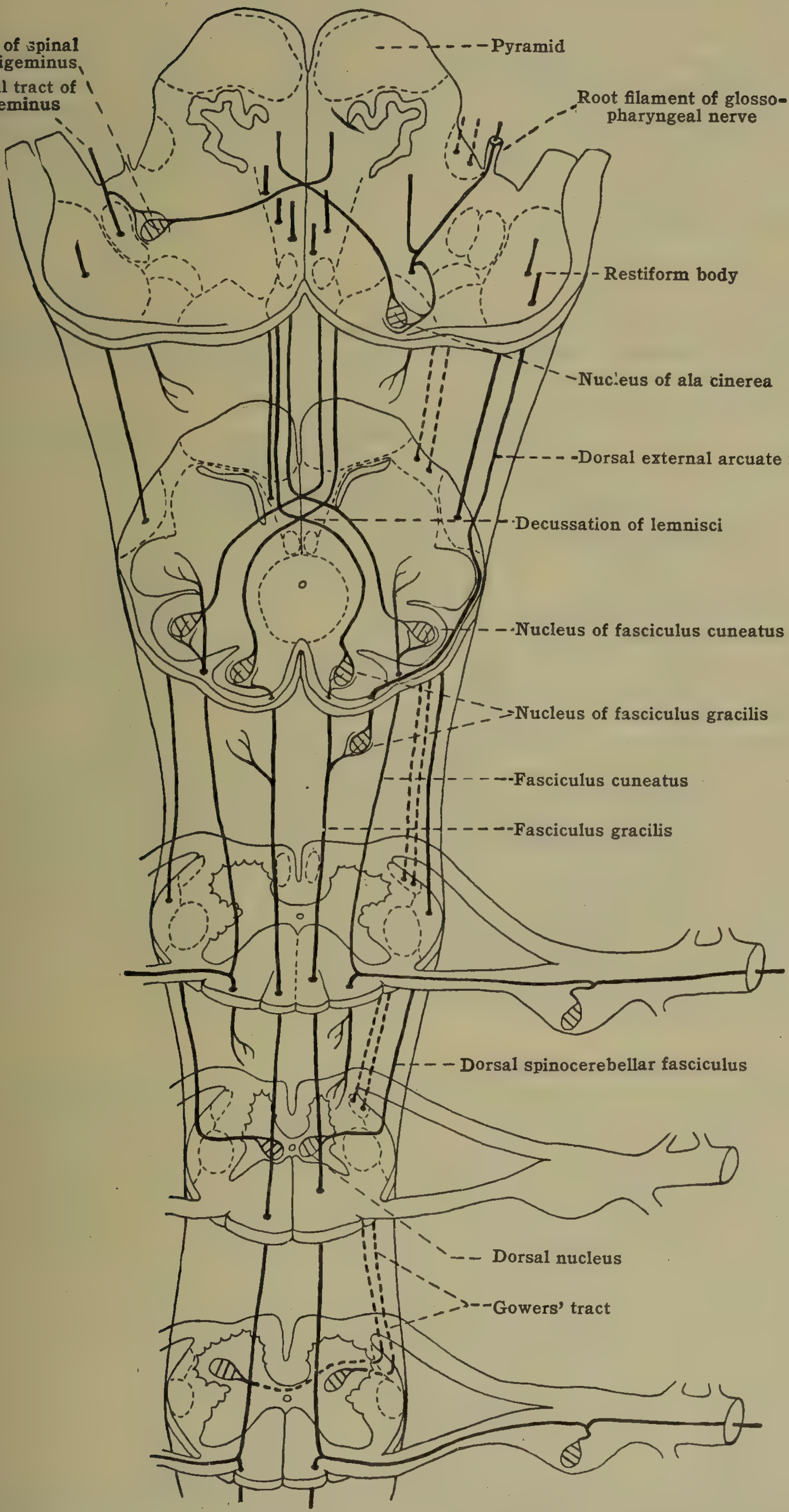


Fig. 711.—Diagram of the Spinocerebellar Fasciculi and the Origin and Decussation of the Medial Lemnisci.

With the termination of the dorsal funiculi and the ventral course of the fibers of the lemnisci in their decussation, the central canal of the spinal cord loses its roof of nervous tissue in the medulla and comes to the surface as the fourth ventricle. The floor of the fourth ventricle, which corresponds to the floor of the central canal, is considerably widened into two **lateral recesses** opposite the junction of the inferior and middle cerebellar peduncles of either side, and, being pointed at both its superior and inferior extremities, it is rhomboidal in shape and thus is the **rhomboid fossa.** The pia mater of the spinal cord is maintained across the tip of the calamus scriptorius to form the **obex,** a small, semilunar lamina roofing over the immediate opening of the central canal. The obex carries a few medullated commissural fibers.

2. THE PONS

The **pons (Varoli)** is, for the most part, a great commissure or 'bridge' of white substance coursing across the ventral aspect of the brain-stem, and connecting the cerebellar hemisphere of one side with that of the other. In addition it contains considerable gray substance and fibers passing both to and from the structures of the brain-stem and the gray substance of the cerebellum, and fibers descending from the cerebral cortex. Each of its lateral halves is continuous into the middle of the three cerebellar peduncles, the *brachium pontis* (or crus pontocerebellare NK) of either side (fig. 747).

In size it naturally varies directly with the development of the cerebellum both in a given animal and relatively throughout the animal series. In man it attains its greatest relative size, and possesses a median or **basilar sulcus** in which lies the basilar artery. Its sagittal dimension varies from 25 to 30 mm., while its transverse dimension (parallel with the course of its fibers) is somewhat greater. It is a rounded white prominence interposed between the visible portion of the cerebral peduncles (crura) above and the medulla oblongata below. Its *inferior margin* is rounded to form the **inferior pontine sulcus,** which, between the region of the emergence of the pyramids, is continuous with and transverse to the foramen cecum. Its *superior margin* is thicker and is rounded to form the **superior pontine sulcus,** which, between the cerebral peduncles, is continuous with and transverse to the interpeduncular fossa (figs. 705, 747). It is bilaterally symmetrical. The ventrolateral bulgings of its sides (and, therefore, the basilar sulcus) are produced by the passage through it of the fibers of the cerebral peduncles from above, to reappear as the pyramids below. Its ventral surface rests upon the basilar process of the occipital bone and the dorsum sellæ of the sphenoid, while its lateral surfaces are adjacent to the posterior parts of the petrous portions of the temporal bones.

The fibers of the thicker superior portion of the pons (*fasciculus superior pontis*) course obliquely downward to their entrance into the brachium of the pons and the cerebellar hemisphere; those of the lower and midportions (*fasciculus medius pontis*) course more transversely, naturally converging upon approaching the cerebellum. Certain fibers of the upper midportion course at first transversely and then turn abruptly downward across the fibers from above them, to join the inferior portion of the brachium pontis. This bundle is termed the **oblique fasciculus** (fig. 747). The *trigeminus* or fifth cranial nerve penetrates the superior lateral portion of each brachium pontis near the point of the downward turn of the oblique fasciculus; its large root and the masticator nerve (its small efferent root) accompany each other quite closely. On either side of the basal surface of the pons usually may be seen a small bundle of fibers which begins in the interpeduncular fossa, near or in the sulcus of the oculomotor nerve. It passes laterally along or under the superior border of the pons, loses some of its fibers in the lateral sulcus of the mesencephalon, then runs inferiorly between the superior cerebellar peduncle and the brachium of the pons to disappear in the junction of these. Being sometimes double, it is known as the **lateral filaments of the pons** (*fila lateralia pontis* or *tenia pontis*). The location of the cell-bodies giving origin to it is uncertain.

That portion of the rhombencephalon forming the dorsal part (tegmentum) of the pons region and making part of the floor of the fourth ventricle is not really a part of the pons at all. It is merely a continuation of the brainstem from the medulla below to the structures above and for this reasons it has been called the *preoblongata.* Therefore on the *dorsal surface* there is no line of demarcation between the pons and medulla below or between the pons and isthmus above. The fibers of the trigeminus and masticator nerve pass through the pontine fibers to and from their nuclei in the brain-stem.

3. THE CEREBELLUM

The **cerebellum** or *hindbrain* is the largest portion of the rhombencephalon. It lies in the posterior or cerebellar fossa of the cranium, and dorsal to the pons and

medulla oblongata, overhanging the latter. It fits under the occipital lobes of the cerebral hemispheres, from which it is separated by a strong duplication of the inner layer of the dura mater, the *tentorium cerebelli.*

Its greatest diameter lies transversely, and its average weight, exclusive of the dura mater, is about 140 gm., or about 10 per cent. of the entire encephalon. It varies in development with the cerebrum, and, like it, averages larger in the male. It is relatively larger in adults than in children. Its development begins as a thickening of the anterolateral portion of the roof (dorsal zone) of the posterior of the three primary brain-vesicles. Resting upon the brain-stem, it roofs over the fourth ventricle and is connected with the structures anterior, below, and posterior to it by its three pairs of peduncles.

The surface of the cerebellum is thrown into numerous narrow **folia** or **gyri,** which in the given localities run more or less parallel with each other. They are separated by narrow but relatively deep **sulci.** Unlike the spinal cord and medulla, in which the gray substance is centrally placed and surrounded by a mantle of white substance, the surface of the cerebellum is itself a cortex of gray substance [substantia corticalis], enclosing a core of white substance, the *medullary*

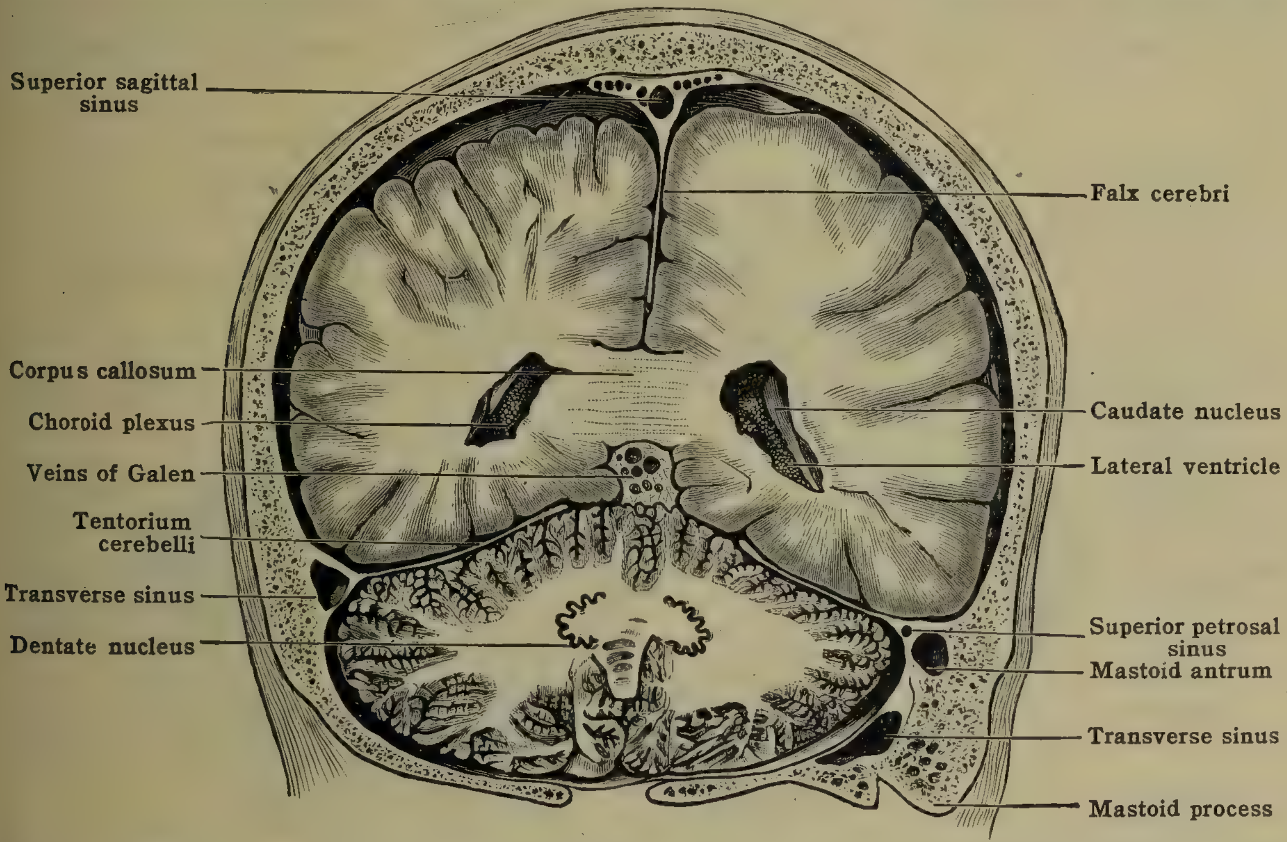


Fig. 712.—Section of Head Passing Through the Mastoid Processes and Behind the Medulla Oblongata, Showing the Position of the Cerebellum.
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

body [corpus medullare]. However, within this central core of white substance are situated definite gray masses, the *nuclei* of the cerebellum.

The **gross divisions** of the cerebellum are three: the two larger lateral portions, the **hemispheres,** and between these the smaller central portion, the **vermis.** The demarcation between these gross divisions is not very evident from the dorsal surface, because the hemispheres in their extraordinary development in man encroach upon the vermis, and, being pressed under the overlapping occipital ends of the cerebral hemispheres, they become partially fused upon the vermis along the dorsal mid~~line (fig. 713~~).

Though differentiated simultaneously with the cerebellar hemispheres in the human fetus, in most of the mammalia, the vermis is the largest and most evident of the parts during early development, and it is practically the only part which exists in the fishes, reptiles, and birds. In man, owing to the fact that the vermis does not keep pace in development with the hemispheres, there results a very decided notch between the two hemispheres along the line of the entire ventral and inferior aspect of the cerebellum, the floor of this notch being the surface of the vermis (fig. 715).

The inferior portion of the notch between the hemispheres is the **posterior cerebellar notch** (incisura marsupialis); its prolongation above is wider than below, and is termed the **superior cerebellar notch.** It is occupied by a fold of the dura mater, the falx cerebelli. With the variations in contour of the cere-

bellum, certain of its sulci are broader and deeper, and merit the name **fissures.** These are more or less definitely placed, and subdivide the hemispheres into **lobes** and the vermis (the median lobe) into **lobules.**

Superior surface.—The superior surface (facies tentoralis NK) is bounded from the inferior surface by the **horizontal fissure** (fig. 713) which extends anterolaterally, to the entrance of the brachium of the pons. Between this and the extreme anterior border of the dorsal surface are two other fissures, the **posterior** and **anterior semilunar fissures.** These, like the horizontal fissure, may be traced, with slight interruptions, across the midline, and consequently mark off not only the two hemispheres but also the vermis into corresponding divisions.

The **superior semilunar lobe** [lobulus semilunaris superior] (posterosuperior lobe) of each hemisphere lies between the horizontal and the posterior semilunar fissures. It largely composes the outer border of the cerebellum, and, therefore, is the longest of the lobes.

The adjacent surface of the hemispheres anterior to the superior semilunar lobe, because of the frequently less complete development of the anterior semilunar fissure, is sometimes referred to as the **quadrangular lobe,** with its *posterior* and its *anterior portions.* On the other hand, especially when the anterior semi-

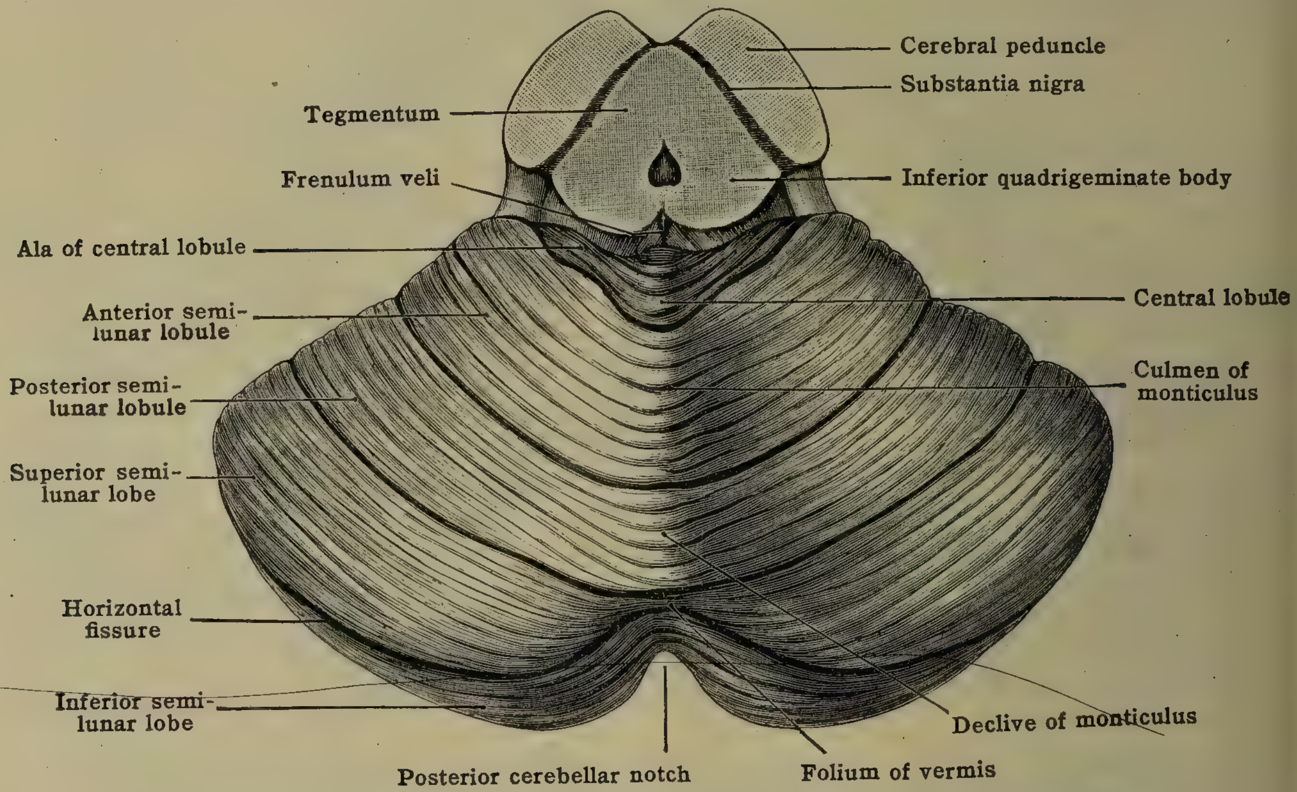


FIG. 713.—DIAGRAM OF THE SUPERIOR SURFACE OF THE CEREBELLUM. (The anterior and posterior semilunar lobes form the quadrangular lobe.)

lunar fissure is well marked, this area may be divided into—(1) the *posterior semilunar lobule,* between the posterior and anterior semilunar fissures, and (2) the *anterior semilunar lobule,* anterior to the anterior semilunar fissure (fig. 713).

Anterior to the quadrangular lobe on each hemisphere is the **ala of the central lobule** bounded by the postcentral and the precentral sulci. Anterior to this, on the anterior margin of the hemisphere, is the **vinculum lingulæ,** a slender process continuous with the lingula of the cerebellum (fig. 738).

The superior aspect of the vermis, the **superior vermis,** because of the fusion of the hemispheres, is, for the most part, a slight ridge, the **monticulus** (fig. 713), instead of a depression. However, in the posterior portion of the superior surface the depression of the posterior notch begins, and here the horizontal and the posterior semilunar fissure approach each other so closely that the corresponding subdivision of the vermis is seldom more than a single folium, the **folium vermis** (*cacuminis*).

The monticulus proper is divided into an inferior lobule, the **declive,** and a superior lobule, the **culmen.** These appear as continuations across the midline of the posterior and anterior semilunar lobes of the hemispheres, and are separated by the corresponding fissures (fig. 713).

At the extreme anterior part of the superior surface and in the bottom of the anterior cerebellar notch lies a more definitely defined portion of the vermis.

This is the **central lobule** (fig. 713). It is broadened laterally into two pointed wings, the *alæ* of the central lobule, the folia of which, if present, are parallel with those of the anterior semilunar lobes and separated from them by the **post-central sulcus.**

If the anterior margin of the central lobule be lifted, the **lingula cerebelli** (*lingula vermis*) will appear separated from the central lobule by the **precentral sulcus.** It is a thin, tongue-like anterior projection of the cortical substance comprising four to eight folia adhering upon the *anterior medullary velum*, the roof of the superior portion of the fourth ventricle (figs. 714, 738).

Inferior surface.—The three cerebellar peduncles of each side join to form a single mass of white substance, and enter the ventral aspect of each hemisphere medially and ventrally in the extremity of the horizontal fissure. The inferior surface of the cerebellum is less convex than the superior surface. The hemispheres are decidedly separated by a continuation of the posterior cerebellar notch, which becomes broader, the **vallecula of the cerebellum,** which contains the inferior portion of the vermis, **vermis inferior,** and whose margins embrace the medulla oblongata. The inferior surfaces of the hemispheres are each divided by the intervening fissures into four lobes (fig. 715).

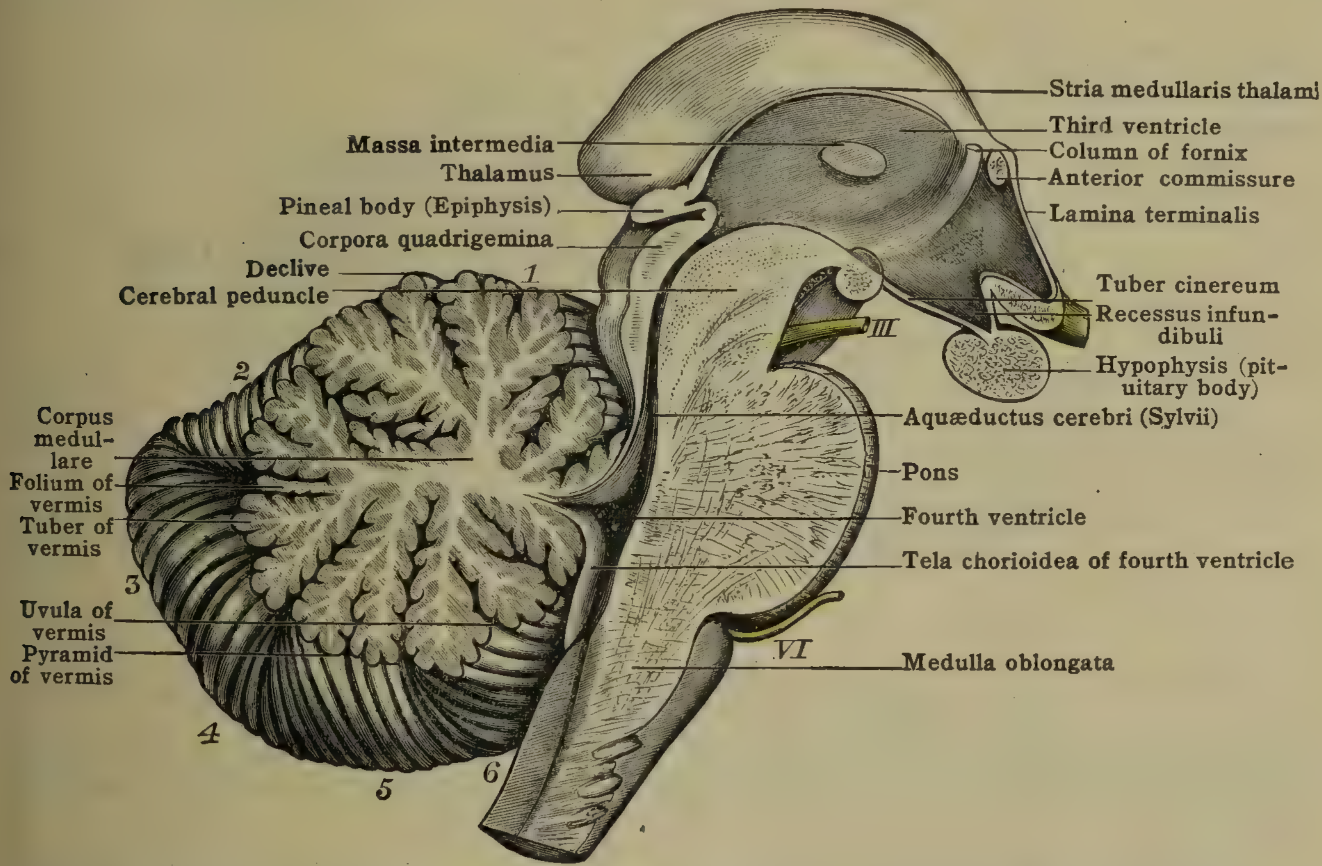


FIG. 714.—MEDIAN SECTION THROUGH CEREBELLUM AND BRAIN-STEM. (Allen Thomson after Reichert.)

1. Culmen monticuli; 2, superior semilunar lobe; 3, inferior semilunar lobe; 4, slender lobe; 5, biventral lobe; 6, tonsil.

Below, the **inferior semilunar lobe** (posteroinferior lobe) is separated from the superior semilunar lobe of the superior surface by the horizontal fissure. It is the largest of the inferior lobes, and is broader at its medial extremity. Frequently two and sometimes three of its curved sulci appear deeper than others, and separate it into two or three **slender lobules** [lobuli graciles]. More commonly there are two of these, the *lobulus gracilis posterior* and *lobulus gracilis anterior*, separated by the *posteroinferior sulcus.*

The **biventral lobe** is smaller and more curved than the inferior semilunar lobe; from the anterior margin of which it is separated by the curved **anteroinferior sulcus.** Its medial extremity is pointed and does not extend to the vermis; its lateral extremity is broader and curves anteriorly to the extremity of the horizontal fissure—the line of outer termination of the inferior semilunar lobe.

The **tonsil** [tonsilla cerebelli] (*amygdala*) is a rounded, triangular mass, placed medially within the inner curvature of the biventral lobe, and separated from it by the **retrotonsillar fissure.** Its inferior medial border slightly overlaps the vermis.

The smallest of the lobes is the **flocculus.** It lies adjacent to the inferior and lateral surface of the mass of white substance produced by the confluence of the three cerebellar peduncles, and extends into the medial extremity of the horizontal fissure. It is so flattened that its short folia give it the appearance suggesting its name. Occasionally there is added a second, less perfectly formed portion, the *secondary flocculus.* From each floccular lobe there passes toward the midline a thin band of white substance, the **peduncle of the flocculus.** From the flocculi of the two sides the peduncles extend to meet each other at the most anterior portion of the inferior vermis, and thus form the narrow **posterior medullary velum.**

The **inferior vermis** (figs. 714, 715) is more definitely demarcated than the superior. Lying in the floor of the vallecula cerebelli, it is separated on each side from the adjacent lobes of the hemispheres by a well-marked sulcus about it, the *nidus avis.* By contour and by deeper transverse fissures (sulci) occurring at intervals across it, four divisions or lobules of the inferior vermis are recognized. These lobules, like those of the superior vermis, are each in intimate relation with the pair of lobes of the hemispheres adjacent to it on either side.

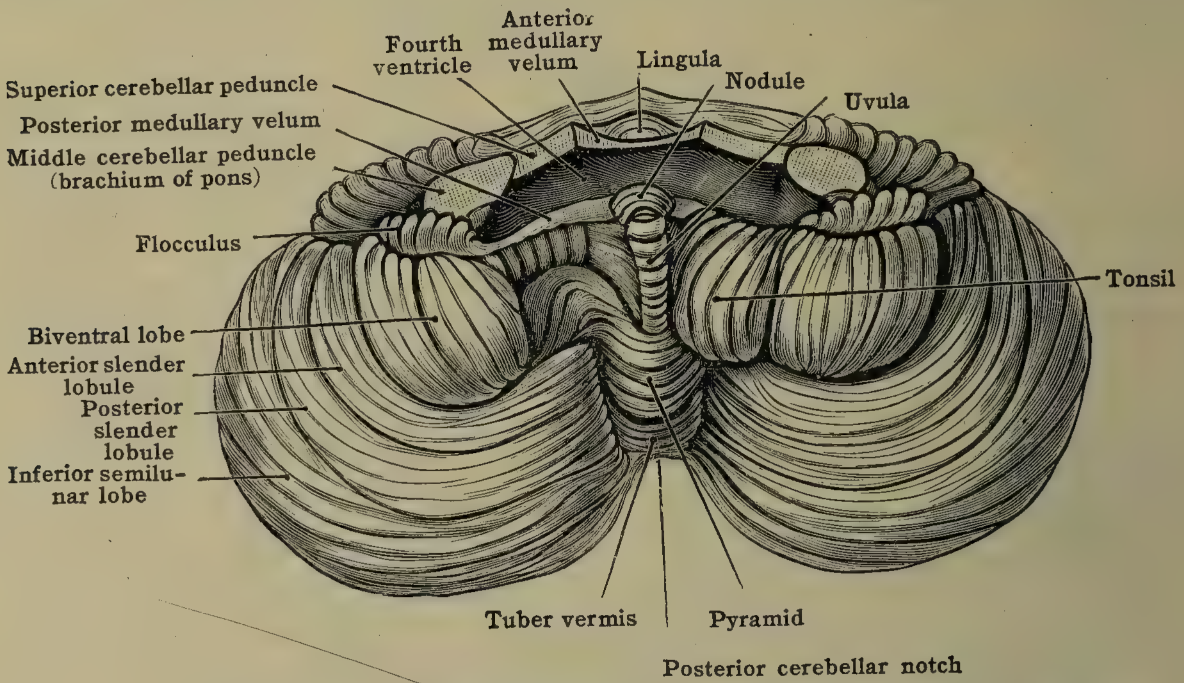


Fig. 715.—Diagram of the Inferior Surface of the Cerebellum after the Removal of the Medulla Oblongata, Pons, and Mesencephalon.

The tonsil of the right side is omitted in order to display the connection of the pyramid with the biventral lobe, the furrowed band of the uvula, and more fully the posterior medullary velum. The anterior notch is less evident than in the actual specimen.

1. The **tuber vermis** is adjacent to the folium vermis of the superior aspect. It is a short, somewhat pyramidal-shaped division, whose four or five transversely arranged folia are continuous with the folia of the inferior semilunar lobes on either side.

2. The **pyramid** is separated from the tuber vermis by the *postpyramidal sulcus.* Its several folia cross the vallecula cerebelli and curve to connect with the biventral lobes on either side.

3. The **uvula** is separated from the pyramid by the *prepyramidal sulcus.* It is triangular in shape. Its base or broader superior portion appears as two laterally projecting ridges of gray substance, the **furrowed bands** or *alæ uvulæ,* which extend across the floor of the nidus avis and under the medial margins of the tonsils on either side. In these bands its folia curve and become continuous with the tonsils. The uvula and the two tonsils are sometimes referred to collectively as the *uvular lobe.*

4. The **nodule** is the smallest and most anterior division of the inferior vermis. It is separated from the uvula by the **postnodular sulcus,** and is closely associated anteriorly with the posterior medullary velum, the transverse continuation of the peduncles of the floccular lobes.

Internal structure of the cerebellum (figs. 714, 716).—The white substance of the cerebellum is continuous with its peduncles and forms a compact central mass [corpus medullare]. Over the surface of this the gray substance or cortex

is spread in a thin but uniform and much folded layer. Upon section of the cerebellum certain of the sulci as well as the fissures are shown to be much deeper than is apparent from the surface. The deeper sulci separate the lobes into divisions, the **medullary laminæ,** each of which is composed of a number of folia and each of which has its own core of white substance. The folia of the laminæ line the sulci (and fissures), and also comprise their surface aspect, and are separated by the shallow, *secondary sulci.* The larger laminæ are subdivided into from two to four secondary laminæ of varying size. Such subdivision is especially marked in the vermis. Here each lamina comprises a lobule and is, therefore, separated by a fissure, and each lobule is usually subdivided, with the exception of the nodule, the folium, and the lingula. In sagittal sections, or sections transverse to the general direction of the sulci, this arrangement of the laminæ gives a foliate appearance, which, especially in sagittal sections of the vermis, is termed the **arbor vitæ** (fig. 714).

Summary of External Features of Cerebellum

	Hemisphere	Vermis	
	Superior Surface		
	Anterior border—Anterior medullary velum—Anterior border		
Vinculum of Lingula		*Lingula*	
	Precentral sulcus		
Ala of central lobule		*Central lobule*	
	Postcentral sulcus		
Quadrangular lobe	*Anterior semilunar lobule*	*Culmen*	*Monticulus*
	Anterior semilunar fissure		
	Posterior semilunar lobule	*Declive*	
	Posterior semilunar fissure		
Superior semilunar lobe		*Folium*	
	Horizontal Fissure		
	Inferior Surface		
	Horizontal Fissure		
Inferior semilunar lobe	*Posterior slender lobule*		*Tuber*
	Posteroinferior sulcus		
	Anterior slender lobule		
	Anteroinferior sulcus	Postpyramidal sulcus	
Biventral lobe		*Pyramid*	
	Retrotonsillar fissure	Prepyramidal sulcus	
Tonsil		*Uvula*	
	Horizontal Fissure	Postnodular sulcus	
Flocculus		*Nodule*	
	Posterior medullary velum		

The **cerebellar cortex** consists of three layers and contains four general types of cell-bodies of neurones, all of which possess features peculiar to the cerebellum.

The outermost or **molecular layer** contains small stellate cells, 'basket cells,' with relatively long dendrites. These serve to associate the different portions of a given folium. The axones of the largest of them give off branches which form pericellular baskets about the bodies of the *cells of Purkinje*, each axone contributing to several baskets. The **layer of Purkinje cells,** or the middle layer, is quite thin. The bodies of the cells of Purkinje are arranged in a single layer, and their elaborate systems of dendrites extend throughout and largely compose the molecular layer. The dendrites of these, the most essential cells of the cortex, are displayed in the form of arborescent fans (see fig. 684), arranged parallel with each other and transverse to the long axis of the folium containing them. Their axones are given off from the base of the cell-body and acquire their medullary sheaths quite close to the cell-body, and, after giving off several collaterals in the inner layer, pass into the general white substance and thence to other laminæ or lobes. Many of them go to structures outside the cerebellum. The inner layer is the **granular layer.** It contains numerous small nerve-cells or 'granule-cells' which possess from two to five radiating dendrites, unbranched except at their termination, which occurs suddenly in the form of three to six claw-like twigs. Their axones are given off either from the cell-body direct or more often from the base of one of the dendrites, and pass outward into the molecular layer, where they bifurcate and course in both directions parallel to the long axis of the folium, to become associated with the dendrites of the cells of Purkinje. In the layer of the cells of Purkinje there is situated at intervals a neurone of the Golgi type II (see fig. 684). The short, elaborately branched axone of this neurone is distributed among the cells of the granular layer. Axones conveying impulses to the cerebellar cortex terminate upon the granule cells in the granular layer as '*moss fibers,*' or directly upon the cells of Purkinje as '*climbing fibers,*' and probably upon the 'basket' cells and the cells of the Golgi type II.

Thus the neurones which receive impulses coming to the cortex are the cells of Purkinje, probably the Golgi cells of type II, the basket-cells and the granule-cells; those which distribute these impulses to other neurones of the folia are the Golgi cells of type II, the granule-cells, and the basket-cells (association neurones), and the collaterals of the cells of Purkinje. Impulses are conveyed from the cortex of a folium to that of other folia, lamina, lobules or lobes, or to the nuclei of the cerebellum, or to structures outside the cerebellum by the axones of the cells of Purkinje.

The **nuclei of the cerebellum** (figs. 716, 730) are in its central core [corpus medullare] of white substance. They are four in number, and all are paired, those of each pair being situated opposite each other on either side of the midline. They include (1) the dentate nucleus, (2) nucleus emboliformis, (3) nucleus globosus, and (4) roof-nucleus.

1. The largest of the cerebellar nuclei is the **dentate nucleus.** This is an isolated mass of gray substance situated in the core of white substance of each hemisphere. It is in the form of a folded or corrugated cup-shaped lamina, with the opening of the cup (*hilus*) directed anteriorly and obliquely toward the midline. It contains a mass of white substance and possesses a capsule. Its cell-bodies give rise to most of the fibers forming the superior cerebellar peduncles. It receives its impulses from axones of Purkinje cells and some direct from the axones of the spinocerebellar fasciculi.

2. The **nucleus emboliformis** is an oblong and much smaller mass of gray substance, which lies immediately medial to the hilus of the dentate nucleus. It is probably of the same significance as the dentate nucleus, being merely a portion separated from it.

3. The **nucleus globosus**, the smallest of the cerebellar nuclei, is an irregular horizontal mass of gray substance with its larger end placed in front. It lies close to the medial side of the nucleus emboliformis (fig. 730), and often appears separated into two or more rounded or globular masses.

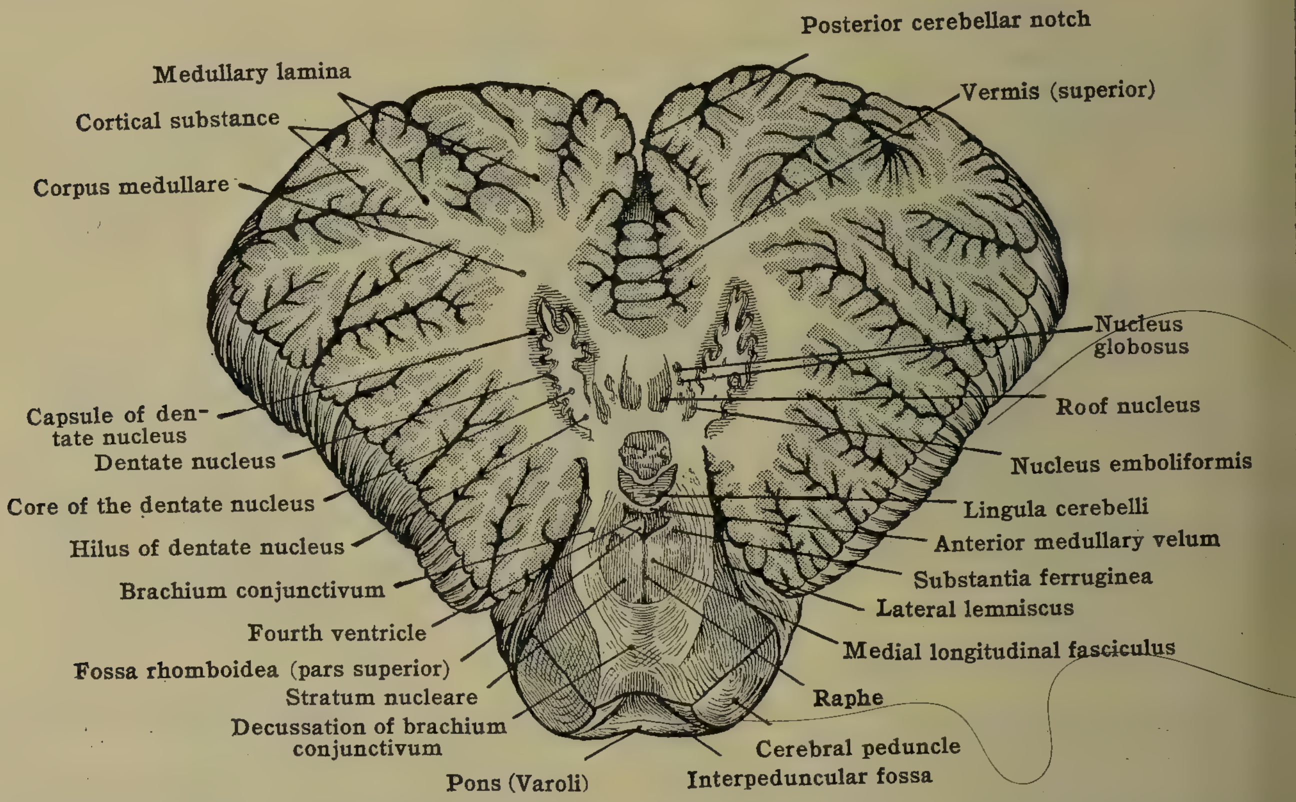


FIG. 716.—SECTION OF CEREBELLUM AND BRAIN-STEM PASSING OBLIQUELY THROUGH INFERIOR PORTION OF CEREBELLUM TO SUPEROIR MARGIN OF PONS. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

4. The **roof-nucleus** [nucleus fastigii] is the second largest of the cerebellar nuclei, and is the most mesially placed. The pair is situated in the roof of the fourth ventricle, and so near the midline that both nuclei are in the white substance of the vermis. They are ovoid in shape, and the nucleus of one side receives axones from the nucleus of the vestibular nerve chiefly of the opposite side, the decussation of these axones taking place in the vermis. Its cells are larger than those of the two first-mentioned nuclei.

The peduncles of the cerebellum.—The peduncles consist of three pairs—the inferior, middle, and superior. The three peduncles of each side come together at the level of the lower border of the pons, and the entering and emerging fibers of which they are composed become continuous with the central core of white substance of the cerebellar hemispheres (figs. 710, 716, 717, 718).

The **restiform body** (fig. 718) of the medulla oblongata is the inferior peduncle (crus medullocerebellare NK). It forms the lateral boundary of the inferior portion of the fourth ventricle, and upon reaching the level of the pons turns sharply backward into the cerebellum. In the region of the turn it is encircled externally by fibers of the cochlear nerve. It contains fibers, both ascending and descending, between the cortex and nuclei of the cerebellum and the structures below the cerebellum.

Its fibers include: (1) fibers from the spinal cord including the dorsal spinocerebellar fasciculus (direct cerebellar tract) and probably a small proportion of the ascending fibers of

the superficial ventrolateral spinocerebellar fasciculus (Gowers' tract); (2) fibers from the olive of the same but chiefly from that of the opposite side of the medulla oblongata; (3) fibers from the nuclei of the funiculus gracilis and cuneatus of the same and opposite sides (dorsal and ventral external arcuate fibers); (4) fibers to the olive of the opposite side; (5) fibers from the nuclei of termination of the sensory cranial nerves, especially those of the vestibular nerve; (6) fibers to the nuclei of the motor cranial nerves; (7) fibers descending to the ventral horn cells of the spinal cord. The ascending or afferent fibers of the spinocerebellar and cerebello-olivary fasciculi are the principal components of the inferior peduncle; the existence of fibers (5) and (6) is not well established. The fibers of the direct cerebellar tract terminate in the cortex of the superior vermis of both sides of the midline, but, for the most part, in that of the same side. The olivary fibers end in the cortex of both the superior vermis and the adjacent cortex of the hemispheres, and some of them terminate in the nucleus dentatus.

The **brachium pontis** or the middle peduncle (crus pontocerebellare NK) (figs. 718, 736) is the largest of the three cerebellar peduncles. In it the pons

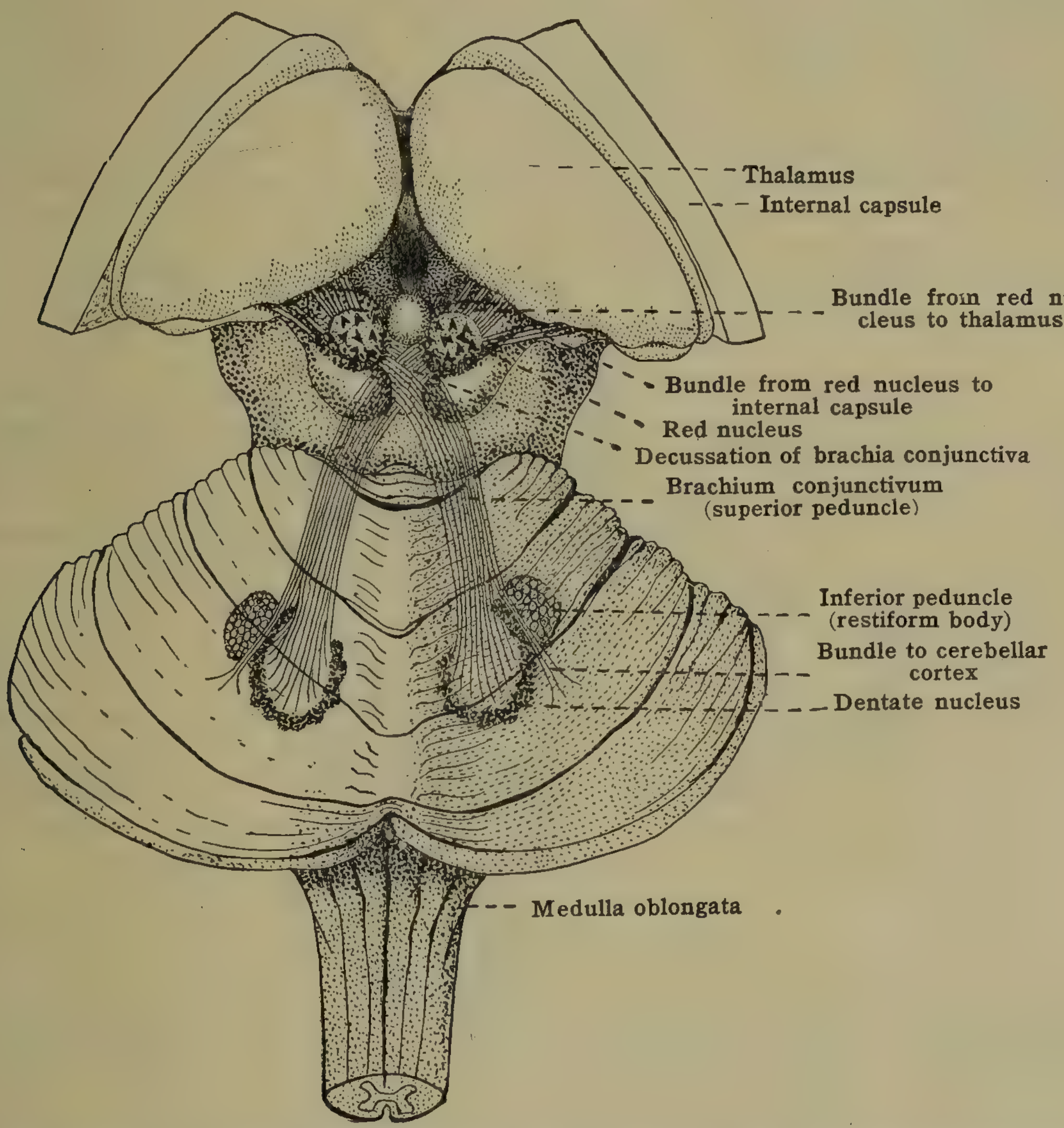


Fig. 717.—Transparency Drawing Showing the Origin, Course, and Connections of the Superior Cerebellar Peduncles (Brachia Conjunctiva) in the Resemblance Known as 'Stilling's Scissors.'

fibers pass into the cerebellar hemisphere, between the lips of the anterior part of the horizontal fissure, entering lateral to the inferior peduncle.

It consists of the transverse fibers of the pons, and within the cerebellum its fibers are distributed in two main groups—the upper transverse fibers of the pons apparently pass downward to radiate in the lower portion of the hemisphere, while the lower transverse fibers pass upward and medialward to radiate in the superior part of the hemisphere and vermis. For the most part the fibers of the middle peduncle may be considered as commissural fibers, passing from one side of the cerebellum to the other. Each peduncle contains fibers coursing in opposite directions. Many of these fibers are interrupted in their course to the opposite side by cells scattered throughout the pons, *nuclei pontis*, and, therefore, in each brachium pontis some of the fibers are processes of the cells of the cerebellum and course toward the opposite side, while others are processes of the cells of the pontine nuclei, which receive impulses from cerebellar axones, and course to the cerebellar hemisphere chiefly of the same side. Many cell-bodies of the nuclei of the pons whose axones terminate in the cerebellum receive impulses from fibers descending from the *cerebral* cortex of the opposite side—*corticopontine fibers*. Furthermore, there are evidences after degeneration that the brachium pontis also contains a few fibers to and from the cerebellum and the structures of the brain-stem and spinal cord.

The **brachium conjunctivum** or superior peduncle (crus cerebrocerebellare NK) (figs. 717, 718) emerges from the cerebellum on the medial side of the brachium pontis and also on the superior and medial side of the course of the restiform body. It forms the lateral boundary of the superior portion of the fourth ventricle and is the cerebello-cerebral peduncle. Its transverse section appears semilunar in shape, with the concave side next to the cavity of the ventricle. The medial border, which inclines toward the midline, is connected with that of the corresponding peduncle of the opposite side by the *anterior medullary velum,* which thus roofs over the superior part of the fourth ventricle. The lateral border is bounded from the pons by an open furrow or lateral sulcus.

The superior cerebellar peduncles are almost entirely efferent pathways as to the cerebellum and form the chief connections between the cerebellum and the cerebrum. They arise almost wholly from the dentate nuclei. As they course forward they converge slightly and disappear under the inferior quadrigeminate bodies. Here, in the tegmentum of the mesencephalon, a division of the cerebrum, they undergo an almost total **decussation,** and then the majority of the fibers of each peduncle, having thus crossed the midline, terminate in the *red nucleus* of the opposite side. The red nucleus lies in the tegmentum of the mesencephalon, below the superior quadrigeminate bodies, and therefore quite close to the decussation. The cells of the red nucleus, about which the fibers of the peduncle terminate, in their turn send processes (axones) into (1) the rubrospinal tract of the spinal cord and (2) into the prosencephalon, most of which

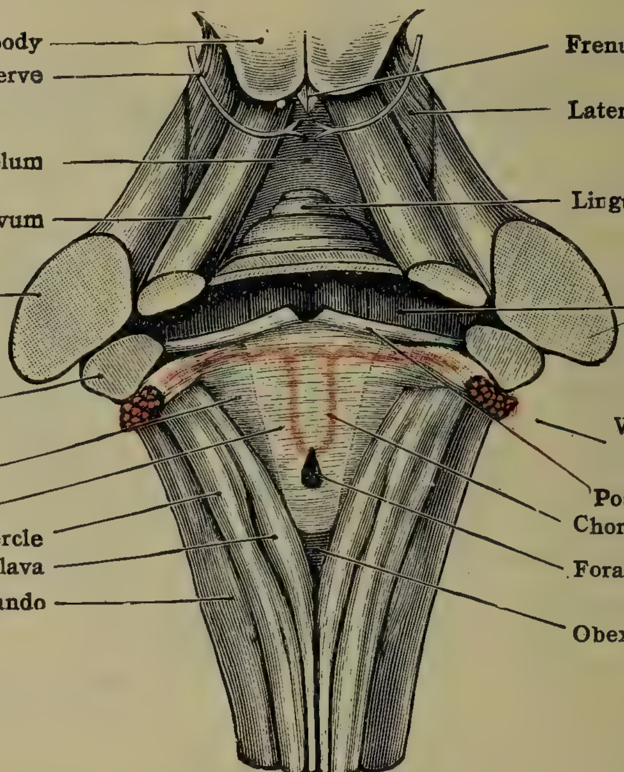


FIG. 718.—DIAGRAM OF THE ROOF AND LATERAL BOUNDARIES OF THE FOURTH VENTRICLE. The trochlear nerve should be shown emerging from the lateral boundary of the frenulum veli.

latter terminate in the thalamus whose cell-bodies give fibers to the cerebral cortex by way of the internal capsule, though some pass from the red nucleus under the thalamus to join the internal capsule.

In addition to the fibers having the origin and course described above, and which constitute the greater mass of the superior cerebellar peduncle, each peduncle is said to contain fibers which—(1) arise in the cerebellar cortex of the same and opposite sides, instead of from the dentate nucleus of one side only, and which join the peduncle at the side of the dentate nucleus, between it and the restiform body; (2) fibers which do not cross the midline in the decussation, but terminate in the red nucleus of the same side; (3) some fibers are not interrupted in the red nucleus, but pass directly into the thalamus; (4) a small proportion of fibers to the cerebellum, which arise in the structures of the cerebrum and pass into the cerebellum; and (5) the greater part, if not all, of the ascending fibers of the superficial ventrolateral spinocerebellar fasciculus (Gowers' tract) of the spinal cord. The latter, instead of entering the cerebellum by way of the restiform body, are deflected in the upper medulla and pass in the lateral tegmentum of the pons to the anterior medullary velum, where they turn backward to enter the cerebellum in its superior peduncle and pass to its cortex, probably by way of the lateral side of the dentate nucleus (see fig. 735). (See also the Extrapyramidal System.)

The anatomy of the fourth ventricle.—The fourth ventricle (figs. 710, 714, 718, 719) is rhomboidal in shape, being considerably widened at the level of the brachia pontis and pointed at each end. Its floor consists of a slight depression in the brain-stem, the *fossa rhomboidea,* and corresponds to the floor of the central canal. Its pointed inferior end, the **calamus scriptorius,** is directly continuous

with the central canal, and its narrowed superior end is continued into the aqueductus cerebri (Sylvii) of the mesencephalon, which is nothing more than a resumption of the tubular form of the canal.

The entire cavity of the ventricle is lined with an epithelium which is continuous with the epithelioid ependyma of the central canal below and the aqueduct above. The entire ventricle involves the *isthmus of the rhombencephalon*, the *metencephalon* and a portion of the *medulla oblongata.* It is divided for study into an inferior, an intermediate and a superior part.

The *roof of the superior portion* of the fourth ventricle is nervous, consisting of a thin lamina of white substance, the *anterior* (superior) *medullary velum*, thickened at the sides by the brachia conjunctiva. At its extreme mesencephalic end (in the isthmus of the rhombencephalon) the anterior medullary velum is slightly thickened by a continuation of the white substance of the inferior quadrigeminate bodies, forming the **frenulum veli.** The inferior portion of the velum is continuous with the white substance of the cerebellum, and is covered by the *lingula cerebelli,* an extension of the cortical substance of the superior vermis (figs. 710, 718).

The *roof of the intermediate portion* of the fourth ventricle is formed by the cerebellum proper, the vermis and the medial portions of the hemispheres. The nervous portion of the roof terminates with the *posterior* (inferior) *medullary velum,* a thin, narrow band of white substance which is the continuation of the peduncles of the floccular lobes, and which connects them at the midline with the nodule of the inferior vermis.

The *roof of the inferior portion* of the fourth ventricle is non-nervous. It is the **choroid tela** of the fourth ventricle, a thin lamina consisting of the ependymal lining of the ventricle, reinforced by a continuation of the connective tissue of the pia mater and the adjacent portion of the arachnoid. Along the line of its attachment to the surface of the medulla it is thickened, and in sections this portion bears the name **ligula** [*tenia ventriculi quarti*]. The thickest portion spans the tip of the calamus scriptorius and is termed the **obex.** The width of the ventricular cavity is extended laterally from its widest part into the *lateral recesses,* narrow pockets on each side and around the upper parts of the restiform bodies, inferior to the choroidal branches of the posterior inferior cerebellar arteries entering on each side to supply the choroid plexus of the fourth ventricle. In the midline of the lower part of the choroid tela there is a more or less well-marked opening, the *foramen of Magendie* (medial aperture of the fourth ventricle), which is an aperture in the ependyma connecting the cavity of the ventricle with the subarachnoid space (fig. 718). There is a similar opening from each lateral recess (*lateral apertures of Key and Retzius*).

The **choroid plexuses** of the fourth ventricle consist of highly vascular, lobular, villus-like processes of the ventricular lining (and pia mater) of the choroid tela. They are reddish in the fresh specimen, and the ependymal lining of the ventricle is closely adapted to the unevennesses of their surfaces. From below they run as two parallel masses on either side of the midline, which become united above, and then are separated again into two lateral processes which bend at right angles and project into the lateral recesses. Portions frequently protrude through the three openings of the ventricle into the subarachnoid space.

The ependyma, an epithelioid lining, is considered physiologically as a semipermeable membrane controlling the amount of cerebrospinal fluid in the ventricles. The foramina are the only openings by which the ventricles may be supposed to communicate with the subarachnoid space. These apertures are webbed over by the arachnoid.

The floor of the fourth ventricle [fossa rhomboidea] (fig. 719).—This is marked by eminences and depressions indicative of the internal structures of the brainstem subjacent to it. Its *inferior portion* is the dorsal surface of the upper portion of the medulla oblongata; its *intermediate portion* is the dorsal surface of the pons region, while its *superior portion* belongs to the isthmus of the rhombencephalon. Its triangular lower extremity terminates as the opening of the central canal of the spinal cord. This portion is deepened at the obex and shows furrows which point downward and converge medialward, giving the appearance known as the **calamus scriptorius.** The midline of the floor is sharply distinguished by the well-marked **median sulcus,** which becomes shallower above than below. In the tip of the calamus scriptorius, immediately ventral to the

obex, the median sulcus deepens as it becomes continuous into the central canal. This terminal depression is known as the **ventricle of Arantius.** Throughout the length of the floor on either side of the median sulcus is a continuous ridge, the **medial eminence,** which is bounded laterally by the **limiting sulcus.** Underlying the floor of the ventricle is a layer of gray substance of varying thickness, which is continuous with the gelatinous substance around the central canal of the cord. The medial eminence is subdivided into portions of unequal width and elevation, and the limiting sulcus accordingly shows foveæ of different depths.

Beginning at the calamus scriptorius, the following areas of the floor of the fourth ventricle are usually distinguished (fig. 719):

The **area postrema** of Retzius is a superficial vascular structure bounded inferiorly by the tenia and overlying the terminal portion of the nucleus of the fasciculus gracilis (clava) and a portion of the nucleus of termination of the vagus nerve. The **funiculus separans,** a short oblique fold of the floor, composed chiefly of neuroglia, separates the area postrema from the **ala cinerea** (*trigonum vagi*), which is an oblique, gray-colored, wing-shaped eminence indicating

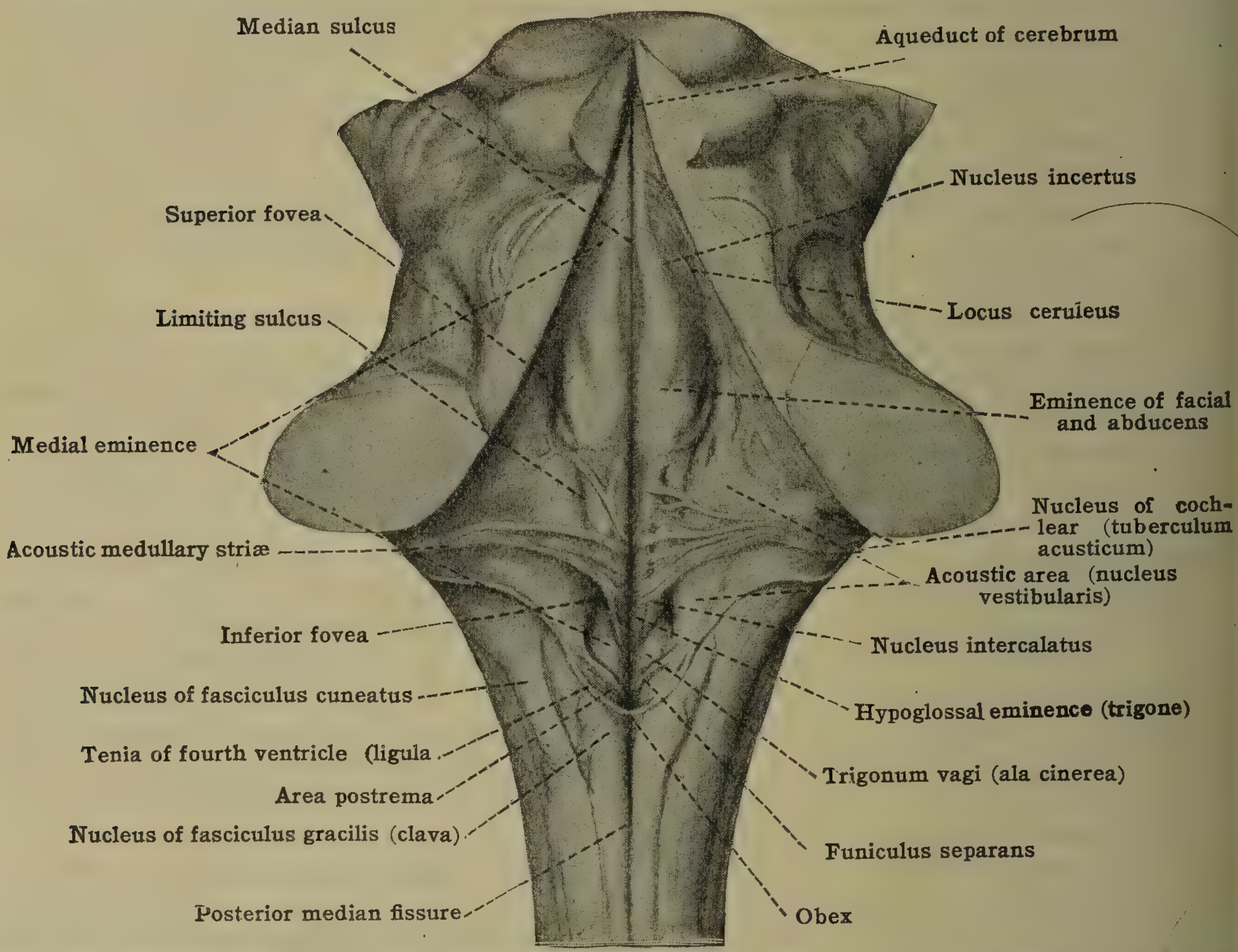


Fig. 719.—Dorsal Surface of the Brain-stem Showing the Anatomy of the Floor of the Fourth Ventricle. (Modified from Spalteholz.)

the middle third of the nucleus of termination (recipient nucleus) of the vagus and glossopharyngeal nerves. At the superior extremity of the ala cinerea is a well-marked triangular depression of the limiting sulcus known as the **inferior fovea.** Medial to and extending above the ala cinerea is a narrow triangular eminence lying close to the median sulcus, which represents the nucleus of origin of the hypoglossal nerve, the **hypoglossal eminence** [trigonum n. hypoglossi]. The lateral field of this eminence shows small oblique rugæ, giving it a 'feathery' appearance, the **area plumiformis** of Retzius. The **nucleus intercalatus** of Van Gehuchten is a wedge shaped portion very slightly demarcated from the hypoglossal eminence, and intercalated between it and the inferior fovea. This nucleus is considered by some observers as an inferior medial extension of the nucleus of termination of the vestibular nerve (area acustica), but Streeter, who has made a detailed study of the floor of the fourth ventricle by means of serial sections, doubts that it is a part of this nucleus. It is much more probable that it supplies visceral efferent fibers to the vagus and thus represents the dorsal efferent nucleus of the vagus.

Superior to the inferior fovea, and crossing each half of the floor of the fourth ventricle, are the **acoustic striæ.** These are bundles of axones arising in part from the dorsal nuclei of termination of the cochlear or auditory nerve, which nuclei are situated in the lateral periphery of each restiform body. The bundles course around the dorsal periphery of the upper portion of the restiform body, then across each half of the floor of the ventricle to the median sulcus, in which they suddenly turn ventrally into the substance of the medulla oblongata, and in doing so they cross the midline to enter the substance of the opposite side. The striæ vary greatly in different individuals, both in the degree of their prominence and their direction. Sometimes no striæ are visible from the surface. Frequently a bundle may be discerned which courses obliquely upward and lateralward from the median sulcus to disappear in the floor further away

from the midline and, again, a bundle may depart from the transverse course before reaching the median sulcus. Such a bundle ascending is sometimes called *conductor sonorus*. The acoustic striæ cross the **acoustic area.** This is the flattened elevation which occupies the whole lateral portion of the intermediate portion of the floor of the ventricle, lateral to the limiting sulcus, and extends into the inferior portion lateral to the inferior fovea. It represents the subjacent nuclei of termination of the vestibular nerve. The dorsal and ventral nuclei of the cochlear nerve are indicated by the ventrolateral fullness (*tuberculum acusticum*) in the contour of the restiform body. In many of the mammals the cochlear nuclei produce a well-marked protuberance.

In its superior portion the medial eminence occupies the greater part of the floor of the fourth ventricle, and in the upper part of the intermediate portion of the floor it presents a broader, well-marked, elongated elevation, the eminence of the facial and abducens or the **colliculus facialis.** This represents the medially placed nucleus of origin of the abducens and the genu of the root (internal genu) of the facial nerve, which root courses around and above the nucleus of the abducens. The nucleus of the facial is too deeply situated to produce an eminence. Lateral to the facial eminence is a depression of the limiting sulcus, which overlies the medial part of the region of the larger portion of the nucleus of termination of the trigeminus. This is the *fovea trigemini* or **superior fovea.** The strip of the floor above the superior fovea and lateral to the medial eminence often appears grayish blue or dark brown, owing to pigmented cells subjacent to it, and is known as the **locus ceruleus.** It also represents a portion of the nucleus of the trigeminus. The most superior portion of the medial eminence becomes narrow and lies close to the midline. The function of the underlying gray substance producing it is uncertain, and for this reason Streeter has named the elevation **nucleus incertus,** noting that by position it is closely related to the upper portion of the nucleus of the trigeminus.

Internal Structure of the Medulla Oblongata and Pons

The finer detail of the internal structure lies within the scope of microscopic rather than of gross anatomy. However, the significance and relations of certain of the more important and larger of the internal structures of the medulla and pons as observed in sections (figs. 720–736) must be considered.

The entire brain-stem may be regarded as an upward continuation of the spinal cord, to which structures are added and in which the structures characteristic of the spinal cord are modified in varying degrees, giving each part its peculiar character and conformation.

The **pyramids,** the great descending or motor cerebrospinal fasciculi, are directly continuous into the pyramidal fasciculi of the spinal cord. They form the extreme ventromedial portion of the medulla, and from the fact that they contribute numerous fibers to the efferent nuclei (nuclei of origin) of the cranial nerves and to other portions of the gray substance of the brain-stem, they decrease appreciably in bulk in descending toward the spinal cord. Most of the fibers contributed to the medulla, as well as to other divisions of the brain-stem, decussate as they leave the pyramids, and terminate in the gray substance of the opposite side. However, the chief **decussation of the pyramids** occurs in the lower end of the medulla. Here usually about three-fourths of the fibers then comprising the pyramids cross the midline to form the lateral cerebrospinal fasciculus (crossed pyramidal tract) of the spinal cord immediately below (fig. 709). The remaining fourth, comprising the more lateral fibers, furthest away from the midline, continues uncrossed into the spinal cord as the ventral cerebrospinal fasciculus or direct pyramidal tract. The majority of the latter fibers decussate gradually in the commissural bundle and in the ventral white commissure of the cord as they approach the levels of their termination. In practically all vertebrates except man and the anthropoid apes there are no ventral pyramidal fasciculi, the decussation in the medulla being a total one. In man, the proportion of fibers crossing in the chief decussation varies. Cases have been noted in which apparently the entire pyramids decussate at this level. In other cases the direct or ventral pyramidal tract may be much larger than usual, at the expense of the lateral. The chief decussation usually appears to be symmetrical and it occurs so suddenly that the fibers, in coursing from the ventral to the lateral positions, 'sew up' the ventral median fissure and detach the tips of the ventral horns of the spinal cord from the remainder of the gray figure, making these appear in transverse sections as isolated, irregularly shaped masses of gray substance (fig. 720). From this level upward the outline of the gray figure of the cord is lost, and the cell-columns of the ventral horns occur in more or less detached groups as the motor nuclei of the cranial nerves. Naturally there are some "aberrant pyramidal fibers" to the nuclei of the motor cranial nerves, cortico-medullary fibers which never enter the pyramids but descend and decussate in the reticular formation of the brain stem (Dejerine).

The **origin and decussation of the lemnisci** (medial lemnisci, fillet). The medial lemniscus of either side begins immediately above the decussation of the pyramids, and here the arrangements characteristic of the spinal cord are further modified. The dorsal portion of the gray figure of the cord is manifest up to this level, but here, after a considerable increase in its thickness, the gray commissure gives rise to two thick dorsal outgrowths on each side of the midline. These dorsal projections of gray substance comprise the nuclei of termination (relays) of the chief ascending or sensory spinocerebral fasciculi of the spinal cord. The **nucleus of the fasciculus gracilis** (nucleus of Goll's column) arises a little before the **nucleus of the fasciculus cuneatus** (nucleus of Burdach's column). The former extends slightly downward from its point of origin, so that its inferior extremity is included in sections through the decussation of the pyramids (fig. 720). It produces a slight bulbous enlargement (the *clava*) of the end of the funiculus gracilis, while the nucleus of the fasciculus cuneatus corresponds to the *cuneate tubercle* of the dorsolateral contour of the medulla (figs. 711, 719). From the cells of these nuclei arise axones which contribute largely to the lemniscus—the cephalic continuation of the spinocerebral pathway which conveys general bodily sensations (proprioceptive) to the cerebrum. In passing out of the nuclei the fibers of the lemniscus course in a ventromedial direction. Curving around the region of the central canal, they contribute largely to the **internal arcuate fibers,**

then, sweeping across the midline, they, together with those from the opposite side, convert it into the **raphe**, and immediately after crossing (decussating) they turn cephalad and collect to form the bundle known as the **lemniscus**. While these two ascending fasciculi, because of their prior discovery, larger size and more general significance, are referred to as the lemnisci they should be called the **medial lemnisci** to distinguish them throughout from the **lateral lemnisci** described below, which have quite different nulcei of origin and are concerned with the apparatus for hearing.

In the medulla, the lemnisci are two thin bands of fibers spread vertically on each side of the raphe, with their lower or ventral edges thicker than their dorsal edges. In their course toward the cerebrum they increase in bulk, owing chiefly to fibers being added to them from

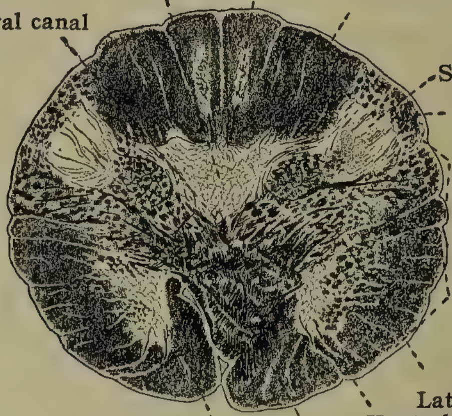


FIG. 720.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT THE LEVEL OF THE DECUSSATION OF THE PYRAMIDS.

the nuclei of termination of the afferent roots of the cranial nerves, which fibers likewise cross the midline as internal arcuate fibers to join the lemniscus of the opposite side. In passing through the pons, the lemnisci gradually become spread laterally (horizontally) and beyond the pons their then more lateral portions are further displaced and come to course in the lateral borders of the isthmus rhombencephali and mesencephalon, while the medial portions remain nearer the midline. This lateral spreading of each lemniscus produces the **lateral lemniscus** and the **medial lemniscus**, distinguished in sections of the superior pons and lower mesencephalic regions of the brain-stem (fig. 740). During the spreading, the lateral lemniscus is contributed very largely by the cell-bodies of the nuclei of termination of the cochlear nerve of he opposite side and is thus the '*auditory lemniscus.*' The **spinal lemniscus** (spinothalamic

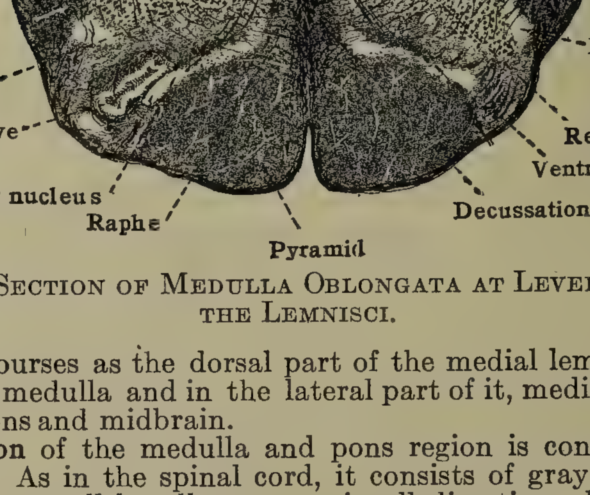


FIG. 721.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT LEVEL OF THE DECUSSATION OF THE LEMNISCI.

and spinotectal paths) courses as the dorsal part of the medial lemniscus during its vertical position throughout the medulla and in the lateral part of it, medial to the lateral lemniscus proper, throughout the pons and midbrain.

The **reticular formation** of the medulla and pons region is considerably more abundant than in the spinal cord. As in the spinal cord, it consists of gray substance through which nerve-fibers, singly and in small bundles, course in all directions, but more sparsely than in other regions. In the medulla it is traversed by the internal arcuate fibers. It may be considered an enlarged continuation of the middle portion of the gray column of the cord, dispersed by numerous fibers, giving it the reticulated appearance which suggests its name. Its numerous nerve-cells belong, for the most part, to the association and commissural systems of the brain

stem, and, therefore, the fibers arising in it correspond largely to the fasciculi proprii of the spinal cord. As in the cord, most of the fibers are of short course, serving to associate different portions of the same level and adjacent levels with each other. Those of long course show a tendency to collect into a small, well-marked bundle which courses one on each side close to the midline, ventral to the central canal in the closed part of the medulla, and near the median sulcus of the floor of the fourth ventricle, in the open part. In the mesencephalon this bundle is continued closely ventral to the aqueductus cerebri. This bundle is known as the **medial longitudinal fasciculus** (posterior longitudinal bundle). It corresponds more nearly to the ventral fasciculus proprius of the spinal cord than to others of the fasciculi proprii. In the medulla it appears as the dorsal edge of the lemniscus, but in the shifting of the position of the lemniscus in the pons region, it retains its medial position and thus becomes isolated. By position it is especially adapted for the association of the nuclei of the cranial nerves. Evidence has been found that those fibers which arise in the superior corpora quadrigemina and descend the spinal cord in its sulcomarginal or ventral mesencephalospinal fasciculus, pass through the medulla in the medial longitudinal fasciculus. (See extrapyramidal system.) The nuclei of termination of the vestibular nerve, and probably those of the cochlear nerve, are said also to contribute many fibers to the medial longitudinal fasciculus.

The **inferior olivary nucleus** is an added structure in the medulla oblongata, i. e., it has no homologue in the spinal cord. The two of them occupy the olivary prominences, *the olives* of the exterior, and constitute the most conspicuous and striking isolated masses of gray substance in sections of the medulla. They appear as crenated laminæ of gray substance folded so as to encup a dense mass of white substance, and in actual shape the entire nucleus has the form of an irregular corrugated cup with the opening or **hilus** on the side toward the midline (fig. 723). The mass is so crumpled that the diameter of the hilus is appreciably less than

Fig. 722.—Transverse Section of Medulla Oblongata Through Nuclei of Vagus and Hypoglossus and Through the Middle of the Olives.

the length of the nucleus, and thus transverse sections of either extremity of it appear as closed capsules.

There are several small detached portions of the olivary nucleus known as the **accessory olivary nuclei.** These are named according to their position with reference to the chief portion or olive proper. They are plates less corrugated than the chief nucleus, and appear rod-like in transverse sections. The largest is the *dorsal accessory olivary nucleus.* The *medial accessory olivary nucleus* is widest at its inferior end, which extends a little below the inferior extremity of the olive proper. The *lateral accessory olivary nucleus* is the smallest. In serial sections the accessory nuclei are found to be plates of gray substance usually continuous with one another.

The olivary nuclei are mainly cerebellar connections. By both ascending and descending fibers each cerebellar hemisphere is connected with the olivary nucleus of the same and opposite sides. Serial sections of a human brain with congenital absence of one cerebellar hemisphere, described by Strong, show that the chief connection of a hemisphere is with the olive of the opposite side. These fibers necessarily pass from the olives to the cerebellum by way of the restiform body, and, in so doing, form an obliquely coursing bundle in the lateral border of the medulla known as the **cerebello-olivary fibers** (fig. 722). The olivary nuclei also comprise a secondary relay between the spinal cord and the cerebellum by way of the spino-olivary fasciculus of the cervical cord, and it will be noted that they receive fibers from the thalami. The latter fibers, the **thalamo-olivary tract**, approach the olive at its lateral periphery, while above through the brain-stem the tract courses in a more medial position. This tract comprises one of the cerebrocerebellar paths. Arising in the thalamus and terminating in the olive, its impulses reach the opposite cerebellar hemisphere by way of the cerebello-olivary fibers.

The **arcuate fibers** are referred to as internal and external, in accordance with their course dorsal or ventral to the inferior olivary nucleus. The **internal arcuate fibers** comprise fibers destined

for both the cerebellum and cerebrum, and also for the association of the tegmental gray substance of the two sides in which they course. Certain of the fibers pass between one restiform body (cerebellar hemisphere) and the olive of the opposite side course internal to the olive of the same side, and thus form the ventral portion of the internal arcuate fibers. As noted above, the internal arcuate fibers consist in greatest part of fibers being contributed to the lemnisci, arising from the cells of the nuclei of termination of the fasciculus gracilis and fasciculus cuneatus and sweeping downward and decussating to form the lemniscus of the opposite side. However, all the fibers arising in these nuclei do not enter the lemniscus. A few of them cross the midline with the internal arcuates, but pass on to enter the restiform body (cerebellar hemisphere) of the opposite side. Some of these course ventrally and, upon approaching the olive of the opposite side, are deflected around the ventral side of both the olive and the pyramid, and thus pass to the restiform body as external arcuate fibers also. Certain of the internal arcuate fibers arise from the cells of the nuclei of termination of the cranial nerves and from small cells situated in the gray substance of the reticular formation. These, in crossing the midline, correspond to the white commissures of the spinal cord. Some of them terminate in the medulla; others, especially those from the nuclei of termination of the sensory cranial nerves, join the lemniscus and pass toward the cerebrum; others reach the cerebellar hemisphere of the opposite side (see figs. 724, 725).

The **external arcuate fibers**, in addition to those mentioned above, comprise certain fibers which arise in the nuclei of the fasciculus gracilis and cuneatus and pursue a dorsolateral course to enter the restiform body (cerebellar hemisphere) of the same side. These form largely the dorsal external arcuate fibers. The greater mass of the external arcuates are cerebello-olivary fibers. Certain of those passing from one olive to the restiform body of the opposite side are deflected at the raphe, and course on the ventral side of both the other olive and the pyramid in order to reach the opposite cerebello-olivary bundle. Likewise, some passing

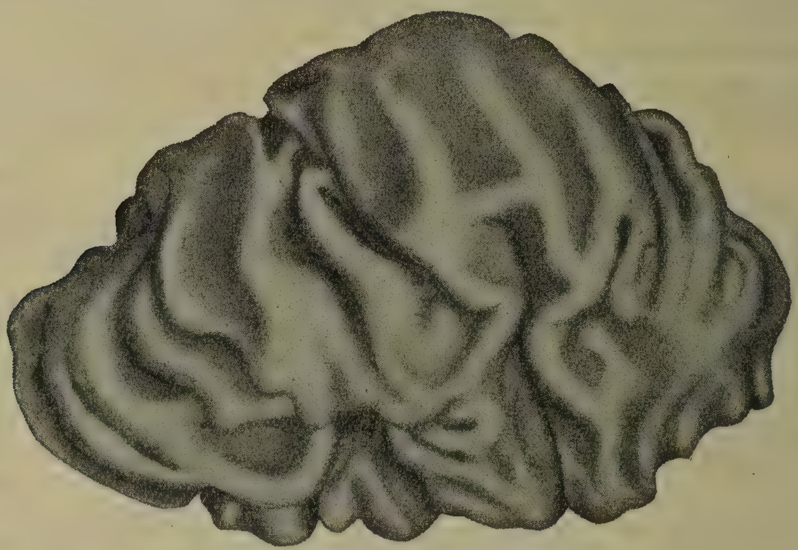


Fig. 723.—Reconstruction of the Inferior Olivary Nucleus, Dorsolateral View. (After Sabin.)

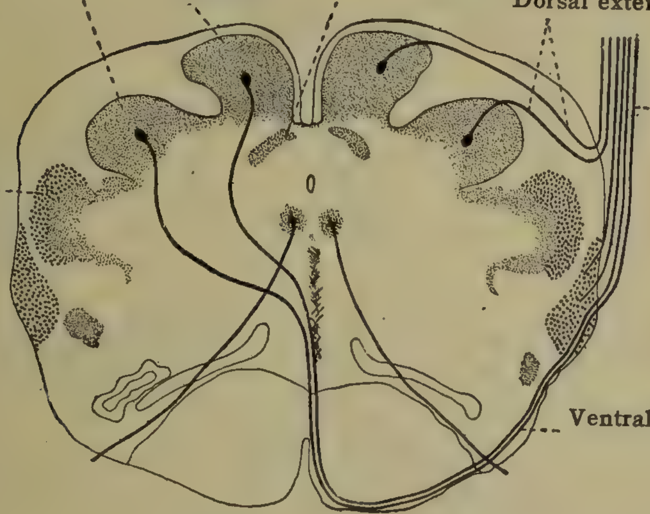
from the restiform body to the opposite olive are deflected by the olive of the same side and pursue a similar course to the raphe. While out of the hilus of each olive streams a dense mass of white substance, the *interolivary fibers*, yet many of the fibers concerned with the olive pierce its walls from all sides. Many of the external arcuate fibers are said to be interrupted in the **nucleus arcuatus.** This is a thin sheet of gray substance, variable in amount, which lies on the ventral aspect of each pyramid, and, though it decreases inferiorly, it may be evident down to the decussation of the pyramids. The nucleus receives its name from the fact that its larger portion is interpolated in the ventral external arcuate fibers. It is continuous anteriorly with the gray substance or nuclei of the pons. The external arcuate fibers of longer course, like the olives with which they are largely concerned, have no homologues in the spinal cord.

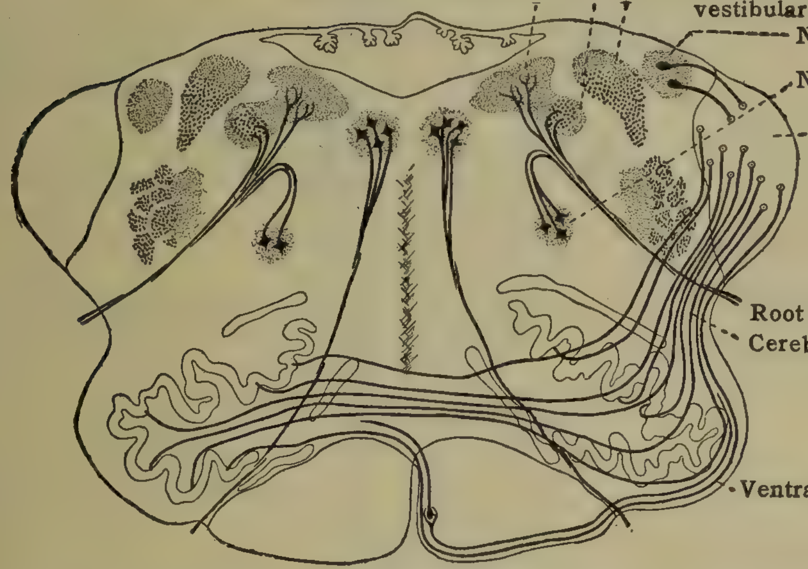
The *central canal* of the closed portion of the medulla is surrounded by a greater amount of **central gray substance** [substantia grisea centralis] than is the canal in the spinal cord. This is largely *the central gelatinous substance,* and the nerve-fibers in coursing through the gray substance are partially deflected by it, leaving it as a cylindrical, more evident area of gray substance than in other regions. In the open portion of the medulla the central gray substance naturally forms a more transparent lamina just under the floor of the fourth ventricle. In the mesencephalon, occurring in still greater amount, it again surrounds the resumed canal or aqueduct of the cerebrum.

The **central connections of the cranial nerves** are easily homologized with spinal cord structures. Functionally the cranial nerves are of three varieties:—(1) the motor or efferent nerves, comprising the oculomotor, the trochlear, masticator, the abducens, the facial, the spinal accessory, and the hypoglossus; (2) the sensory or afferent, comprising the olfactory, the optic, the trigeminus, the vestibular, and the cochlear and (3) the mixed, motor and sensory nerves, comprising the glossopalatine, the glossopharyngeal, and the vagus. The **nuclei of origin** of the motor or efferent cranial nerves and the efferent portions of the mixed nerves are directly continuous with the cell-columns of the ventral horns of the spinal cord, while the emerging root-filaments and roots of these nerves

correspond to the ventral roots of the spinal nerves. The **nuclei of termination** of the afferent or sensory cranial nerves and of the sensory portions of the mixed nerves correspond directly to the nuclei of the fasciculus gracilis and fasciculus cuneatus, and to the cell-bodies of association and commissural neurones of the medulla and cord and, functionally, are merely superior continuations of these.

The nuclei of the efferent or motor cranial nerves lie in two parallel lines, one near the midline and the other more laterally placed. The nuclei giving origin to the oculomotor, the trochlear, the abducens, and the hypoglossus are near the midline, and correspond to the ventromedial and dorsomedial cell-groups of the ventral horns of the spinal cord; the nuclei of origin of the masticator (motor root of the trigeminus), of the facial, and the nucleus ambiguus contributing to





FIGS. 724 AND 725.—DIAGRAMS SHOWING THE COMPOSITION OF THE CEREBELLAR PORTIONS OF THE INTERNAL AND EXTERNAL ARCUATE FIBERS.

the motor portions of the glossopharyngeal and vagus nerves, together with the nucleus of the spinal accessory, correspond to the ventrolateral and dorsolateral (intermediolateral) cell-groups of the ventral horns of the spinal cord. The nerve-roots having medial nuclei of origin are those which make their exit from the brain-stem along the more medial superficial line, while those having the more lateral nuclei comprise the more lateral line of roots apparent on the surface of the stem. Some of the efferent fibers of the vagus, supposedly visceral efferent, arise from a small nucleus dorsomedial to the nucleus ambiguus, the *dorsal efferent of the vagus.* Visceral efferent fibers in the glossopharyngeal and glossopalatine nerves arise chiefly in nuclei corresponding to the dorsal efferent nucleus of the vagus, that for the glossopalatine being called the *salivatory nucleus.* The first two pairs of cranial nerves, the olfactory and optic, are attached to the prosencephalon. These are purely sensory, and make their entrance near the midline of the brain, both having superficially placed nuclei of termination.

The two are peculiar in that their ganglia of origin are situated in the neuro-epithelium of their end-organs. Of the other nerves, all having sensory or afferent functions enter the brain along the lateral or more dorsal line, and the ganglia giving origin to their afferent axones correspond directly to the spinal ganglia of the dorsal or afferent roots of the spinal nerves.

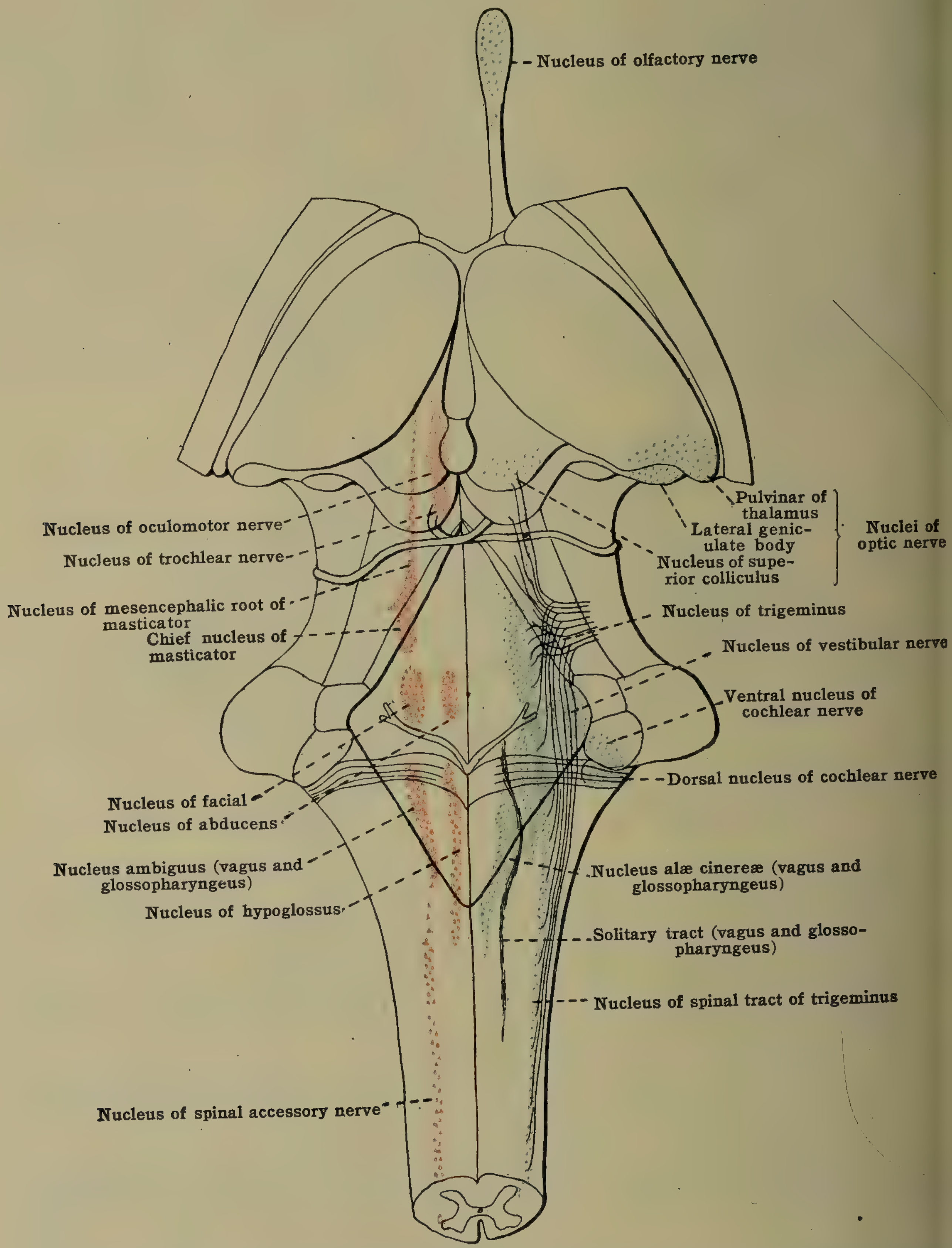


FIG. 726.—SCHEME SHOWING THE RELATIVE SIZE AND POSITION OF THE NUCLEI OF ORIGIN (RED) OF THE MOTOR AND THE NUCLEI OF TERMINATION (BLUE) OF THE SENSORY CRANIAL NERVES.

Commissural and associational neurones are much more numerous in the brain-stem than in the spinal cord. Their axones serve to correlate the structures on the two sides of the midline and to associate the different levels of the same side. Just as in the spinal cord, those of longer course form fasciculi proprii. Many of their axones descend into the spinal cord.

Of the fifteen pairs of cranial nerves, eleven pairs are attached to the medulla oblongata and pons, viz., the trigeminus, the masticator, abducens, facial,

glossopalatine, vestibular, cochlear, glossopharyngeal, vagus, spinal accessory, and hypoglossus.

The **hypoglossus,** the motor nerve of the tongue, has its nucleus of origin beginning in the lower portion of the floor of the fourth ventricle caudal to and at the level of the acoustic striæ. It is a long nucleus, lying close to the midline and just under the floor of the ventricle (hypoglossal eminence) and extending down to the region of the funiculus separans. Here it curves ventrally to a slight degree, and below the obex assumes a position ventrolateral to the central canal, and thus extends a short distance below the level of the inferior tip of the olive. The nerve arises as a series of rootlets which traverse the entire thickness of the medulla (fig. 722), to emerge in line in the furrow between the olive and the pyramid and fuse to form the trunk of the nerve. The lowermost of the rootlets usually emerge below the olive. The nucleus

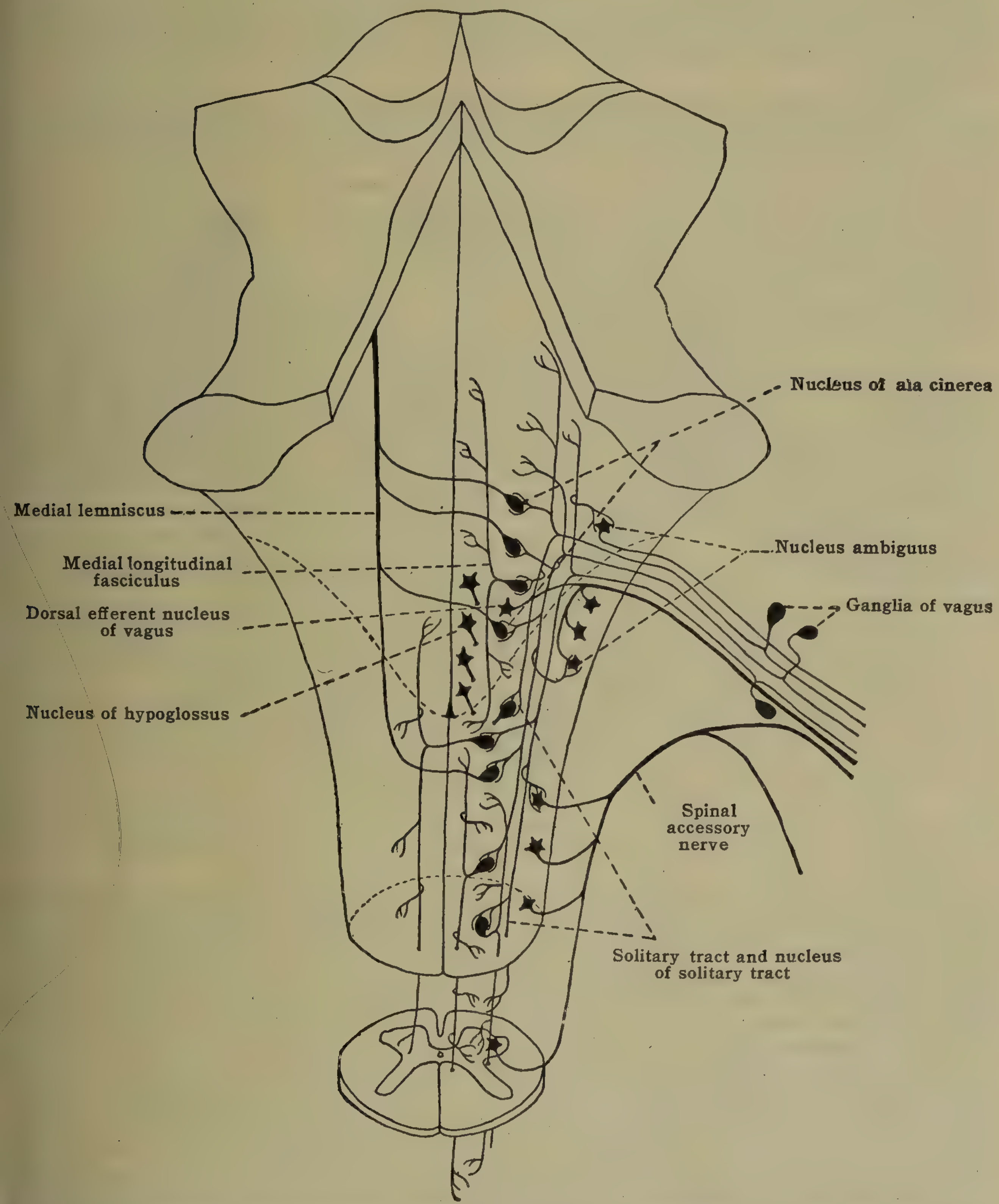


Fig. 727.—Diagram Illustrating Principal Central Relations of the Vagus Nerve exclusive of Relations to Descending Cerebral or Pyramidal Fibers.

receives impulses—(1) from the cerebrum by way of divergent fibers from the pyramid of the opposite side (voluntary); (2) impulses brought in by the sensory fibers of the cranial nerves (reflex); and (3) by axones from other levels of the medulla (associational). None of its axones are supposed to decussate, though numerous commissural fibers are known to pass between the nuclei of the two sides.

The **spinal accessory** is likewise a purely motor nerve, and has a laterally placed, long, and much attenuated nucleus of origin. Above, its nucleus is in line with and practically continuous with the nucleus giving motor fibers to the vagus and glossopharyngeus (nucleus ambiguus).

Below, it is the nucleus lateralis of the medulla in large part and it consists of the lateral an dorsolateral groups of cells of the ventral horn of the first five or six segments of the spina cord. The nerve arises as a series of rootlets which emerge laterally and join a commo trunk, which passes upward between the dorsal and ventral roots of the upper cervical nerve and parallel with the medulla to turn lateralward in company with the vagus. (See figs. 72 and 747.) The upper rootlets arise from that part of the nucleus contiguous to the inferior en of the nucleus ambiguus, and are described as comprising the medullary (bulbar) or *accessor part* of the nerve; those which arise from the ventral horn cells below are described as the *spina part.* The trunk of the spinal accessory fuses with the vagus in the region between its tw ganglia, and, before separation, contributes fibers (the accessory part) to the trunk of the vagus Some of the accessory fibers are distributed as motor fibers to the muscles of the larynx an some of them are visceral efferent fibers (visceral effectors). The latter probably terminat chiefly in sympathetic ganglia which send axones to the heart. The spinal part is distributed t the sternomastoid and trapezius muscles. The nucleus of the spinal accessory receives termina twigs of pyramidal fibers from the opposite side and is subjected to sensory impulses similar t those affecting the cells giving origin to other motor cranial nerves and motor roots of th spinal nerves.

The vagus and the glossopharyngeal, though they have widely different peripheral distri butions, are so similar in origin and central connections that they may be described together Both contain efferent fibers, though both are in greater part sensory. They are similar as t the origin of both their efferent and afferent components. The afferent fibers of the vagu arise in its jugular ganglion and its nodosal ganglion (ganglion of the trunk); the afferen fibers of the glossopharyngeal arise in its superior ganglion and its petrosal ganglion. In bot nerves these fibers enter the lateral aspect of the medulla and bifurcate into ascending and de scending branches, similar to those of the dorsal root-fibers in the spinal cord. Some of these branches terminate in practically the same level of the medulla about cell-bodies situated on the same and the opposite sides. Such branches end chiefly in the nuclei of the hypoglossal and spina accessory, and about the cells giving origin to the efferent components of the vagus and glosso pharyngeal themselves—short reflex arcs. However, most of the afferent fibers terminate in the nucleus of termination of the vagus and glossopharyngeal:—(1) the **nucleus of the ala cinerea**, the middle portion of which is indicated in the floor of the fourth ventricle by the ala cinerea; (2) in the closed portion of the medulla, the lower end of the nucleus of the ala cinerea comes to lie in the dorsolateral proximity of the central canal, and this portion is known as the *commissural nucleus of the ala cinera* (figs. 721 and 724) from the fact that fibers may be seen which pass directly from it across the midline; (3) the longer of the descending branches of the bifurcated fibers collect to form the **solitary tract**, a compact bundle situated dorsally just ventro ateral to the nucleus of the ala cinerea and quite conspicuous in sections of the lower olivary levels of the medulla. The fibers of this bundle terminate in the *nucleus of the solitary tract*, which is but a ventrolateral and downward continuation of the nucleus of the ala cinerea enclosing the bundles forming the tract. It is most probable that the fibers of the solitary tract are chiefly from the vagus (pneumogastric), though Bruce has found evidence that the glossopharyngeal contributes to it appreciably. It decreases rapidly in descending the medulla, owing to the rapid termination of its fibers about the cells of its nucleus. It, with the axones given by the cells of its nucleus, is believed to extend as far downward as the level of the fourth cervical segment of the spinal cord. This being in the level of origin of the phrenic nerve, the tract forms a link in the respira tory apparatus which aids in the coordinated respiratory movements. The axones given off by the cells of the nucleus of the ala cinerea (terminal nuclei of the vagus and glossopharyngeal) course on both sides of the midline, associating nuclei of other cranial nerves with vagus and glossopharyngeal impulses, many decussating to be distributed to the structures of the opposite side. Many join the lemniscus of the opposite side and pass into the cerebrum; others are distributed to the motor neurones of the cervical cord of the same and opposite sides (reflex axones), and no doubt others form central connections with the cells of the reticular formation of the medulla, though their precise relations have not been determined.

Cell-bodies in the nucleus of the ala cinerea, the nucleus of the solitary tract and in the commissural nucleus of the ala cinerea comprise the so-called **respiratory** and **vasomotor nuclei** ('centers') of the medulla. Some of the caudal branches of the axones given off by the cells of these nuclei descend the spinal cord, not only to the segments giving origin to the phrenic nerve, but also to those supplying the intercostal and levatores costarum muscles. Some of these augment the solitary tract; most of them descend in the reticular formation of the medulla and cord. Further, axones given off by these cells convey vasomotor impulses which are distributed to visceral efferent neurones throughout the cord.

The nuclei of origin of the motor fibers of the vagus and glossopharyngeal are the **dorsal efferent nucleus of the vagus** and the **nucleus ambiguus**. The cells of the dorsal nucleus of the vagus lie somewhat clustered in the ventromedial side of the nucleus of the ala cinerea and lateral to the nucleus of the hypoglossus. Their axones pass outward among the entering or afferent vagus fibers, and it is suggested that most of them are visceral efferent fibers of the vagus, i.e., they form synapses with sympathetic neurones. Those from the dorsal efferent nucleus especially are thought to convey inhibitory impulses carried in the vagus. The *nucleus ambiguus* or ventral efferent nucleus of both nerves lies in the lateral half of the reticular forma tion, about midway between the olive and the line traversed by the rootlets of the two nerves. Its upper end is larger. Its cells are considerably dispersed by the fibers of the reticular forma tion. The axones arising from its cells course at first dorsalward and then turn abruptly out ward to join the rootlets of the vagus or glossopharyngeal, as the case may be. The vagus is thought to receive more efferent fibers from the nucleus ambiguus than does the glossopharyn geal, and Cunningham notes that it may be questioned whether the latter nerve contains any motor fibers at all, there being paths by which the fibers of its motor branch (to the stylopharyn geus muscle) might enter it other than directly from motor nuclei.

The *vestibular* and *cochlear* nerves have been considered as one nerve and together designated as the **acoustic or eighth cranial nerve**. While both are purely sensory, are similar in develop-

ment and their roots course together, they are distinct as to function and origin and their nuclei of termination differ. They are here described as separate cranial nerves. The two nerves approach the brain stem together and enter it at the lateral aspect of the junction of medulla oblongata and pons.

The **vestibular nerve** (nerve of equilibration) arises as the central processes of the bipolar cells of both the superior and inferior parts of the *vestibular ganglion*, and passes into the brain-stem on the ventromedial side of the restiform body to find its nucleus of termination (nucleus vestibularis) in the floor of the fourth ventricle. This nucleus occupies a triangular area of considerable extent (area acustica, fig. 719), and is usually subdivided into a *lateral nucleus* (Deiters'), a *medial nucleus* (Schwalbe's), a *superior nucleus* (Bechterew's), and an *inferior nucleus* (nucleus spinalis). The latter is a downward prolongation of the general nucleus vestibularis which accompanies the *descending or spinal root* of the nerve and may be traced to near the superior extremity of the nucleus of the fasciculus gracilis. The fibers of the vestibular nerve, like those of other sensory nerves, bifurcate after entrance into ascending and descending branches. Some of the fibers arising from the superior part of the vestibular ganglion pass dorsolaterally around the vestiform body to reach the nucleus of the vestibular and in passing thus, they must mingle with cochlear fibers.

From the cells of the lateral and inferior nuclei axones are given off which form paths to the lateral funiculus of the spinal cord (lateral vestibulospinal fasciculus, fig. 698) and to its anterior marginal fasciculus (ventral vestibulospinal tract). From both the lateral nucleus and

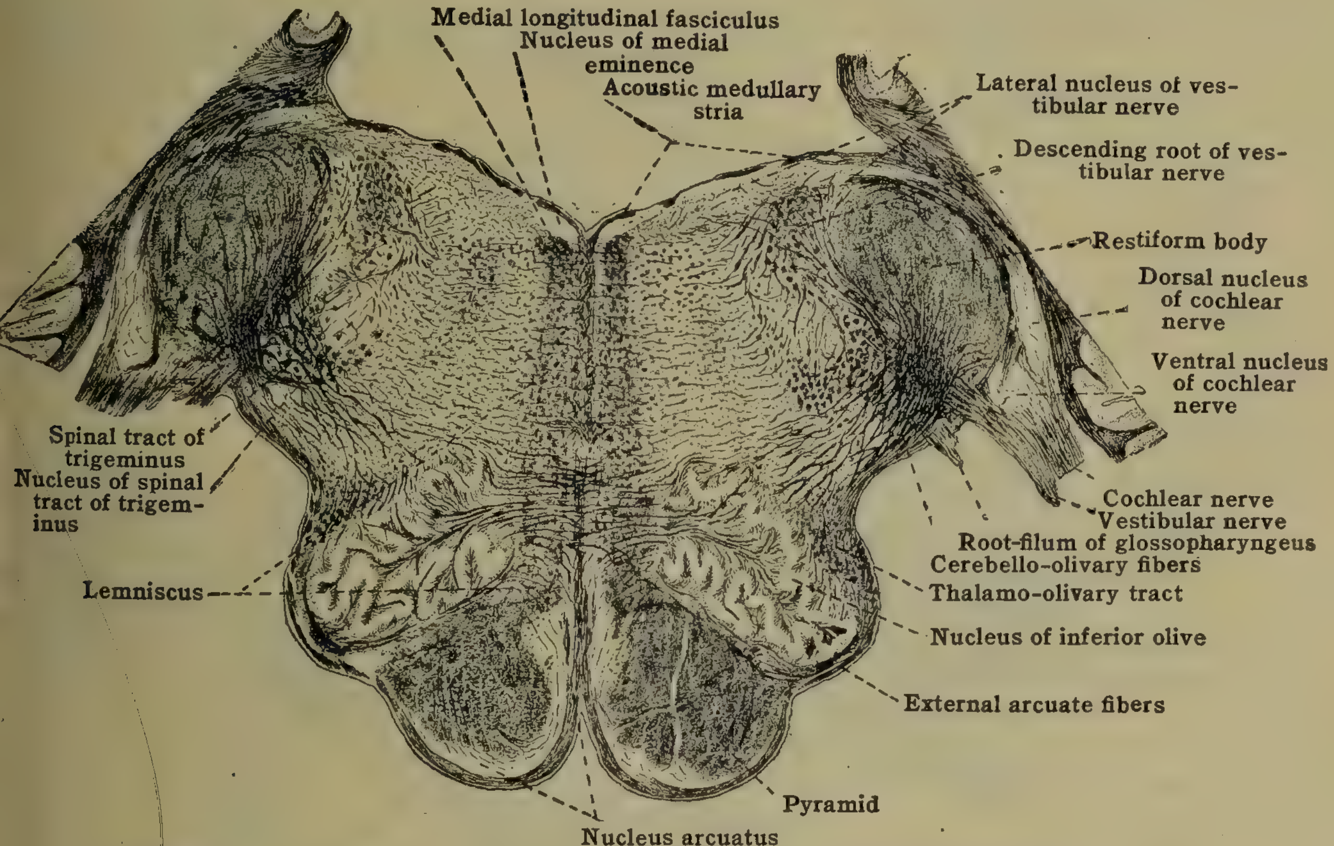


FIG. 728.—TRANSVERSE SECTION OF MEDULLA AT INFERIOR BORDER OF PONS.

the superior nucleus a special path is given off which passes upward and terminates in the roof nucleus of the cerebellum (nucleus fastigii) of the opposite side and in the nucleus dentatus and the cortex of the vermis. Also, fibers arising in the nuclei fastigii are said to terminate in the lateral (Deiters') nucleus and other gray substance of the medulla (forming the *fastigiobulbar tract*). Some fibers from the roof nucleus possibly descend into the anterior marginal fasciculus of the spinal cord. From the medial and also from the superior nucleus fibers pass to the medial longitudinal fasciculus of both sides, and are distributed to the nuclei of the abducens and facial nerves of the same side and to the nuclei of the trochlear and oculomotor nerves of the opposite side and of the masticator nerve of the same and opposite sides. From the lateral and medial nuclei, and probably from all, a few fibers arise which cross the midline to enter the lemniscus and ascend to the cerebrum (lateral portion of the thalamus) on the opposite side.

Deiters' nucleus is said to contribute more fibers to the medial longitudinal fasciculus than does a nucleus of any other sensory cranial nerve and fewer, if any, fibers to the lemniscus. If any of these fibers descend the cord, they must do so in its anterior marginal fasciculus.

The *inferior nucleus* is accompanied by the *descending* or *spinal root* of the vestibular nerve, which begins to assemble in the nuclei above. This root is composed of both caudal branches of the entering fibers of the nerve and chiefly of fibers arising from the cells of its nuclei. Thus for the vestibular nerve it corresponds in every way to the solitary tract for the vagus, and to the spinal tract of the trigeminus. Such of its fibers as descend into the spinal cord most probably do so in the lateral vestibulospinal fasciculus.

Many of the anatomical details of the central connections of the vestibular nerve have not yet been determined with exactness. In addition to whatever other functions it may have, it is considered to be the nerve of equilibration, and the connections noted above may be considered the pathways by which it exercises this function. The fibers of the apparatus which are represented in the spinal cord are supposed to convey impulses to the ventral horn (motor) cells of the cord as far down as the sacral region.

The **cochlear nerve**, the auditory nerve proper, arises as the central processes of the bipolar cells of the *spiral ganglion* of the cochlea. Its fibers enter the medulla laterally at the inferior border of the pons and divide into ascending and descending branches. In the lateral periphery of the restiform body, just before the latter enters the cerebellum, the nerve finds its two nuclei of termination, the *ventral nucleus* and the *dorsal nucleus* (tuberculum acusticum, figs. 719, 728).

From the **dorsal nucleus** arise many of the fibers forming the *acoustic medullary striæ.* These bundles pass around the dorsal aspect of the restiform body and course just under the ependyma of the floor of the fourth ventricle to the midline, where they suddenly turn downward into the substance of the medulla and in doing so, cross to the opposite side and join the lemniscus (fig. 729). As the lemniscus becomes separated higher up into a medial and lateral portion, these auditory fibers course in the lateral lemniscus and are distributed chiefly to the grey substance of the inferior quadrigeminate body and medial geniculate body of that side. At the midline some of their fibers join the medial longitudinal fasciculus and by way of it are distributed to the nuclei of origin of the efferent fibers of other cranial nerves. In frequent cases, the acoustic striæ course so deeply beneath the ependyma as not to be superficially visible in the floor of the fourth ventricle. It has been asserted recently that there are many fibers in these striæ which are passing between the olivary nuclei and the cerebellum as 'superficial internal arcuate fibers' and may not be cochlear connections at all.

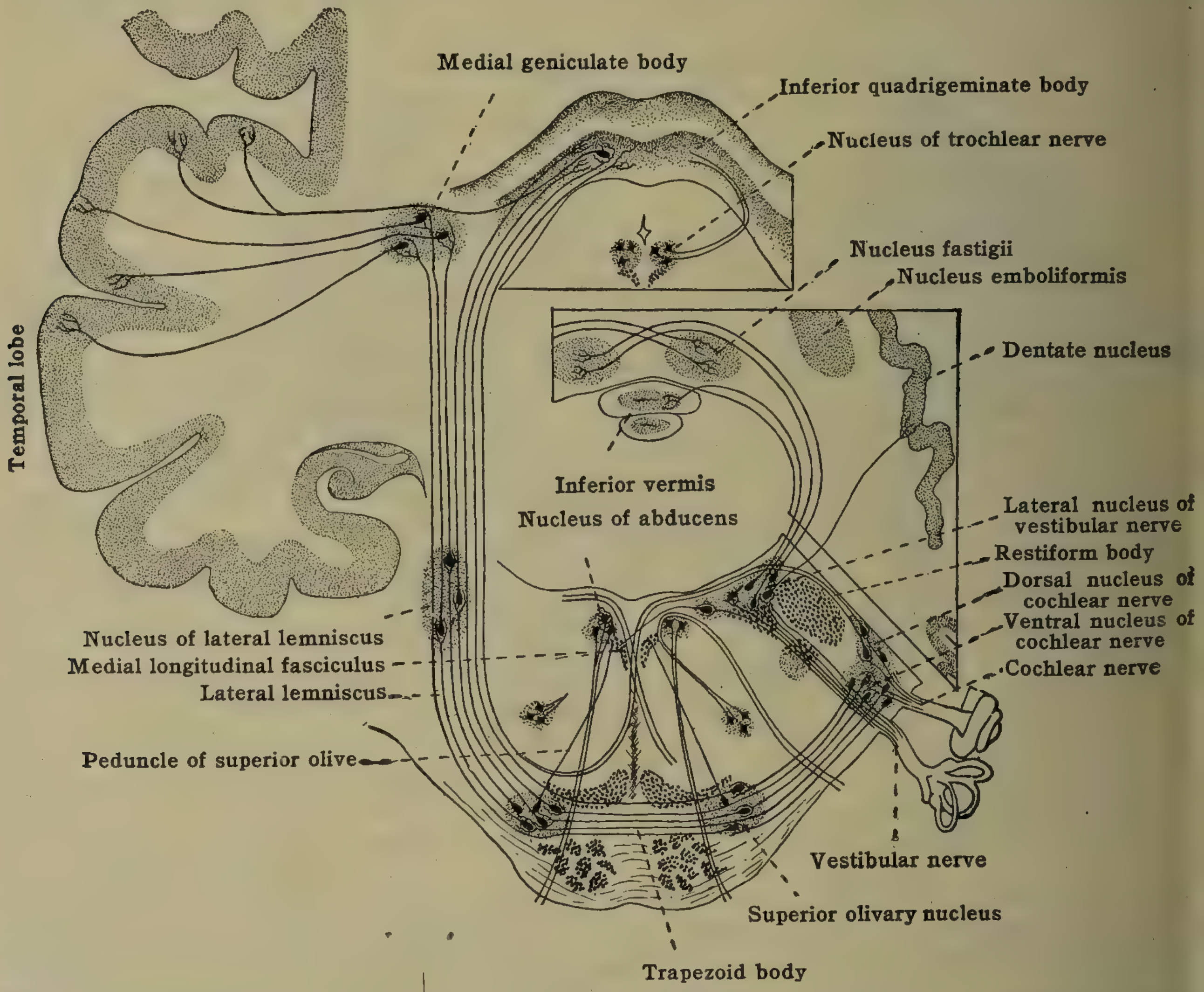


FIG. 729.—SCHEME SHOWING SOME OF THE CENTRAL CONNECTIONS OF THE ACOUSTIC NERVE. (In part after Edinger.)

From the **ventral nucleus**, fibers arise which terminate about (or give collaterals to) the cells of the **superior olivary nucleus** of the same and opposite sides. The superior olive is a small accumulation of gray substance which lies in the level of the inferior portion of the pons, and in line with the much larger inferior olivary nucleus of the medulla. However, it is not analogous to the latter in any sense. The two superior olives form links in the central acoustic chain. From cells of the superior olivary nucleus of the same and opposite sides, fibers arise which join the lateral lemniscus and terminate in the gray substance of the inferior quadrigeminate body and in the medial geniculate body, thus associating these bodies with the ventral nucleus of cochlear termination of the opposite side. From the medial geniculate body fibers arise which pass to the cortex of the superior temporal gyrus. Only a few of the fibers arising in the inferior quadrigeminate body terminate in the cortical area of hearing. In the lateral lemniscus some of the acoustic fibers are interrupted by cells of the *nucleus of the lateral lemniscus.* In crossing the midline, between the superior olives, the ventral fibers from the two sources form a more or less compact bundle, the **corpus trapezoideum** (trapezium). To this are added fibers crossing between the **nuclei trapezoidei**, smaller masses of gray substance just ventral to the superior olive and probably of the same significance. Experimental evidence has suggested that the more ventrally coursing fibers in the trapezoid body are not concerned with auditory impulses proper, but instead are concerned with cochlear motor reflexes only. And further it is asserted that some vestibular fibers cross in the trapezium.

Also, some fibers arising in the nuclei of termination of the cochlear nerve pass to the inferior quadrigeminate body of the same side. On the other hand, the relation with the medial geniculate body is thought to be wholly a crossed one. Further, some fibers are described as terminating in the *superior quadrigeminate body* of both the same and the opposite side. These, forming the *stratum lemnisci* of this body, are especially suggestive of associating auditory impulses with eye-movements.

All the fibers arising in the superior olivary nucleus do not enter the corpus trapezoideum. A small bundle, the **peduncle of the superior olive,** arises in each nucleus and courses dorsally to the region of the nucleus of the abducens. Here certain of its fibers terminate about the cells of the nucleus of the abducens, while others enter the medial longitudinal fasciculus and pass to the nuclei of the trochlear and oculomotor nerves, thus further establishing connections between auditory impulses and eye-movements. Also fibers from the nuclei of termination of the cochlear nerve are known to enter the medial longitudinal fasciculus and doubtless by way of this they distribute impulses to the motor nuclei of other cranial nerves and to the ventral hours of the spinal cord.

The vestibular and cochlear nerves enjoy a certain amount of community of origin in their ganglia and a certain community of distribution as to the origin and general character of the ectodermal neuroepithelium in their respective divisions of the labyrinth. Winkler's work has suggested that to some extent they may use their nuclei of termination in common and to some extent share each other's central paths in the medulla and midbrain, making paths usually considered purely vestibular and purely cochlear doubtfully so. It is not impossible that sound vibrations may arouse impulses in the macula sacculi and maybe changes in body posture can arouse impulses in the cochlea. However, it can be said with certainty that each of these nerves is chiefly concerned with the functions long ascribed to it.

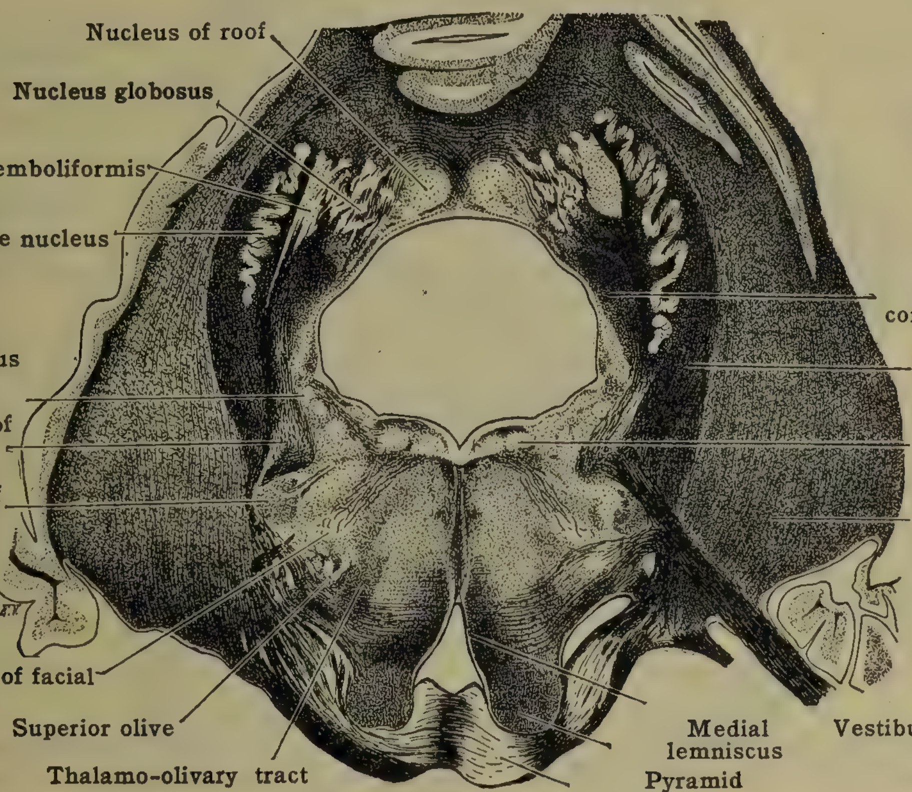


Fig. 730.—Transverse Section through Inferior Border of Pons and Portion of Overlying Cerebellum. (From Villiger.)

The **facial nerve** is commonly described as consisting of the 'facial proper' and its so-called sensory root or *pars intermedia,* the two together being designated as the seventh cranial nerve. However, the pars intermedia neither serves as a sensory root for the facial nor is it purely sensory. Many years ago Sapolini considered it a separate nerve and later it was called the *intermediate nerve of Wrisberg.* More recent investigations of its development and distribution, especially those of Streeter and Sheldon, further indicate that it merits a separate description and a separate name, and, indicative of its distribution, it is here described as the *glossopalatine nerve.* The facial, the glossopalatine and the abducens all have their nuclei within the level of the pons, though the roots of all appear from under its inferior border and are considered as attached to the medulla.

The **facial** [nervus facialis] has its nucleus (of origin) in the ventrolateral region of the reticular formation, superior to and in line with the nucleus ambiguus (figs. 726, 730). The axones given off by the cell-bodies of the nucleus collect into a bundle which, instead of passing ventrally and directly to the exterior of the pons, courses at first dorsomedially to the mesial side of the nucleus of the abducens (ascending root of the facial); then it turns and courses superiorly for a few millimeters, parallel with the nucleus of the abducens immediately beneath the floor of the fourth ventricle (*genu internum,* figs. 731 and 732); then it turns abruptly in a ventrolateral and inferior direction to its point of exit at the inferior border of the pons, just lateral to the olive and medial to the entrance of the vestibular nerve. Its exit usually involves a few pons fibers. In transverse sections through the middle of the nucleus of the abducens the genu of the facial appears as a compact transversely cut bundle at the dorsomedial side of this nucleus.

The nucleus of the facial is described as consisting of two chief groups of cells, an anterior and a posterior group which give rise respectively to the axones of the superior and inferior branches of the facial nerve. It receives cortical impulses from the lower portion of the anterior central gyrus of the cerebral cortex, from the root fibers of the trigeminus of the same side, which serves as its sensory root, and (chiefly) fibers arising from the nuclei of termination of the trigeminus. The nuclei of termination of the optic and the cochlear nerves of the same and opposite sides give rise to fibers which terminate about its cells. The fibers from the cerebral cortex descend in the pyramidal fasciculi and cross by way of the raphe and arcuate fibers to terminate in the nucleus of the opposite side. The anterior group of the cells of the facial nucleus must receive cortical fibers not only from the cerebral hemisphere of the opposite but also from that of the same side, evidenced by the fact that the superior branch of the nerve is but little affected in facial paralysis resulting from a lesion in the cerebral cortex of one side. A lesion destroying the root of the nerve or its nucleus of origin will of course give total facial paralysis of the side of the lesion.

The glossopalatine nerve (*nervus intermedius*, sensory root of facial, etc.) is a mixed nerve but largely sensory. It accompanies the facial nerve trunk from a short distance beyond the geniculum (genu externum) of the facial to its attachment to the brain stem. Its *sensory fibers* arise as T-fibers of the cells of the *geniculate ganglion* (at the geniculum of the facial). The peripheral processes go as the *chorda tympani* to supply the epithelium of the anterior part of

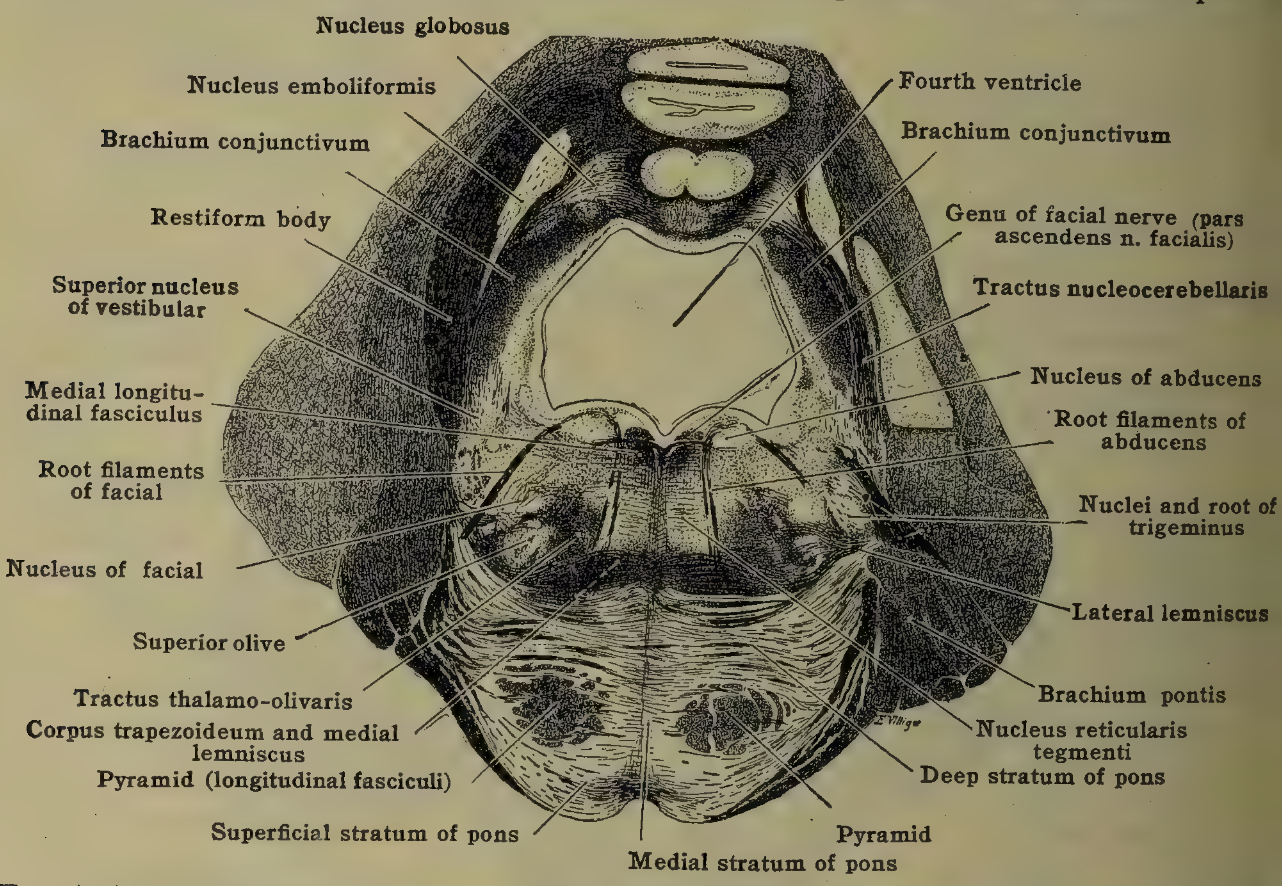


FIG. 731.—TRANSVERSE SECTION THROUGH PONS AND PORTION OF CEREBELLUM AT LEVEL OF NUCLEI AND ROOT FILAMENTS OF ABDUCENS AND FACIAL NERVES. (From Villiger.)

the tongue and that of the palate, especially of the palatine arches, and some of its fibers share with the glossopharyngeal nerve the innervation of the taste-buds. The central processes enter the brain stem, bifurcate into caudal and cephalic branches, and find their nucleus of termination in a superior extension of the nucleus of the solitary tract (the ventral portion of the nucleus of the ala cinerea). The geniculate ganglion contains some cell-bodies of sympathetic neurones, left over in it during the period of migration of the sympathetic neuroblasts.

The *efferent fibers* of the glossopalatine arise from cell-bodies lying dorsomedial to the nucleus of the facial and in the level between this and the nucleus of the masticator nerve superior to it. Its cells are usually scattered in the reticular formation in line with the dorsal efferent nucleus of the vagus. Since most of its fibers, at least, are visceral efferent and are concerned with sympathetic neurones (terminate in sympathetic ganglia) and convey secretory impulses destined for the salivary glands, chiefly the submaxillary and sublingual, this nucleus has been called the **nucleus salivatorius.**

The **abducens** is a small, purely motor nerve, which supplies the lateral rectus muscle of the eye. Its *nucleus of origin* lies close to the midline in the medial eminence of the floor of the fourth ventricle, superior to and in line with that of the hypoglossus. Its root-fibers, uncrossed, pursue a ventral course, inclining a little laterally and curving inferiorly to emerge from under the inferior border of the pons. They pass lateral to the pyramid, and often between some of its fasciculi. The nucleus receives cortical or voluntary impulses by way of the pyramidal fasciculi chiefly of the opposite side. Its connection with the auditory apparatus and the medial longitudinal fasciculus has already been noted. It probably receives afferent impulses through the fibers of the trigeminus as well as by fibers descending from the nuclei of termination of the optic nerve. It is also associated, by way of the medial longitudinal fasciculus, with the nucleus of the oculomotor nerve of the same and opposite side.

The **trigeminus** is considerably larger than any of the nerves inferior to it, and has the most extensive central connections of any of the cranial nerves. It is a purely sensory nerve which

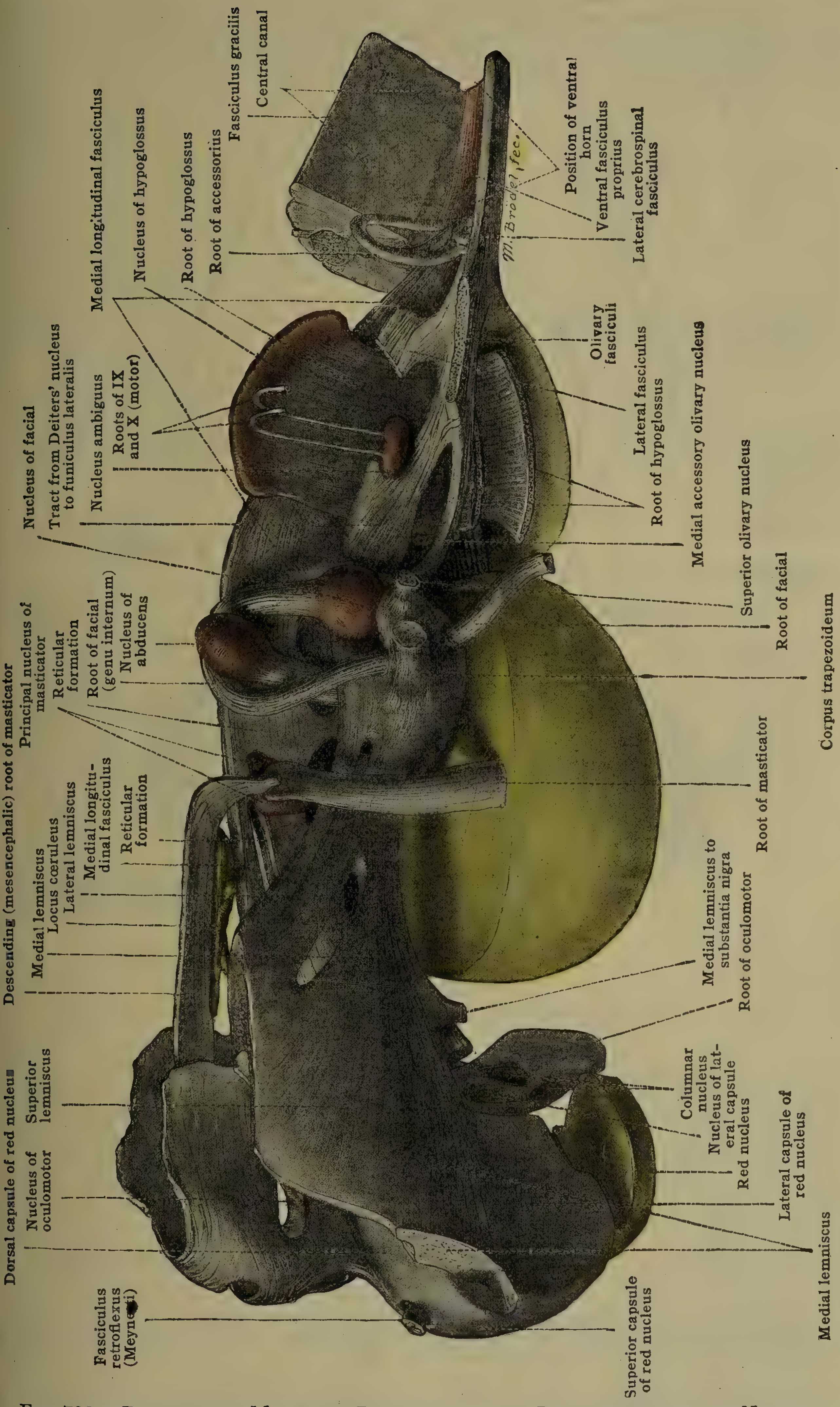


Fig. 732.—Drawing of Model of Brain-stem of an Infant, showing the Nuclei of Origin of the Motor Cranial Nerves. (After Sabin.)

enters through the brachium pontis in line with the facial nerve. It serves as the nerve o general sensibility for the face from the vertex of the scalp downward, and thus it correspond to the afferent fibers (dorsal root) for all the nerves giving motor supply to structures underlyin its domain, including the eye-muscles. Its fibers arise from its large, trilobed, **semilunar** (Gas serian) **ganglion,** situated outside the brain. This corresponds to the dorsal root-ganglion of

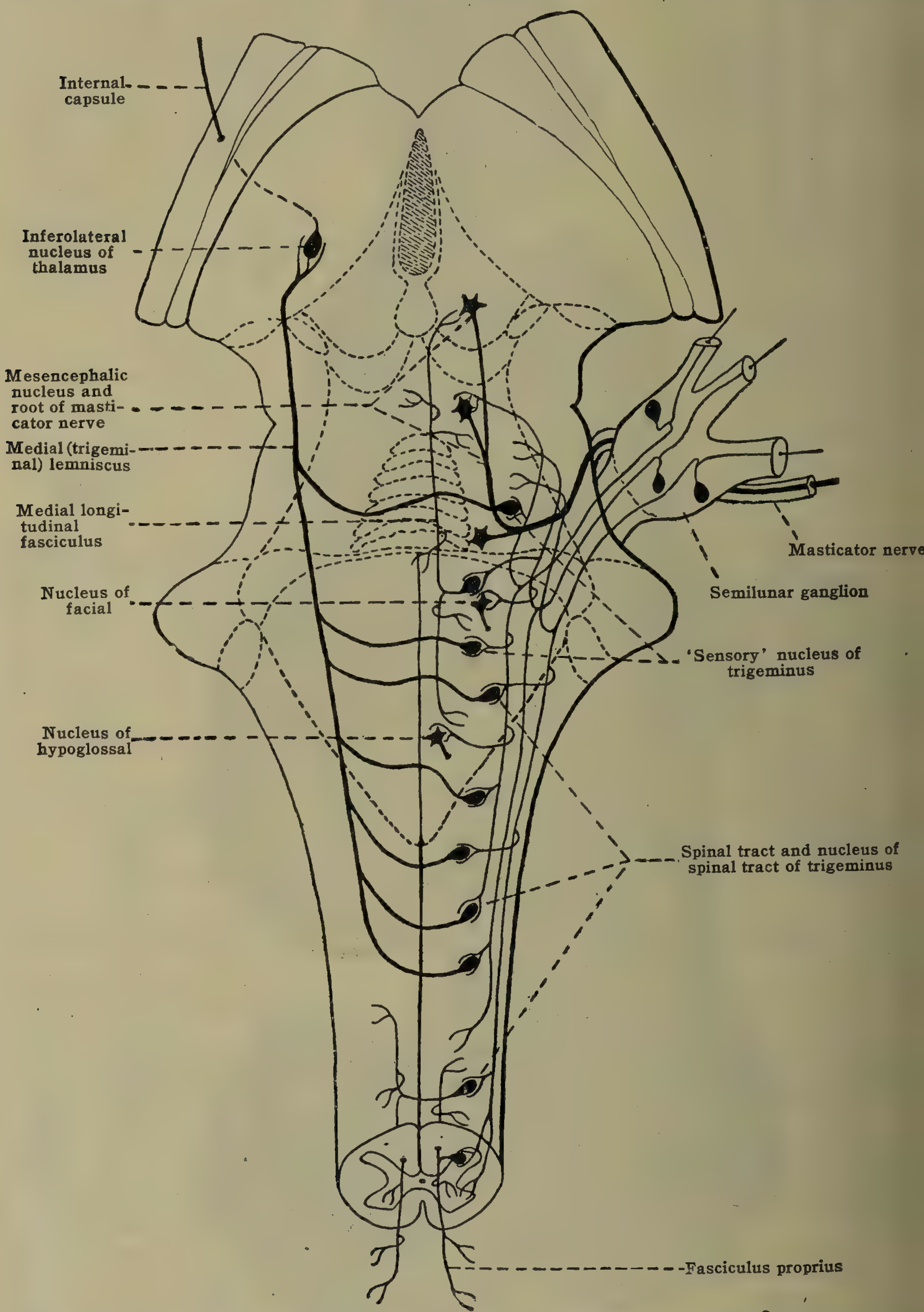


FIG. 733.—DIAGRAM ILLUSTRATING THE PRINCIPAL CENTRAL CONNECTIONS OF THE TRIGEMINUS AND MASTICATOR NERVES, EXCLUSIVE OF RELATIONS TO DESCENDING CEREBRAL OR PYRAMIDAL FIBERS.

spinal nerve, and its cells give off the characteristic T-fibers with peripheral and central branches. The central or afferent branches upon entering the brain-steam bifurcate into ascending and descending divisions, just as the entering dorsal root-fibers of the spinal nerves, and find their *nucleus of termination* in a dorsolateral column of gray substance, lying deeply and extending longitudinally through the brain stem, and consisting of the upward continuation of the gelatin-

ous substance of Rolando of the spinal cord. Opposite the entrance of the nerve is a considerably thickened portion of this column of gray substance, known as the *sensory nucleus* of the trigeminus. The remainder of it extending below is called the *nucleus of the spinal tract* (figs. 726, 733). Both parts are equally 'sensory.' After bifurcation the branches of the entering fibers of the trigeminus terminate about the cells of these nuclei. The descending branches are much longer than the ascending, and in passing downward form the **spinal tract of the trigeminus,** well marked in all transverse sections of the medulla oblongata (figs. 720, 722, 728). The spinal tract decreases rapidly in descending the medulla, owing to the rapid termination of the fibers in the nucleus of the tract. It has been traced as far down as the second cervical segment of the spinal cord. The ascending branches terminate in the 'sensory nucleus,' and in its extension upward into the mesencephalon. This mesencephalic nucleus of termination of the trigeminus is both shorter and more scant than the spinal extension. It may extend to the superior quadrigeminate body.

Axones from the nucleus of termination of the trigeminus are distributed—(1) to the nuclei of the masticator nerve of the same and opposite sides (short or simple reflex fibers); (2) to the nuclei of the other motor cranial nerves, especially of the facial; (3) to the thalamus of the same and chiefly the opposite side, and thus, through interpolation of thalamic neurones, their impulses reach the somesthetic area of the cerebral cortex. These fibers form a *'trigeminal lemniscus.'* They ascend in the recticular formation of the opposite side, most of them finally coursing within the medial lemniscus. In crossing the midline they contribute to the internal arcuates. (4) Some fibers of both the trigeminus direct and from its nucleus pass laterally into the cerebellum. (5) Fibers to the quadrigeminate bodies. The longer of the reflex or association axones arising in the nucleus of termination may contribute to the medial longitudinal fasciculus; many of them descend to terminate in the gray substance of the spinal cord below the levels in which the fibers of the spinal tract proper terminate. The nucleus of termination is directly homologous to the nuclei of the fasciculus gracilis and fasciculus cuneatus, and, like

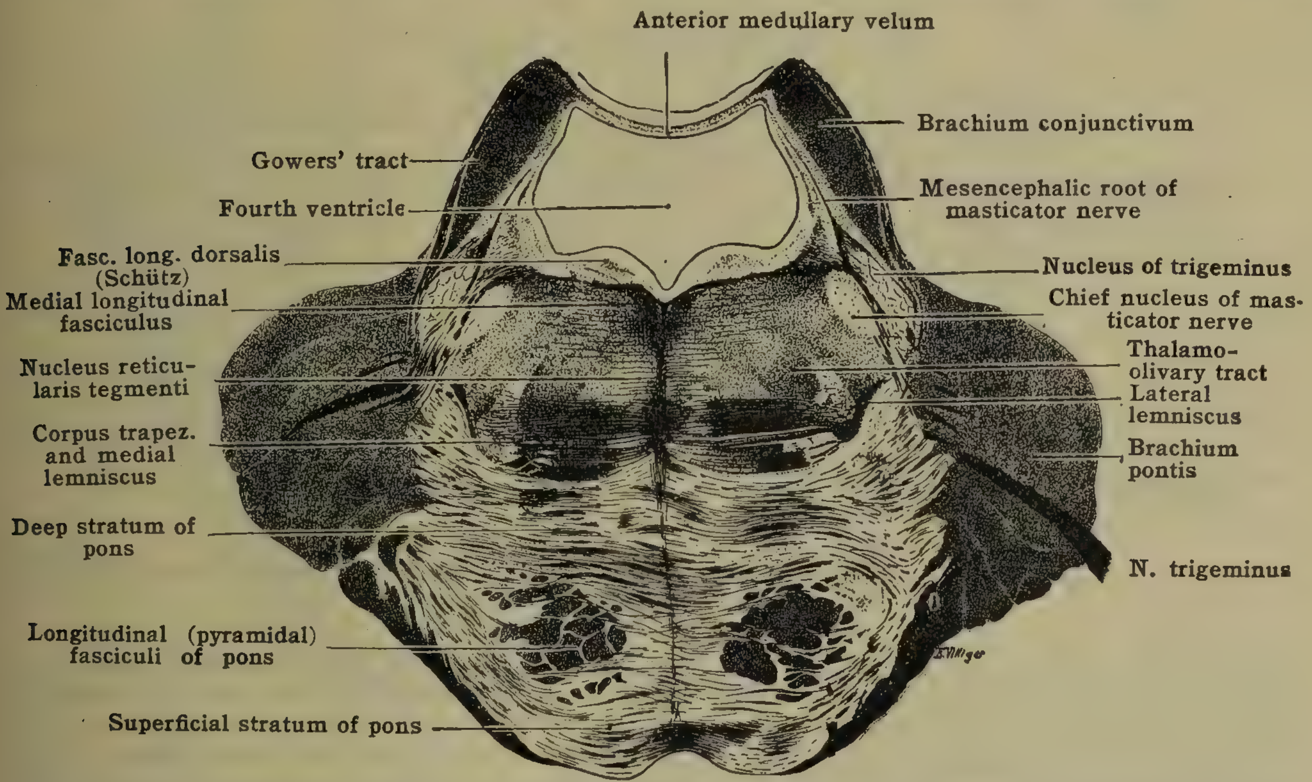


Fig. 734.—Transverse Section Through Upper Part of Pons at the Level of the Entrance of the Trigeminus. (From Villiger.)

the nuclei of termination of all sensory cranial nerves, it contains cell-bodies homologous to those which give rise to the fasciculi proprii and commissural fibers of the spinal cord.

The **masticator nerve** [*portio minor n. trigemini*] is a purely motor nerve, usually called the motor root of the trigeminus from the fact only that it makes its exit from the pons by the side of the entering fibers of the trigeminus, passes outward over the ventromedial side of the semilunar ganglion and accompanies the inferior maxillary division (mandibular nerve) of the trigeminus till it divides totally into its branches for the motor supply of the muscles of mastication. It serves, therefore, as but a relatively small part of the 'motor root' of the trigeminus.

The nucleus of origin of the masticator nerve is attenuated into two parts: (1) The *chief nucleus (nucleus princeps)* lies on the dorsomedial side of the larger portion (sensory nucleus) of the nucleus of termination of the trigeminus. It is the larger of the two parts and gives origin to much the greater part of the masticator. (2) Scattered anteriorly and continuous with the mesencephalic extension of the chief nucleus, in line with the *locus ceruleus*, are the cell-bodies usually described as the *nucleus of the mesencephalic* (descending) *root*. These cells lie in decreasing linear distribution, through the mesencephalon, as far anterior as the posterior commissure of the cerebrum, and the *mesencephalic root* of the nerve accumulates as it descends to join the exit of the fibers arising from the chief nucleus. The average diameter of its cells is somewhat less than for the chief nucleus.

It is not clearly settled that the fibers arising from the mesencephalic nucleus of the masticator nerve go to the muscles of mastication. As suggested by Kölliker, some of these may supply the tensor veli palatini and tensor tympani muscles. Investigations of lower animals by Johnston and Willems indicate that the mesencephalic root may contain but few motor

fibers, representing instead a portion of the sensory trigeminus fibers, whose cell-bodies of origin are retained during development within the central system, their peripheral processes passing out in the root of the trigeminus. It is claimed that some fibers, probably sensory, in descending give off collaterals which terminate about cells in the chief nucleus, to form simple reflex arcs.

It is claimed also that each masticator nerve receives a few fibers arising from the cells of the nucleus of that of the opposite side.

Both parts of the nucleus of the masticator receive afferent impulses brought in by the trigeminus of the same (chiefly) and of the opposite side, and both receive cortical impulses by fibers from the inferior portion of the precentral gyrus which descend in the cerebral peduncles and cross to terminate in the nucleus of the opposite side.

The internal structure of the pons.—The nuclei and roots of the trigeminus, masticator, abducens, facial, glossopalatine, cochlear and vestibular nerves are extended within the level of the pons, and their position and course have been described above. The pons proper (the bridge) consists of a mass of transversely running fibers continuous on either side into the brachia pontis or middle cerebellar peduncles. In the animal series the relative amount of these fibers varies with the size of the cerebellum upon which they are dependent. They are relatively more abundant in man than in other animals.

In transverse sections the pons fibers are seen to course ventrally about the main axis of the brain-stem, making it possible to divide the section into a *basilar* or *ventral part* (pons proper) and a *dorsal part* (*tegmentum* or *preoblongata*). The fibers in their transverse and ventral course around the medulla oblongata involve the pyramids. At the inferior border of the pons the

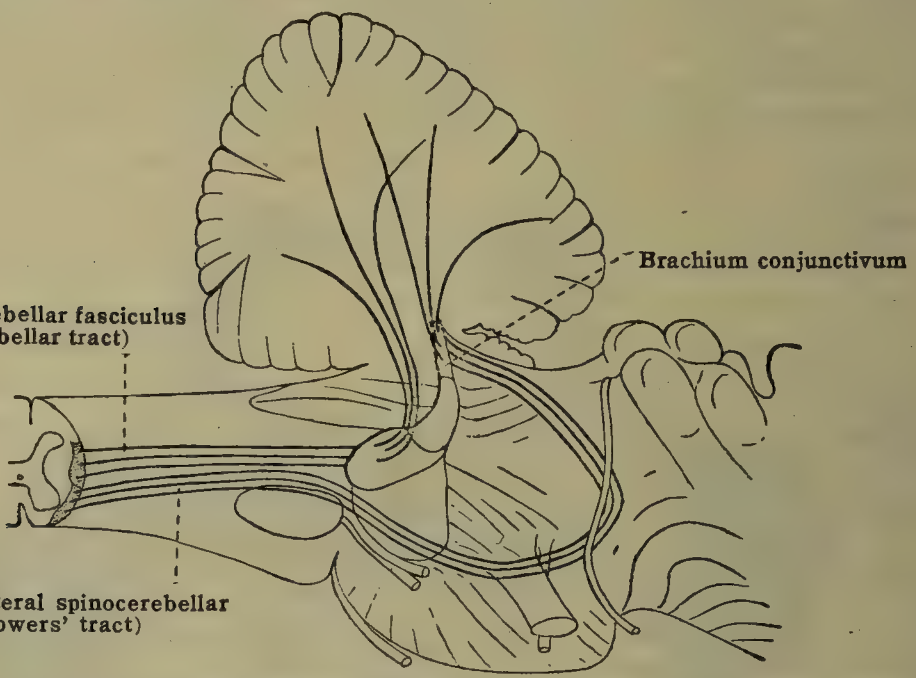


Fig. 735.—Diagram showing the Rhombencephalic Course of Gowers' Tract and the Direct Cerebellar Tract.

fibers little more than separate the pyramids as such from the main axis of the brain-stem, but more superiorly the pons fibers pass through the pyramids, splitting them into the pyramidal fasciculi. These pyramidal or chief *longitudinal fasciculi* of the pons are the continuation of the basal portion of the cerebral peduncles through the pons, to emerge as the pyramids proper at its inferior border. They occupy an intermediate or central area among the pons fibers of either side, leaving the periphery of the pons uninvaded. The *superficial pons-fibers* form the solid bundle of its ventral and lateral periphery and the *deep pons-fibers* form similar bundles dorsally enclosing the area of pyramidal fasciculi, which latter are involved in a *medial stratum of the pons* (figs. 731, 734, 736).

In the transverse sections through the *inferior portion* of the pons, the *dorsal or tegmental part* consists of structures continuous with and analogous to the structures of the medulla oblongata immediately below, exclusive of the pyramids. In addition, this region contains the superior olivary nucleus and the corpus trapezoideum. The significance of these structures and their relation to the nucleus of termination of the cochlear nerve are shown in figs. 729–731. In this region the *lemniscus* (fillet) changes from the sagittal to the coronal plane, and its lateral edges are becoming drawn outward and carry the lateral lemniscus of the regions superior to this. The medial longitudinal fasciculus, left alone by the change in the arrangement of the lemniscus, maintains its dorsal and medial position throughout the pons and into the mesencephalon above. The **thalamo-olivary tract** appears loosely collected in the dorsal part of the pons, dorsomedial to the nucleus of the superior olive.

The **restiform body** acquires in this inferior region a more dorsolateral position than in the medulla below. Its fibers are beginning to turn upward in their course to the cerebellum mesial to the brachium pontis. Here the restiform body is nearing completion, and the fibers now contained in it may be summarized as follows:—

(1) The fibers of the dorsal spinocerebellar fasciculus (direct cerebellar tract) of the same side.

(2) Fibers from the nuclei of the fasciculus gracilis and fasciculus cuneatus of the same and opposite side (external and internal arcuate fibers).

(3) Fibers to and from the inferior olives of the same and (chiefly) the opposite side (cerebello-olivary fibers).

(4) Sensory cerebellar fibers from the nuclei of termination of the vagus, glossopharyngeal, vestibular and trigeminus, vestibular especially, and from the cells of the reticular formation.

(5) Descending fibers to the motor nuclei of the vagus and glossopharyngeal, and possibly some fibers descending into the anterior marginal fasciculus of the spinal cord, the latter, however, being in large part interrupted by cells in the nuclei of the vestibular nerve.

(6) A few fibers arising from the arcuate nuclei. These nuclei are continuous superiorly with the nuclei of the pons and some of their fibers are described as entering the cerebellum by way of the restiform body instead of by way of the brachium of the pons as in the levels above.

The ascending fibers of the restiform body are distributed to the cortex of the vermis, the nucleus of the roof (*fastigii*), the nucleus dentatus, nucleus emboliformis, and nucleus globosus.

Very few if any of the fibers ascending the cord in *Gowers' tract* enter the cerebellum by way of the restiform body. This tract (the superficial anterolateral spinocerebellar fasciculus) ascends the medulla, dispersed in the reticular formation, and therefore in a more ventral position than that of the direct cerebellar tract. In this position it becomes enclosed by the fibers of the pons, and so it passes upward, beyond the pons, around the lateral lemniscus to the brachium conjunctivum, and there turns back to enter the cerebellum by way of this brachium. Certain clinical phenomena, probably purely psychological, have been alleged to indicate that some of the fibers of Gowers' tract pass on to the cerebrum instead of turning in the medullary velum to enter the cerebellum.

The dorsal part of a transverse section through the *upper part* of the pons contains the **superior cerebellar peduncles** [brachia conjunctiva] instead of the restiform bodies (inferior

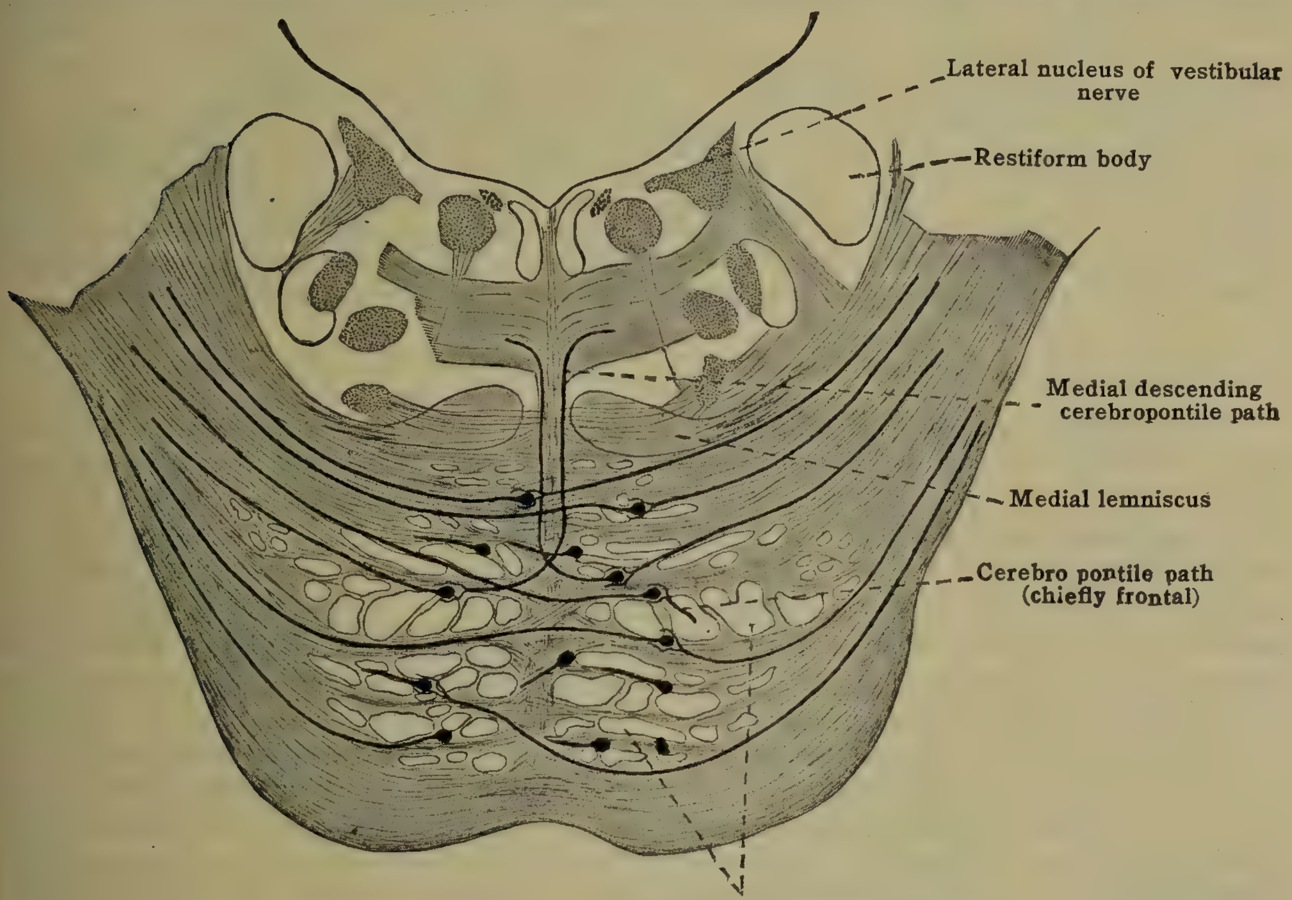


FIG. 736.—DIAGRAM SHOWING CONNECTIONS OF THE NUCLEI OF THE PONS.
The plane of the section is obliquely transverse or parallel with the direction of the brachia pontis.

peduncles). Instead of the cerebellum forming the roof of the fourth ventricle, in this region the roof is formed by the anterior medullary velum bridging the space between the two brachia conjunctiva (fig. 734). Adhering upon the medullary velum is the **lingula cerebelli**—the superior and ventral extremity of the superior vermis. This is the only portion of the cerebellum attached to this region.

The lemniscus (fillet) is found more lateral than at the inferior border of the pons, and is divided into the *medial lemniscus* and *lateral lemniscus* proper. The lateral lemniscus has shifted dorsally until in this region it courses in the dorsolateral margin of the section external to the brachium conjunctivum. The mesencephalic root of the masticator nerve occurs in the dorsolateral margin of transverse sections through this region, and this and the trigeminus are the only cranial nerves represented here.

The transverse fibers of the ventral part of the section (pons proper), and therefore the brachia pontis, consist of fibers coursing in opposite directions. Many are fibers which are outgrowths of the Purkinje cells of the cortex of the cerebellar hemispheres, and pass either directly to the cerebellar hemisphere of the opposite side or turn dorsalward in the raphe to course longitudinally in the brain-stem both toward the spinal cord and toward the mesencephalon. Others terminate in the gray substance (nuclei) of the pons. Others are fibers which arise in the gray substance of the pons and pass to the cerebellar hemispheres, and still others are the cerebropontile fibers, from the temporal, occipital and frontal lobes.

The **gray substance of the pons** [nuclei pontis] occurs quite abundantly. At the inferior border of the pons it is found concentrated about the then more accumulated bundles of the emerging pyramids, and serial sections show it to be a direct upward continuation of the arcuate

nuclei of the medulla oblongata below. Higher up it is dispersed throughout the central ar in the interspaces between the transverse pontile and longitudinal pyramidal fasciculi. large portion of the nerve-fibers passing through it are thought to be interrupted by its cel which thus serve as links in some of the neurone-chains represented by the fibers of the por Of the more important of such relations, the following are said to exist:—

(1) Fibers which arise in the cortex of one cerebellar hemisphere and terminate about ce of the nucleus pontis of the same and opposite sides of the midline. These cells give off axon which pass to the other cerebellar hemisphere. In this relation the nuclei of the pons a analogous to the arcuate nuclei, save that the cerebellar fibers interrupted in the former a connected with the cerebellum by way of the brachia pontis instead of the restiform bodies.

(2) Certain of the descending cerebropontile fibers terminate about cells of the nuclei the pons. Such cells give off fibers which probably, for the most part, pass to the cerebell hemispheres, the impulses from the cerebral hemisphere of one side being conveyed to t opposite cerebellar hemisphere. Most of the descending cerebropontile fibers are thought cross the midline to terminate about cells of the nuclei of the pons of the opposite side, a relatic not sufficiently emphasized in the accompanying diagram (fig. 736).

Of the cerebropontile paths, (see fig. 775) the **frontal pontile path** (Arnold's bundle) described as arising in the cortex of the frontal lobe (frontal operculum), passing in the anteri portion of the internal capsule down into the medial part of the base of the cerebral peduncl and terminating in the gray substance of the pons. The descending **temporal pontile pat** (Türk's bundle), arises in the cortex of the temporal lobe, traverses the posterior portion of t internal capsule, lies lateral in the pyramidal portion of the cerebral peduncle, and terminat in the gray substance of the pons. In the posterior part of the internal capsule, the tempor pontile path is joined by a small bundle arising in the occipital lobe and going to the pons nucle This, supposedly smaller than the other two, adds an **occipitopontile path.**

The total area in cross section of the pyramidal fasciculi as they enter the pons above considerably greater than that which they possess as they emerge as the pyramids of the medul below. The difference is considered very appreciably greater than can be explained as du to the loss of pyramidal fibers supplied to the nuclei of origin of the motor cranial nerves lyin within the level of the pons, and the additional difference is explained as due to the terminatio within the pons of the cerebropontile paths. Because of this difference, in the pons regio these fasciculi must be given the more general name, *longitudinal fasciculi of the pons.*

THE ISTHMUS OF THE RHOMBENCEPHALON

The isthmus of the rhombencephalon is nothing more than the transition o the metencephalon into the mesencephalon above. It is quite short and com prised of only the structures which run through it, namely, the *brachia conjunc tiva* (superior peduncles of the cerebellum), the anterior medullary velum, th lateral sulcus of the mesencephalon, the substantia nigra, the cerebral peduncles and the inferior end of the interpeduncular fossa. It surrounds the superio extremity of the fourth ventricle. The lateral and medial lemnisci, the superio extension of the nucleus of the trigeminus, the mesencephalic nucleus and roo of the masticator nerve and Gowers' tract extend through it. At the midline just inferior to the inferior quadrigeminate bodies is the **frenulum** of the anterio medullary velum and the trochlear nerves, decussating in the velum, emerge at it sides and course ventrally around the sides of the isthmus. In the lateral sulcus the isthmus shows usually a more triangular elevation known as the **trigonum lemnisci** from the fact that the lateral lemniscus tends towards the surface in this region and the nucleus of the lateral lemniscus begins there.

Functions of the cerebellum.—From the above descriptions involving the structures of the metencephalon, it may be noted: (1) that a given side of the cerebellum is associated chiefly with the same side of the general body and with the opposite side of the cerebrum. (2) That it receives afferent impulses from the spinal cord (brought into the cord by the dorsal roots of the spinal nerves) by way of the direct cerebellar fasciculus of the same side, and by Gowers' tract, arising in the same and opposite sides of the cord, and from the nuclei of the fasciculus gracilis and cuneatus of the same and opposite sides. It further receives afferent impulses from the nuclei of termination of the trigeminus, glossopharyngeal and vagus of the same side chiefly, and especially does it receive afferent impulses from the nuclei of the vestibular nerve of the opposite and same side. (3) That the cerebellum sends impulses to the red nucleus, the thalamus and the cerebral cortex of the opposite side, and some of its fibers terminate in the nuclei of termination of the vestibular nerve and possibly some fibers arising in its roof nuclei descend into the spinal cord direct. (4) That the cerebellum receives impulses from the thalamus of the opposite side by way of the thalamo-olivary tract and the inferior olive, and especially from the cerebral cortex of the opposite side by way of the frontal, temporal and occipital pontile paths and the nuclei of the pons. Further, fibers from the longitudinal pyramidal fasciculi are described as terminating about cells of the nuclei of the pons and bearing impulses which are distributed to the opposite side of the cerebellum.

Taking into consideration these known associations of the cerebellum, the anatomically possible paths which in part may distribute cerebellar impulses to the gray substance which sends efferent fibers to the peripheral tissues are (1) the pyramidal fasciculi whose cortex of origin may receive impulses by *fibræ propriæ* from the cortical areas receiving impulses from the cerebellum. The pyramidal fasciculi, decussating, distribute impulses to the gray substance of the medulla and cord of the same side as that from which the cerebellocerebral impulses

passed to the cortex. (2) The lateral vestibulospinal and the anterior marginal fasciculi to the ventral horn of the spinal cord of the same side, probably carrying impulses descending from the cerebellum as well as impulses brought in by the vestibular nerve and descending direct from its nuclei of termination into the spinal cord. (3) The rubrospinal tract of the cord and probably some of the thalamospinal fibers (corpora-quadrigemina-thalamus path), since the red nuclei and thalami are associated abundantly with the cerebellum. These tracts likewise decussate in descending, but also do the cerebellar impulses ascending to the red nuclei and thalami.

Whatever other functions it may possess, developmental defects and pathologic lesions show that the cerebellum has to do with muscular tone, with the equilibration of the body and the finer coördinations, the adjustive control of contractions of functionally correlated groups of muscles. Making this possible, in part at least, it is seen above that it is associated (1) directly with the special nerve of equilibration, the vestibular; (2) with the optic apparatus by way of the thalamus, and (3) with the afferent impulses from the general body, by way of the direct cerebellar and Gowers' tracts, by way of the nuclei of the fasciculus gracilis and cuneatus, and the nuclei of termination of the trigeminus, glossopharyngeal and vagus. It has been suggested that by way of these latter paths the cerebellum deals especially with those general afferent impulses which arise within the muscles of the body (sensory fiber-terminations on tendons, muscle-sheaths, neuromuscular spindles, etc.), and which are grouped under the name 'Pro-

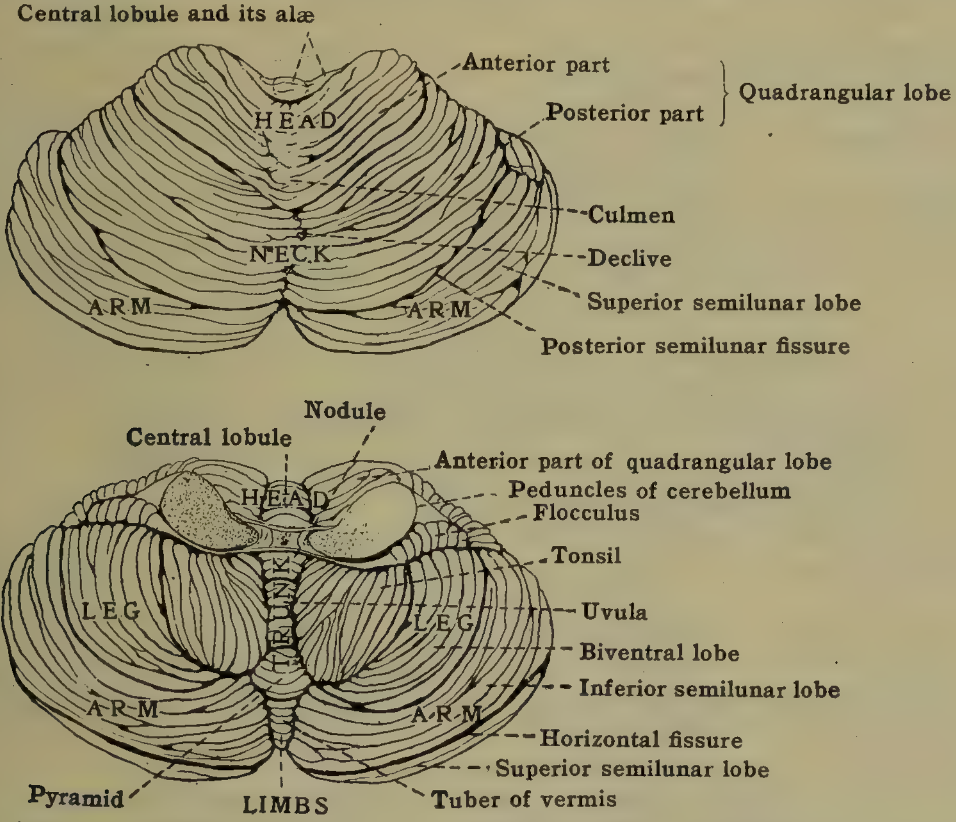


Fig. 737.—Suggested Functional Areas of the Cerebellar Cortex.
(In part from Herrick's Introduction to Neurology.)

prioceptive.' Its activities are considered as not entering 'consciousness.' The sensations of 'muscular sense,' and pain from joints, muscles and tendons must reach the *cerebral* cortex to be recognized as such. (See also extrapyramidal system.)

Studies of the comparative anatomy of the cerebellum by Elliot Smith, Bolk and van Rynberk, experimental studies by André-Thomas, Luciani and Durupt, and clinical studies of symptoms resulting from localized lesions in the human cerebellum by Bárány and others have led to the conclusion that there is a certain amount of localization of function in the cerebellar gray substance. In fig. 737 are indicated some of the functional areas of the cerebellar cortex suggested. It will be seen that the anatomical distinction made between the cerebellar hemispheres and the vermis is not functionally important, especially on the superior surface. Beginning on the superior surface, the following areas may be noted:—The anterior part of the quadrangular lobe, the culmen and the central lobule with its ala comprise an unpaired area for the coördinations of muscular contraction resulting in subconscious movements of the head. The posterior portion of the quadrangular lobe, anterior part of it especially, together with the declive comprise an unpaired area for the similar control of movements of the neck. The tuber of the vermis is given as an unpaired area for similar control of bilateral movements of the upper and lower limbs. The superior and inferior semilunar lobes are considered paired areas for the control of unilateral movements of the arms, and, on the inferior surface, the biventral lobes are paired areas likewise controlling unilateral movements of the lower extremities. The pyramid, uvula and nodule of the inferior vermis are given as unpaired areas for coördinating contractions of the muscles of the trunk. The tonsil and flocculus are concerned with tail movements in the tailed mammals. Their significance in man is unknown. The chief function of cerebellar control of muscular contraction is for equilibration of the body, it being especially large in the primates. Of the nuclei of the cerebellum, the roof nuclei, associated as they are with the (vestibular) nerve of equilibration, are especially concerned with this function, probably bilaterally.

The cerebellum and medulla oblongata can be considered as an enlarged and modified portion of the spinal cord, receiving a greater number and variety of sensory impulses, and with

these mediating more comprehensive and complicated reflex (unconscious) activities than a possible in the less abundant gray substance of a given portion of the cord proper. Tl cerebellum itself may be considered as an elaboration of the primary vestibular (equilibratic and orientation) region as found in the lower forms of vertebrates, in which the cerebellum often rudimentary. Unlike the different areas of the cerebral cortex, the cell structure of tl cerebellar cortex is quite similar throughout. This must indicate greater similarity function throughout and greater simplicity of neurone chains than occur in the cerebr hemispheres.

SUMMARY OF PRINCIPAL STRUCTURES IN THE RHOMBENCEPHALON

A. Gross Exterior.

1. Medulla oblongata (Myelencephalon).
2. Metencephalon
   - Cerebellum
     - Hemispheres—lobes and lobules.
     - Vermis—lobules and lingula.
   - Pons
     - Dorsal part (tegmentum or preoblongata).
     - Ventral part (pons proper).
   - Cerebellar peduncles
     - superior—brachium conjunctivum.
     - middle—brachium of pons.
     - inferior—restiform body.
3. Isthmus of rhombencephalon.
4. Fourth ventricle and its choroid tela.
5. Anterior and posterior medullary vela.

B. Grey and white substance.

1. Funiculus gracilis, nucleus of fasciculus gracilis, funiculus cuneatus, nucleus of fascicul cuneatus.
2. Internal and external arcuate fibers, decussation of lemnisci, lemniscus, medial lemniscu lateral lemniscus.
3. Cerebral peduncles, pyramidal fasciculi, pyramids, decussation of pyramids.
4. Superficial and deep strata of pons, nuclei of pons, arcuate nuclei, brachia of pons.
5. Inferior olivary nuclei, cerebello-olivary fibers, thalamo-olivary tract, spino-olivar tract.
6. Nuclei emboliformis, globosus and fastigii (of the roof), and nucleus dentatus with bra chium conjunctivum of cerebellum.
7. Central gelatinous substance and gelatinous substance of Rolando.
8. Reticular formation.
9. Hypoglossal nerve and nucleus of hypoglossal.
10. Spinal accessory nerve and lateral nucleus.
11. Vagus and glossopharyngeal nerves, nucleus of ala cinerea, solitary tract and nucle of solitary tract, commissural nucleus of ala cinerea, nucleus ambiguus, dorsal efferent nucle of vagus.
12. Vestibular nerve—its superior nucleus (Bechterew), its medial nucleus (Schwalbe its lateral nucleus (Deiters), and the nucleus of its descending (spinal) root.
13. Cochlear nerve, dorsal nucleus and ventral nucleus of cochlear, acoustic medullary stria nucleus of superior olive, trapezoid body, nucleus trapezoidei, lateral lemniscus, nucleus c lateral lemniscus.
14. Facial nerve and nucleus of facial nerve.
15. Glossopalatine nerve, nucleus of glossopalatine and nucleus salivatorius.
16. Abducens and nucleus of abducens.
17. Trigeminus, 'sensory nucleus' of trigeminus, spinal tract and nucleus of spinal trac of trigeminus.
18. Masticator nerve, chief nucleus and (so-called) mesencephalic nucleus and root c masticator.
19. Medial longitudinal fasciculus.
20. Nucleus intercalatus, nucleus of medial eminence, nucleus incertus.

THE CEREBRUM

1. THE MESENCEPHALON

The mesencephalon or midbrain (figs. 681, 704, 714, 738, 747) is that smal portion of the encephalon which is situated between and connects the rhomben cephalon below with the prosencephalon above. It is continuous with the isth mus rhombencephali, and occupies the tentorial notch, the aperture of the dur mater which connects the meningeal cavity containing the cerebellum with tha occupied by the prosencephalon. Its greatest length is about 18 mm., and it i broader ventrally than dorsally. Its dorsal surface is hidden by the overlapping occipital lobes of the cerebral hemispheres. It consists of—(1) the **lamina quad rigemina,** a plate of mixed gray and white substance which goes over lateralwar and below into (2), the **cerebral peduncles** (crura) and their tegmental structures and it contains (3), the *nuclei of origin* of the *trochlear* and *oculomotor* nerves. I arises from thickenings of the walls of the middle cerebral vesicle of the embryo the lamina quadrigemina arising from the dorsal or alar lamina of this portion of the neural tube, while the basal lamina thickens to form the nuclei of the nerves the substantia nigra, etc., and is thickened by the ingrowing of the cerebra

peduncles. By means of the lamina quadrigemina roofing it over, the central canal throughout the mesencephalon retains its tubular form and is known as the **aqueductus cerebri** (Sylvii), connecting the cavity of the fourth ventricle below with that of the third ventricle above.

External features.—*Dorsal surface* (figs. 710, 738).—The lamina quadrigemina shows four well-rounded elevations, the quadrigeminate bodies [**corpora quadrigemina**], separated from each other by the *cruciate sulci,* that is, by a flat median groove crossed at right angles by a transverse groove. The anterior pair of these, the *superior quadrigeminate bodies* [colliculi], are larger though less prominent than the inferior pair or *inferior colliculi.* Each colliculus is continued laterally and upward into its arm or brachium. The **inferior brachium** proceeds from the inferior colliculus, disappears beneath and is continuous into the **medial geniculate body,** and disappears beneath the thalamus. The **superior brachium** proceeds from the superior colliculus, passes between the medial geniculate body and the overlapping pulvinar of the thalamus, and becomes continuous with the **lateral geniculate body** and thus with the lateral root of the optic tract.

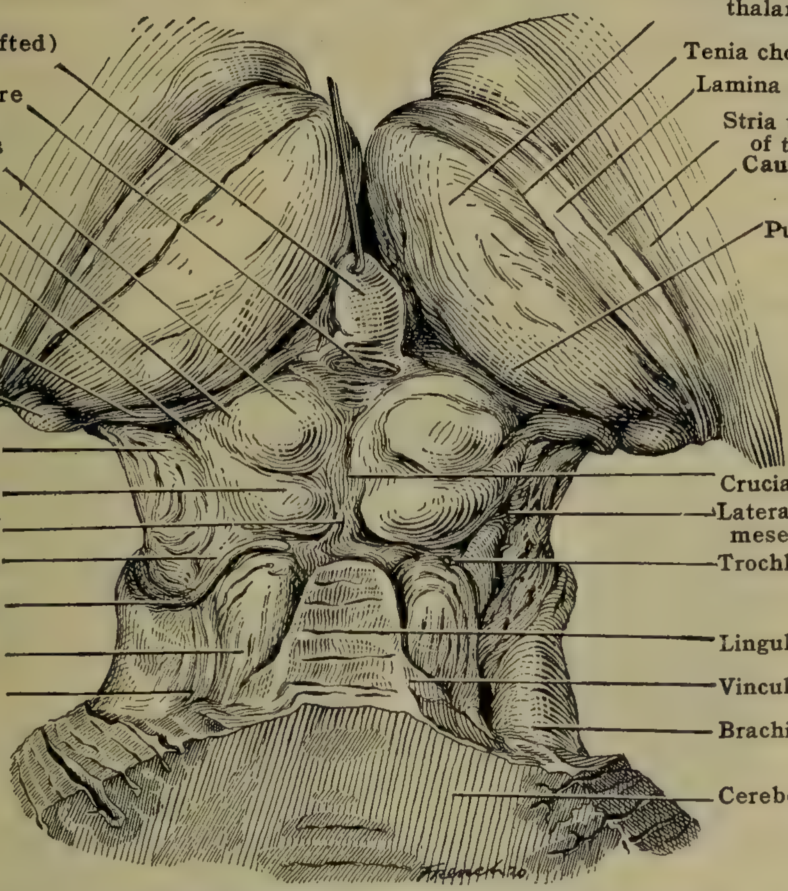


FIG. 738.—DORSAL SURFACE OF MESENCEPHALON AND ADJACENT PARTS. (After Spalteholz.)

The geniculate bodies are rounded elevations of gray substance which arise as detached portions of the thalami, and therefore belong to the thalamencephalon rather than to the mesencephalon. The superior quadrigeminate body or superior colliculus and the lateral geniculate body are parts of the *optic apparatus,* while the inferior colliculus and the medial geniculate body belong chiefly to the *auditory apparatus* (see CENTRAL CONNECTIONS OF COCHLEAR NERVE). Just as the cochlear nuclei of termination are connected by a few fibers with the superior colliculus, so do some fibers from the optic tract pass into the inferior colliculus. Also some fibers from the optic tract (medial root) are said to terminate in the medial geniculate body. Resting in the broadened medial groove between the superior quadrigeminate bodies lies the non-nervous **pineal body** (epiphysis). This also belongs to the thalamencephalon. Within the stem of the pineal body is a strong transverse band of white substance crossing the midline as a bridge over the opening of the cerebral aqueduct into the third ventricle. This is the **posterior commissure** of the cerebrum, and contains commissural fibers arising in both the thalamencephalon and mesencephalon. The triangular area bounded by the stem of the epiphysis, the thalamus, and the superior colliculus with its brachium, is known as the **habenular trigone.**

Inferiorly, the lamina quadrigemina is continuous with the isthmus of the rhombencephalon by way of the brachia conjunctiva or superior cerebellar peduncles, and the anterior medullary velum which bridges between the medial margins of these peduncles. The narrowed superior end of the velum, the part directly below the inferior quadrigeminate bodies, is thickened into a well-defined white band known as the **frenulum veli.** From the lateral margins of this band on each

side and just below the inferior quadrigeminate bodies emerge the **trochlear nerves** (the fourth pair of cranial nerves), and the increased thickness of the band is largely due to the decussation of this pair of nerves taking place within it.

The brachium conjunctivum, together with the inferior and superior colliculi of each side, form a marked ridge which results in the *lateral sulcus* of the mesencephalon, a lateral depression between the base of this ridge and the cerebral peduncle below and continuous into the transverse sulcus at the superior border of the pons. The ridge is thickened laterally by the lateral lemniscus, which is disposed as a band of white substance passing obliquely upward from under the brachium pontis, applied to the lateral surface of the brachium conunctivum and which enters the lateral margin of the mesencephalon. The region at which the lateral lemniscus approaches nearest the surface and in which the largest portion of its nucleus lies is the slightly elevated **trigone of the lemniscus.**

The **ventral surface** of the mesencephalon is formed by the **cerebral peduncles** (crura), two large bundles of white substance which are close to one another at the superior margin of the pons, but immediately diverge somewhat, producing the **interpeduncular fossa,** and in so doing disappear beneath the optic tracts (fig. 747). The *posterior recess* of the interpeduncular fossa extends slightly under the superior margin of the pons, while its *anterior recess* is occupied by the corpora

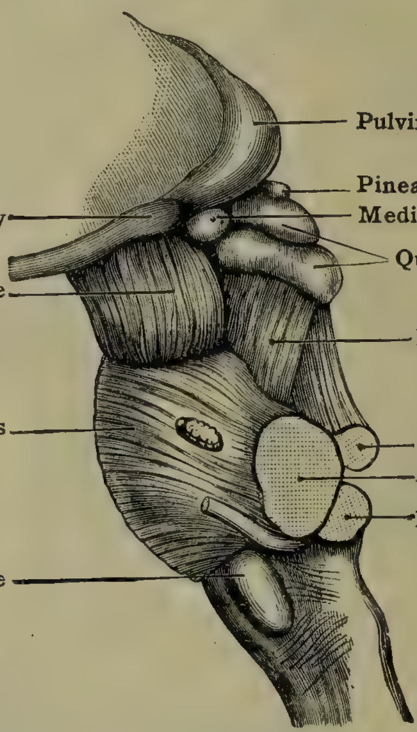


Fig. 739.—Diagram of Lateral View of Mesencephalon and Adjacent Structures. (After Gegenbaur, modified.)

mammillaria of the prosencephalon (fig. 747). The triangular floor of the fossa is the **posterior perforated substance,** a grayish area presenting numerous openings for the passage of blood-vessels. It is divided by a shallow median (oculomotor) groove and is marked off from the medial surface of each peduncle by the lateral furrows, out of which emerge the root filaments of the **oculomotor nerve.** Each oculomotor nerve, formed by assembly of its root filaments makes an impression in the medial surface of the peduncle, the *oculomotor sulcus.* The ventral surface of each peduncle is rounded and has a somewhat twisted appearance, indicating that its fibers curve from above medialward and downward.

Sometimes two small, more or less transverse bands of fibers may be noted crossing the peduncle—an inferior, the *tenia pontis,* and a superior, the *transverse peduncular tract.* The inferior represents detached fibers of the pons; the superior, running from the brachium of the inferior quadrigeminate body and disappearing in the oculomotor sulcus, appears to be derived from the quadrigeminate bodies. Since it is well developed in the cat, dog, sheep, and rabbit, but is absent or little marked in the mole, it is supposed to be concerned with the optic apparatus.

Internal structure.—Transverse sections of the mesencephalon (figs. 740, 741) throughout are composed of—(1) a *dorsal part,* consisting of the lamina quadrigemina or the gray substance of the corpora quadrigemina, with the strata and bundles of nerve-fibers connected with them, and the abundant central gray substance surrounding the aqueduct; (2) a *tegmental part,* consisting of the upward

continuation of the reticular formation of the medulla oblongata and that of the dorsal (tegmental) portion of the pons region, to which are added the superior cerebellar peduncles and the red nuclei of the tegmentum in which these peduncles terminate; (3) a paired *ventral part*, the cerebral peduncles, each of which consists of a thick, pigmented stratum of gray substance, the *substantia nigra*, spread upon the large, superficial, and somewhat crescentic tract of white substance known as the *basis* of the peduncle. The bases of the peduncles correspond to the longitudinal or pyramidal fasciculi of the pons and medulla. Likewise the lemniscus and the medial longitudinal fasciculus of the medulla and pons continue through all sections of the mesencephalon, dorsal to the substantia nigra.

The **central gray substance** is a continuation of the central gelatinous substance of the spinal cord and the similar stratum of the medulla and pons which immediately underlies the ependymal floor of the fourth ventricle. As in the spinal cord and medulla, it is largely composed of gelatinous substance. It is much

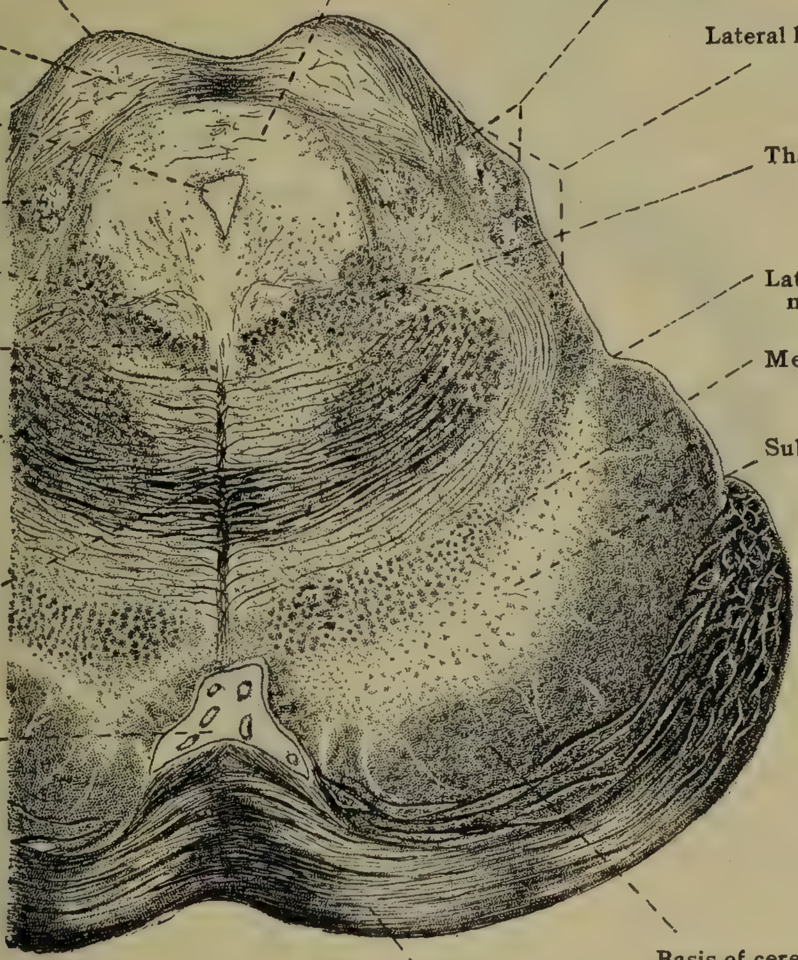


FIG. 740.—TRANSVERSE SECTION THROUGH THE INFERIOR QUADRIGEMINATE BODIES.

more abundant in the mesencephalon, and in sections appears as a circumscribed area comparatively void of nerve fibers.

The nucleus of the *mesencephalic root of the masticator nerve* and that of the mesencephalic tract of the trigeminus may likewise be traced throughout the mesencephalon. The former consists of a few small bundles of fibers surrounding a thin strand of nerve cells which give origin to its fibers. It courses caudalward close to the lateral margin of the central gray substance, and is quite small at its begining in the extreme superior part of the mesencephalon, but as it descends toward the exit of its fibers from the pons, it increases slightly in size, due to the progressive addition of fibers. Its nucleus also increases slightly in bulk in approaching its continuation with the chief motor nucleus of the nerve. As mentioned above, the investigations of Johnston and Willems in lower animals suggest that many cells of the mesencephalic nucleus of the masticator may be sensory instead of motor in character. The sensory nucleus (nucleus of termination) of the mesencephalic tract of the trigeminus tapers rapidly but probably extends throughout the mesencephalon.

The nuclei of the *trochlear* and *oculomotor* nerves form a practically continuous column of nerve-cells extending close to the midline and ventral to the aqueduct of the cerebrum. They are in line with the nuclei of origin of the abducens and hypoglossus, and, like them, may be regarded as an upward continuation of the ventral group of the cells of the ventral horn of the

spinal cord. The upper portion of the column, giving origin to the oculomotor nerve, is considerably larger than that for the trochlear.

A transverse section through the inferior quadrigeminate bodies involves the nuclei of origin of the trochlear nerves and a portion of the decussation of the brachia conjunctiva, while a transverse section through the superior quadrigeminate bodies passes through the red nuclei of the tegmentum and the nuclei of origin of the oculomotor nerves. The latter section will also involve the brachia of the inferior quadrigeminate bodies and the medial geniculate bodies connected with them, and, if slanting slightly forward it will involve the pulvinars of the thalami and the lateral geniculate bodies.

The **trochlear** (or fourth) is the smallest of the cranial nerves, and is the only one which makes its exit from the dorsal surface of the brain, as well as the only one whose fibers undergo a total decussation.

FIG. 741.—TRANSVERSE SECTION THROUGH LEVEL OF SUPERIOR QUADRIGEMINATE BODIES.

Its nucleus of origin is situated beneath the inferior quadrigeminate bodies in the ventral margin of the central gray substance, quite close to the midline and to its fellow nucleus of the opposite side, and it is closely associated with the dorsomedial margin of the medial longitudinal fasciculus. Its root-fibers pass lateralward and dorsalward, curving around the margin of the central gray substance, medial to the mesencephalic root of the masticator nerve. As the root curves toward the midline in the dorsal region just beneath the inferior quadrigeminate bodies, it turns sharply and courses inferiorly to approach the surface in the superior portion of the anterior medullary velum, the frenulum veli. In this it meets and undergoes a total decussation with the root of its fellow nerve, and then emerges at the medial margin of the superior cerebellar peduncle of the opposite side. Having emerged, it passes ventrally around the cerebral peduncle, and thence pursues its course to the superior oblique muscle of the eye. It receives optic impulses from the superior quadrigeminate bodies and impulses from the cerebral cortex of chiefly the same side, and it is associated with the nuclei of other cranial nerves by way of the medial longitudinal fasciculus.

The **oculomotor** (or third) nerve, like the trochlear, is purely motor. It is the largest of the eye-muscle nerves. It supplies in all seven muscles of the optic

apparatus:—two intrinsic, the sphincter iridis and the ciliary muscle (indirectly by its visceral efferent fibers), and five extrinsic (by somatic efferent fibers). Of the latter, the levator palpebræ superioris is of the upper eyelid, while the remaining four, the superior, medial, and inferior recti and the obliquus inferior, are attached to the eyeball. As is to be expected, its nucleus of origin is larger and much more complicated than that of the trochlear nerve.

Practically continuous with that of the trochlear below, the nucleus is 5 or 6 mm. in length and extends anteriorly a short distance beyond the bounds of the mesencephalon into the gray substance by the side of the third ventricle. It lies in the ventral part of the central gray substance, and is very intimately associated with the medial longitudinal fasciculus. Its thickest portion is beneath the summit of the superior quadrigeminate body. The root-fibers leave the nucleus from its ventral side and collect into bundles which pass transversely through the medial longitudinal fasciculus and course ventrally to the medial portion of the substantia nigra, where they emerge in from six to fifteen filaments which blend to form the trunk of the nerve in the oculomotor sulcus of the cerebral peduncles. Those bundles which arise from the more lateral portion of the nucleus course in a series of curves through and around the substance of the

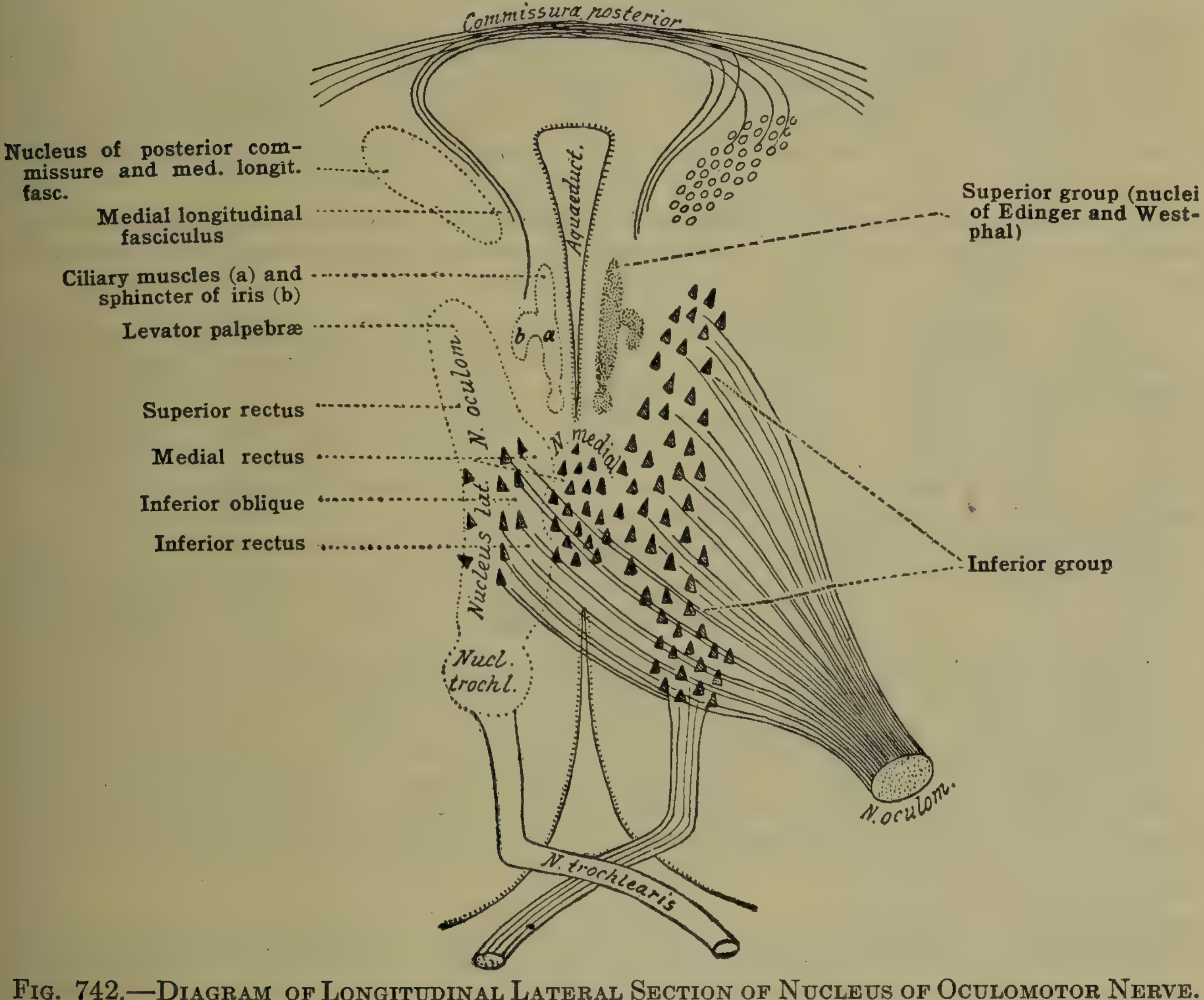


FIG. 742.—DIAGRAM OF LONGITUDINAL LATERAL SECTION OF NUCLEUS OF OCULOMOTOR NERVE. (After Edinger.)

red nucleus below and, in the substantia nigra, join those which pursue the more direct course. The trunk thus assembled passes lateralward around the medial border of the cerebral peduncle.

A portion of the fibers of the oculomotor nerve upon leaving the nucleus decussate in the tegmentum immediately below and pass into the nerve of the opposite side, in which they are believed to be distributed to the opposite medial rectus muscle. The cells of the nucleus have been variously grouped (fig. 742) and subdivided with reference to the different muscles supplied by the nerve. Perlia has divided them into eight cell-groups. The nucleus may be more easily considered as composed of an inferior group and a superior-medial group. The inferior group consists of a long lateral portion continuous with the nucleus of the trochlear nerve below, and a smaller medial portion, situated in the medial plane and continuous across the midline with its fellow of the opposite side. The superior medial group consists of cells of smaller size than the inferior, and is known as the *nucleus of Edinger and Westphal*. It is believed to give origin to the fibers (visceral efferent fibers) which terminate in the ciliary ganglion, axones from which supply the two intrinsic muscles concerned, viz., the ciliary muscle and the sphincter iridis.

The nucleus of the oculomotor is associated with the remainder of the optic apparatus—(1) by way of the neurones of the superior quadrigeminate body with the optic tract (retina) and it receives impulses from the occipital part of the cerebral cortex of the same and the opposite sides, and probably from the motor cortex of the frontal lobe; (2) by way of the medial longitudinal fasciculus with the nuclei of the trochlear and abducens (the latter making possible the co-

ordinate action of the lateral and medial recti for the conjugate eye-movements produced by these muscles), and with the nucleus of the facial (associating the innervation of the levator palpebræ with that of the orbicularis oculi); (3) with the nuclei of termination of the sensory nerves, especially the auditory, by way of the lateral lemniscus and medial longitudinal fasciculus. It is probably associated with the cerebellum by way of the brachia conjunctiva and red nuclei.

The eminence representing the **inferior quadrigeminate body proper** (colliculus caudalis NK) consists of an oval mass of gray substance, the *nucleus of the inferior colliculus*, containing numerous nerve-cells, most of which are of small size. A thin superficial lamina of white substance, the **stratum zonale**, forms its outermost boundary, and fibers from the lateral lemniscus enter it laterally and from below (*stratum lemnisci*). Near the lateral margin of the central gray substance occurs the beginning of the *inferior brachium*, a bundle containing fibers chiefly from the lateral lemniscus to the medial geniculate body and from the cerebral cortex to the inferior quadrigeminate body.

The **lemniscus** in the mesencephalon is considered in three parts. The more lateral portion of the lemniscal plate occurring in the pons has here spread dorsolaterally, and occupies a position in the lateral margin of the section, and is known as the **lateral lemniscus**, while the medial portion which remains practically unchanged in the tegmentum is distinguished as the **medial lemniscus** (fig. 740). In the upper portion of the lateral lemniscus occurs a small, scattered mass of gray substance, *nucleus of the lateral lemniscus*, in which a few of its fibers are interrupted. The **trigeminal lemniscus** is described as being detached from the medial lemniscus throughout the mesencephalon and as coursing in the gray substance, medial to the lateral lemniscus.

The greater portion of the **lateral lemniscus** with its nucleus belongs to the auditory apparatus, bearing impulses from the nuclei of termination of the cochlear nerve, chiefly of the opposite side (fig. 729). A large part of the fibers of this cochlear portion terminate in the inferior quadrigeminate bodies. Many of the latter enter at once the nucleus of the body (nucleus of inferior colliculus) of the same side, and disappear among its cells; smaller numbers cross the midline to the quadrigeminate body of the opposite side. In crossing, some pass superfically and thus contribute to the stratum zonale, while others pass either through the nucleus or below it and cross beneath the floor of the median groove between the stratum zonale and the dorsal surface of the central gray substance, forming there an evident decussation with similar fibers crossing from the opposite side. Many fibers arising from the nucleus of the lateral lemniscus and most of those from the inferior quadrigeminate bodies are said to pass into the reticular formation, serving in auditory reflexes. Most of the fibers arising from the cells of the nucleus of the inferior quadrigeminate body pass ventrally to terminate in the nucleus of origin of the trochlear nerve, but very few pass forward and laterally to terminate in the cortex of the superior gyrus of the temporal lobe, the cortical area of hearing. A large portion of the lateral lemniscus passes obliquely forward in the inferior brachium, and terminates in the medial geniculate body, the cells of which send fibers to the cortical area of hearing. Thus a large portion of the lateral lemnisci, a smaller portion of the inferior quadrigeminate bodies with their brachia and most of the medial geniculate bodies are concerned with the sense of hearing. The nucleus of the inferior quadrigeminate body receives fibers which arise in the cortex of the superior temporal gyrus of chiefly the same side. It is concerned with both cochlear reflexes and auditory reflexes proper.

The remaining portions of the lateral lemniscus consist of (1) the spinothalamic part of the spinal lemniscus which, occupies the ventral edge of the lateral lemniscus and courses forward to terminate in the ventral part of the thalamus, and (2) the spinotectal part of the spinal lemniscus, which courses in the extreme dorsal edge of the lateral lemniscus and is dispersed to terminate in the nuclei of the quadrigeminate bodies. In terminating in the nucleus of the superior quadrigeminate body, these spinotectal fibers are joined by some fibers of the auditory portion of the lateral lemniscus of the same and opposite side. Together, the spinal and auditory fibers approach the nucleus from below, and contribute to the well-marked band of fibers coursing on the dorsolateral margin of the central gray substance, and known as the '*optic-acoustic reflex path*' or *stratum lemnisci* (fig. 741).

The **medial lemniscus** arises in the medulla oblongata from the nuclei (of termination) of the funiculus gracilis and funiculus cuneatus of the opposite side, and likewise from the nuclei of termination of the sensory roots of the cranial nerves of the opposite side. It is, therefore, a continuation of the central sensory pathway conveying the general bodily (including the head) sensations into the prosencephalon. Coursing still more laterally than in the pons below, it passes into the inferolateral gray substance of the thalamus, in which most of its fibers terminate. By axones given off from the cells of the inferolateral thalamic gray substance the impulses borne thither by the lemniscus are conveyed by way of the internal capsule and corona radiata to the gyri of the somesthetic area of the cerebral cortex. The trigeminal lemniscus, here detached from the medial as noted above, arises from the nucleus of termination of the trigeminus of the opposite side and terminates as does the remainder of the medial lemniscus.

The **basis pedunculi** (crus cerebri NK) comprises the great descending pathway from the cerebral cortex, and thus is continuous with the internal capsule of the telencephalon.

The principal components of each basis pedunculi are as follows:—(1) The *pyramidal fibers*. which occupy the middle portion of the peduncle and comprise three-fifths of its bulk, and which are outgrowths of the giant pyramidal cells of the motor areas of the cerebral cortex, chiefly anterior central gyrus. These supply 'voluntary' impulses to the motor nuclei of the cranial nerves on the opposite side, form the pyramids of the medulla, and are distributed to the ventral horn cells of the spinal cord of the opposite side. (2) The *frontal pontile fibers*, which course in the mesial part of the peduncle from the cortex of the frontal lobe to their termination in the gray substance of the pons. (3) The *occipital and temporal pontile fibers* which run in the lateral portion of the peduncle from their origin in the occipital and temporal lobes to their termination in the gray substance of the pons.

The **substantia nigra** (nucleus niger NK) is continuous below with the gray substance of the pons, the arcuate nuclei, and that of the reticular formation; and above with that of the hypothalamic region. Its remarkable abundance begins at the superior border of the pons, and it conforms to the crescentic inner contour of the base of the peduncle, sending numerous processes which occupy the interfascicular spaces of the latter. It contains numerous deeply pigmented nerve-cells, which in the fresh specimen give the appearance suggesting its name.

Its anatomical significance is not well understood. It is known that some fibers of the medial lemniscus terminate about its cells instead of in the hypothalamus higher up, and Mellus has found in the monkey that many of the pyramidal fibers arising in the motor thumb area of the cerebral cortex are interrupted in the substantia nigra. It is probable that other fibers of the peduncle also terminate here, its cells serving as relays in the descending cortical chains including the extrapyramidal.

The **brachia conjunctiva** or superior cerebellar peduncles, in passing from their origin in the dentate nuclei, lose their flattened form and enter the mesencephalon as rounded bundles. In the tegmentum, under the inferior colliculi, the two brachia come together and undergo a sudden and complete decussation. Through this decussation the fibers of the brachium of one side pass forward to terminate, most of them, in the red nucleus [nucleus ruber] of the tegmentum of the opposite side (fig. 741). Some fibers are said to pass the red nucleus and terminate in the inferolateral part of the thalamus.

The **red nuclei** are two large, globular masses of nerve-cells situated in the tegmentum under the superior quadrigeminate bodies. At all levels they are considerably mixed with the entering bundles of the brachia conjunctiva, and they contain a pigment which, with their blood supply, in the fresh condition gives them a reddish color, suggesting their name.

They receive in addition descending fibers from the cerebral cortex (frontal operculum) and from the nuclei of the corpus striatum. From the cells of each red nucleus arise fibers which pass—(1) into the thalamus and to the telencephalon (prosencephalic continuation of the cerebellar path), and (2) fibers which descend as the 'rubroreticular' and the 'rubrospinal tracts' in the lateral funiculus (fig. 698). The latter cross from the red nucleus of the opposite side and descend in the tegmentum. The red nuclei are also in relation with the *fasciculus retroflexus* of Meynert, which belongs to the interbrain.

The **thalamo-olivary tract** courses in the mesencephalon more dorsally than in the pons region. It runs in the ventrolateral boundary of central gray substance just lateral to the nuclei of the trochlear and oculomotor nerves.

A small *quadrigeminopontile* strand of fibers has been described as arising in the quadrigemina, especially the inferior pair, and terminating in the nuclei of the pons. Impulses carried by these fibers are probably destined for the cerebellar hemisphere of the opposite side.

The **superior quadrigeminate bodies (superior colliculi)** are phylogenetically more important than the inferior. In certain of the lower vertebrates they are enormously developed and in most of the mammals they are relatively larger and appear more complicated in structure than in man. They are concerned almost wholly with the visual apparatus, mediating most of the reflexes with which it is concerned.

Though they receive some retinal fibers, in man they have little or nothing to do with actual visual sensation or perception. For such sensations the lateral geniculate body is the nucleus of termination especially concerned.

The *nucleus* of the superior colliculus is of somewhat greater bulk than that of the inferior. It is capped by a strong *stratum zonale* (fig. 741), which has been described as composed chiefly of retinal fibers, passing to it from the optic tract by way of the superior brachium; but, since Cajal found in the rabbit that extirpation of the eye is followed by very slight degeneration of the stratum zonale, it is probable that it is composed of other than retinal fibers—possibly fibers from the occipital cortex and fibers arising within the nucleus itself. The nucleus is separated from the central gray substance by a well marked band of fibers, the *stratum album profundum*. This contains fibers from two sources:—(1) fibers from the lateral lemniscus which approach the nucleus from the under side, some to terminate within it, others to cross to the nucleus of the opposite side; (2) fibers which arise within the nucleus and course ventrally

around the central gray substance, both to terminate in the nucleus of the oculomotor nerve and to join the medial longitudinal fasciculus and pass probably to the nuclei of the trochlear and abducens. The lemniscus fibers often course less deeply than (2) and give the *stratum lemnisci.* The optic fibers proper approach the nucleus by way of the *superior brachium*, and are dispersed directly among its cells; only a small proportion of them cross over to terminate in the nucleus of the opposite side. They consist of two varieties:—(1) retinal fibers which arise in the ganglion-cell layer of the retina and enter the superior brachium at its junction with the lateral root of the optic tract, and (2) fibers from the visual area of the occipital lobe of the cerebral hemisphere. Sometimes the optic fibers in their course within the nucleus of the superior colliculus form a more or less evident stratum near the stratum zonale This is known as the *stratum opticum* (stratum album medium). The portion of the nucleus between this stratum and the stratum zonale is then called the *stratum cinereum.* Experimental evidence indicates that, of the retinal fibers entering the nucleus, those from the lower half of the retina are distributed to the anterior portion of the nucleus and those from the superior half to the caudal portion.

The fibers entering the nucleus from the lateral lemniscus probably all represent auditory connections. The stratum album profundum, composed of the lemniscus fibers and fibers from cells of the nucleus, and the stratum opticum together, form the so-called **'optic-acoustic reflex path'** (fig. 741).

The **tectospinal** and the **spinotectal** (spinomesencephalic) paths course together ventrolateral to the nuclei of the colliculi. In the superior quadrigeminate bodies they course in the dorsal edge of the medial lemniscus, between the stratum opticum and stratum album profundum.

From the various studies that have been made it appears that the superior colliculus of the corpora quadrigemina is merely the central reflex organ concerned in the control of the eye muscles—eye muscle reflexes which result from retinal and cochlear stimulation, and from some general body sensations by way of the spinal cord and trigeminus. Fibers from its nucleus to the visual area of the occipital cortex have been claimed for certain mammals, but in man the superior colliculus may be entirely destroyed without disturbance of the perception of light or color and fibers arising from its nucleus to terminate in the cerebral cortex are denied.

In the level of the anterior part of the superior colliculus the fibers which arise from the cells of its nucleus and course ventrally in the stratum album profundum collect into a strong bundle. This bundle passes ventral to the medial longitudinal fasciculus and, in the space between the two red nuclei, it forms a dense decussation with the similar bundle from the opposite side. In decussating the fibers turn in spray-like curves downward and soon join the medial longitudinal fasciculus. This is the **'fountain decussation'** of Forel. Decussating fibers which arise in the nucleus of the oculomotor nerve also cross in this decussation and it is said to be augmented by decussating fibers from the two red nuclei.

There is abundant evidence that fibers arising in the corpora quadrigemina descend into the spinal cord. Various studies make it appear that at least part of these are fibers from the fountain decussation, and that these course through the medulla oblongata in the ventral part of the medial longitudinal fasciculus, and thence descend into the cord as the sulcomarginal fasciculus and in the tectospinal path of the opposite side. The termination of some of these fibers about those ventral horn cells of the cervical and upper thoracic cord which send fibers through the rami communicantes probably establishes the pathway by which the superior quadrigeminate bodies are connected with the cervical sympathetic ganglia, and by which may be explained the disturbances in pupillary reflexes induced by lesions of the cervical and upper thoracic spinal cord.

The medial geniculate body and the medial root of the optic tract, which runs into the former, probably have nothing to do with the functions of the optic apparatus. Both remain intact after extirpation of the eyes. The medial root of the optic tract is apparently nothing more than the beginning of the *inferior cerebral* (*Gudden's*) *commissure*, a bundle passing by way of the optic tract and chiasma, connecting the medial geniculate body of one side with that of the other side, and probably with the inferior colliculus.

The **medial longitudinal fasciculus** (posterior longitudinal fasciculus), continuous into the ventral fasciculus proprius and the sulcomarginal fasciculus of the spinal cord, extends throughout the rhombencephalon and mesencephalon, and is represented in the hypothalamic region of the prosencephalon. Deserted by the lemniscus at the inferior border of the pons, it maintains its closely medial position and courses throughout in the immediate ventral margin of the central gray substance of the medulla and floor of the fourth ventricle, and likewise in the ventral margin of the central gray substance of the mesencephalon.

The two fasciculi constitute the principal of the longer association pathways of the brain stem, and, true to their nature as such, they are among the first of its pathways to acquire medullation. In the mesencephalon they become two of its most conspicuous tracts, and their course in most intimate association with the nuclei of origin of the nerves supplying the eye-muscles suggests what is probably one of their most important functions, viz., that of associating these nuclei with each other and of bearing to them fibers from the nuclei of the other cranial nerves necessary for the co-ordinate action of the muscles of the optic apparatus associated with the functions of these other nerves.

Fibers from each medial longitudinal fasciculus terminate either by collaterals or terminal arborizations about the cells of the motor nuclei of all the cranial nerves, and each nucleus probably contributes fibers to it. It also receives fibers from the nuclei of termination of the sensory nerves especially those of the optic, the vestibular and cochlear. Thus it contains fibers coursing in both directions, and, while it is continually losing fibers by termination, it is being continually recruited and so maintains a practically uniform bulk. Thus, a given lesion never

results in its total degeneration. Many of the fibers coursing in it arise from the opposite side of the midline. A special contribution of fibers of this kind is received by way of the fountain decussation from the nucleus of the superior colliculus of the opposite side. As noted above, it is in part continuous into the spinal cord as the ventral fasciculus proprius. It receives some fibers by way of the posterior commissure of the prosencephalon from a small nucleus, common to it and the posterior commissure, situated in the superior extension of the central gray substance of the mesencephalon. Van Gehuchten and Edinger describe for it a special *nucleus of the medial longitudinal fasciculus* situated beyond this commissure in the hypotha-

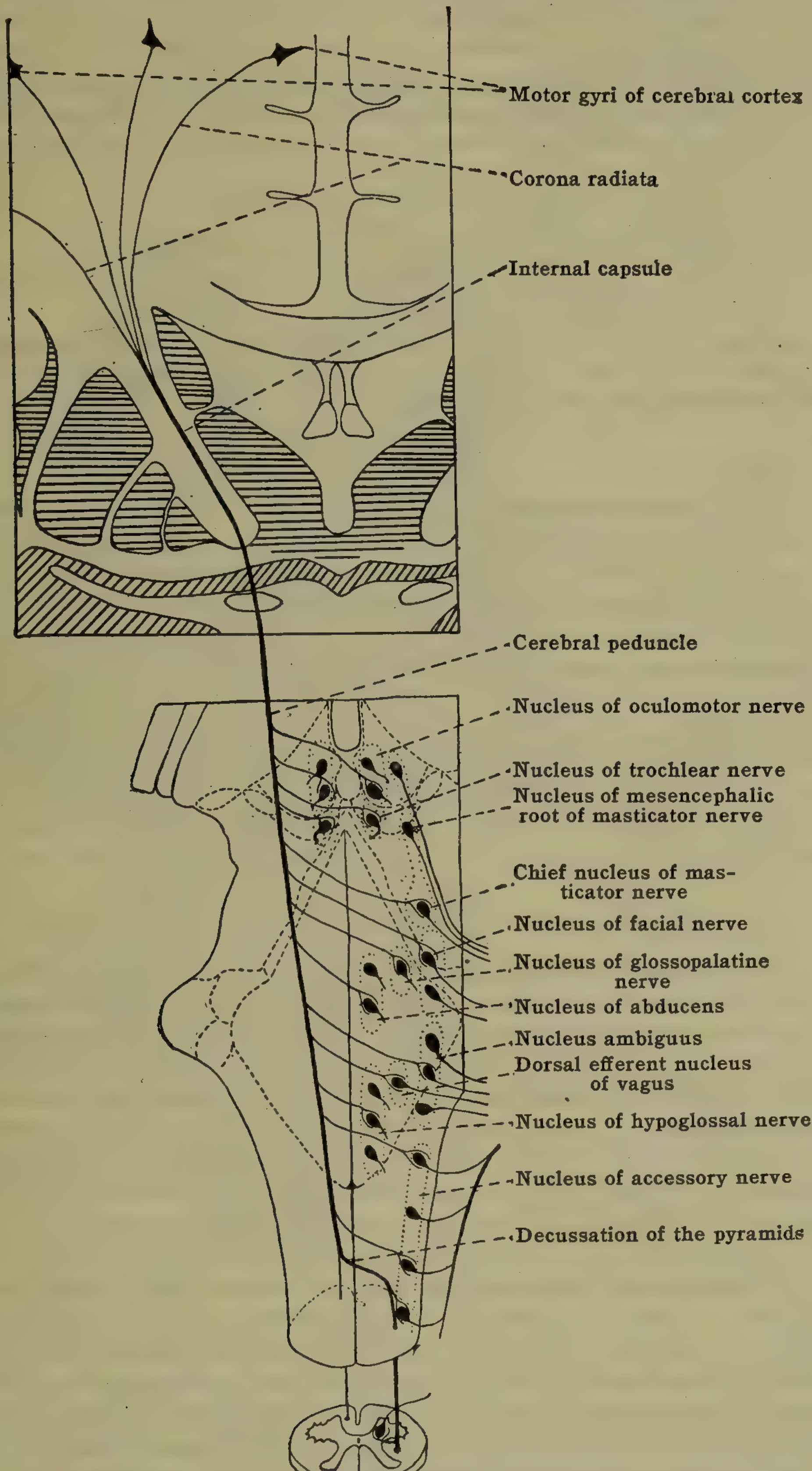


FIG. 743.—SCHEME TO ILLUSTRATE THE PRINCIPAL OR CROSSED RELATIONS OF THE DESCENDING CORTICAL (PYRAMIDAL) FIBERS TO THE NUCLEI OF ORIGIN OF THE CRANIAL NERVES.

lamic region. This nucleus may be explained as an accumulation of the gray substance of the reticular formation below and as receiving impulses from the structures of the prosencephalon which are distributed by its axones to the structures below by way of the medial longitudinal fasciculus.

Scattered in the posterior part of the posterior perforated substance, near the superior border of the pons, is a small group of cell-bodies forming the interpeduncular nucleus (interpeduncular ganglion of von Gudden). Fibers arising in the habenular nucleus of the diencephalon curve posteriorly, forming the *fasciculus retroflexus of Meynert,* and terminate about its

cells. Fibers arising from its cells course dorsalward and terminate about association neurones in the ventral periphery of the central gray substance. It is concerned with olfactory impulses.

SUMMARY OF THE MESENCEPHALON

1. Quadrigeminate bodies:
   (a) Inferior colliculi, their nuclei and brachia.
   (b) Superior colliculi, their nuclei and brachia.
2. Peduncles of the cerebrum.
3. Aqueduct of the cerebrum.
4. Central gray substance.
5. Substantia nigra.
6. Decussation of superior cerebellar peduncles; the red nuclei.
7. Medial lemniscus, lateral lemniscus and nucleus of lateral lemniscus.
8. Mesencephalic nucleus and root of masticator nerve, and mesencephalic tract of the trigeminus with its nucleus.
9. Trochlear nerve and its nucleus.
10. Oculomotor nerve and its nucleus.
11. Thalamospinal, tectospinal and rubrospinal tracts.
12. Medial longitudinal fasciculus, its nucleus, and fibers from the posterior commissure.
13. The fountain decussation.
14. Interpeduncular nucleus.

As frequently realized in the above, the structures of the mesencephalon are both overlapped by, and are of necessity functionally continuous with, the structures of the next and most anterior division of the encephalon, the prosencephalon.

2. THE PROSENCEPHALON

The **prosencephalon** or **forebrain** includes those portions of the encephalon derived from the walls of the anterior of the three embryonic brain-vesicles. In its adult architecture it consists of—(A) the **diencephalon (interbrain),** comprising the thalamencephalon or the thalami and the structures derived from and immediately adjacent to them, and, in addition, the mammillary portion of the hypothalamic region; (B) the **telencephalon (endbrain),** comprising the optic portion of the hypothalamic region and the cerebral hemispheres proper. The last mentioned consist of the entire cerebral cortex or superficial mantle of gray substance, including the rhinencephalon, and also the basal ganglia or buried nuclei (corpus striatum), together with the tracts of white substance connecting and associating the different regions of the hemispheres with each other and with the structures of the other divisions of the central nervous system.

EXTERNAL FEATURES OF THE PROSENCEPHALON

A. THE DIENCEPHALON.—The *basal surface* of this division of the brain consists of only the mammillary portion of the hypothalamic region (fig. 747). This comprises—(1) the mammillary bodies [**corpora mammillaria**] (albicantia), the two rounded projections situated in the anterior part of the interpeduncular fossa, and (2) the anterior portion of the **posterior perforated substance** or the small triangle of gray substance forming the floor of the posterior part of the third ventricle, and which presents numerous openings for the passage of branches of the posterior cerebral arteries. The hypothalamic portions of the cerebral peduncles might be included. The structures of the optic or remaining portion of the hypothalamus belong to the telencephalon.

The upper or *dorsal surface* of the diencephalon is completely overlapped and hidden by the telencephalon, and covered by the intervening ingrowth of the cerebral meninges, the tela chorioidea of the third ventricle (velum interpositum). These removed (fig. 744), it is seen that the thalami on either side are by far the most conspicuous objects of the diencephalon. They, together with the parts developed in connection with them, are distinguished as the **thalamencephalon.** The thalamencephalon consists of—(1) the *thalami;* (2) the *metathalamus* or geniculate bodies; and (3) the *epithalamus,* comprising the pineal body (epiphysis) with the posterior commissure below it and the habenular trigone on either side.

The **thalami** are two ovoid, couch-like masses of gray substance which form the lateral walls of the third ventricle. The cavity of the ventricle is narrow, and quite frequently the thalami are continuous through it across the midline by a small but variable neck of gray substance, the **massa intermedia** ('middle commissure'). The upper surfaces of the thalami are free. The edges of the tela chorioidea of the third ventricle are attached to the lateral part of the surface of each thalamus, and, when removed, leave the *tenia chorioidea* lying in the chor-

oidal sulcus. Each thalamus is separated laterally from the caudate nucleus of the telencephalon by a linear continuation of the white substance below, known as the **stria terminalis thalami** (tenia semicircularis) in which runs the terminal vein. Like the quadrigemina, each thalamus is covered by a thin capsule of white substance, the **stratum zonale.** The average length of the thalamus is about 38 mm., and its width about 14 mm.; its posterior extremity (pulvinar) is obliquely lateralward. The dorsal surface usually shows four eminences, indicating the position of the so-called nuclei of the thalamus within. These are the anterior nucleus or *anterior tubercle,* the *medial nucleus* or tubercle, the *lateral nucleus,* and the *pulvinar,* the tubercle of the posterior extremity. The pulvinar of the human brain is peculiar in the fact that it is so developed as to project

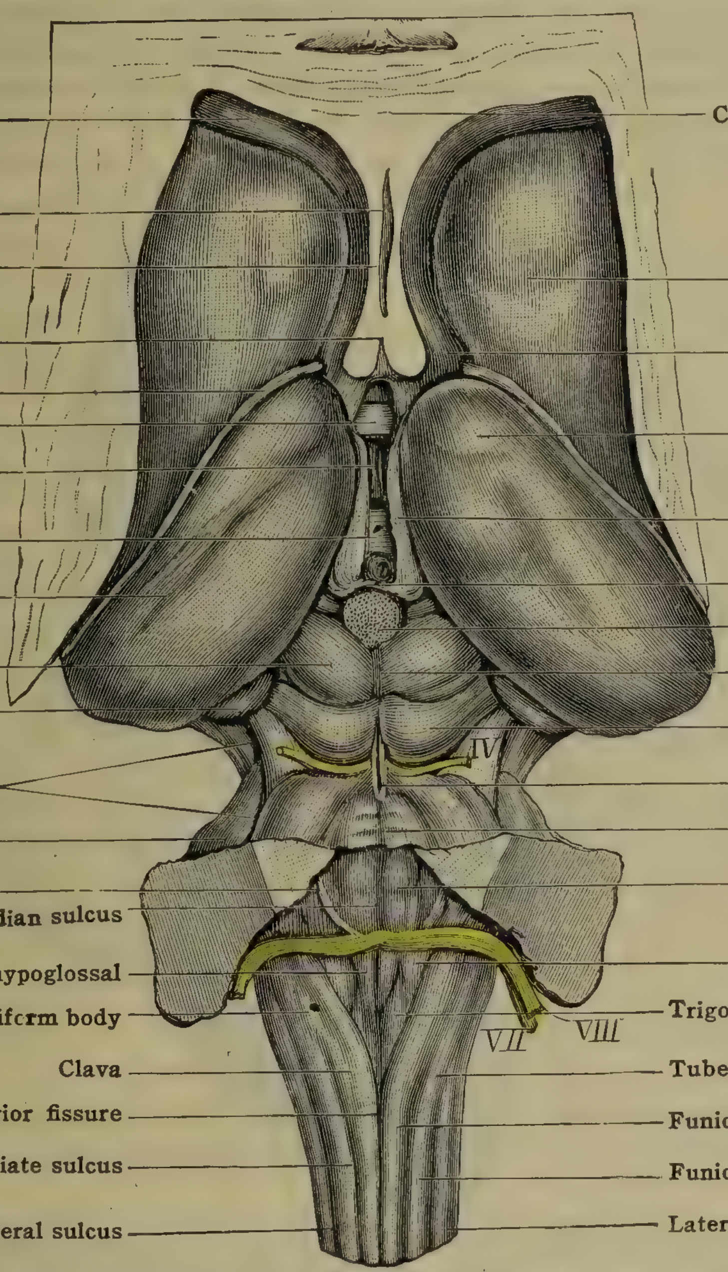


FIG. 744.—DORSAL SURFACE OF DIENCEPHALON WITH ADJACENT STRUCTURES. (After Obersteiner.)

inferiorly and slightly overhang the level of the quadrigeminate bodies. The projecting portion assumes relations with the optic tract and the metathalamus.

Both the structures of the **metathalamus,** the lateral and medial geniculate bodies, are connected with the optic tract, but it is thought that actual visual axones terminate only in the lateral geniculate body. As the optic tract curves around the cerebral peduncle it divides into two main roots. The *lateral geniculate body* receives a portion of the fibers of the lateral root of the optic tract; the remainder pass under this body and enter the pulvinar of the thalamus. The *medial geniculate body* is in relation with the medial root of the optic tract, which root consists partly, not of retinal fibers, as does the lateral root, but of the fibers forming Gudden's commissure (the inferior cerebral commissure). The retinal fibers contained in the medial root pass to terminate in the superior quadrigeminate bodies.

Of the **epithalamus**, the *pineal body* (epiphysis) is the most conspicuous external feature. This is an unpaired, cone-shaped structure, about 7 mm. long and 4 mm. broad, which also projects upon the mesencephalon so that its body rests in the groove between the superior quadrigeminate bodies. Its stem is attached in the midline at the posterior extremity of the third ventricle, and therefore just above the posterior commissure of the cerebrum (fig. 738). It is covered by pia mater, and is involved in a continuation of the tela chorioidea of the third ventricle. Though it develops as a diverticulum of that portion of the anterior primary vesicle which gives origin to the thalamencephalon, it is wholly a non-nervous structure, aside from the sympathetic fibers which enter it for the supply of its blood-vessels. (For further details, see p. 1433.)

Apparently arising from the base of the pineal dody, but having practically nothing to do with it, are the **striæ medullares of the thalamus** (striæ pineales, pedunculi conarii, tenia thalami, habenulæ). These are two thin bands of white substance which extend from under the pineal body anteriorly upon the thalamus, along the superior border of each lateral wall of the third ventricle, forming the boundaries between the superior and medial surface of each thalamus (fig. 710).

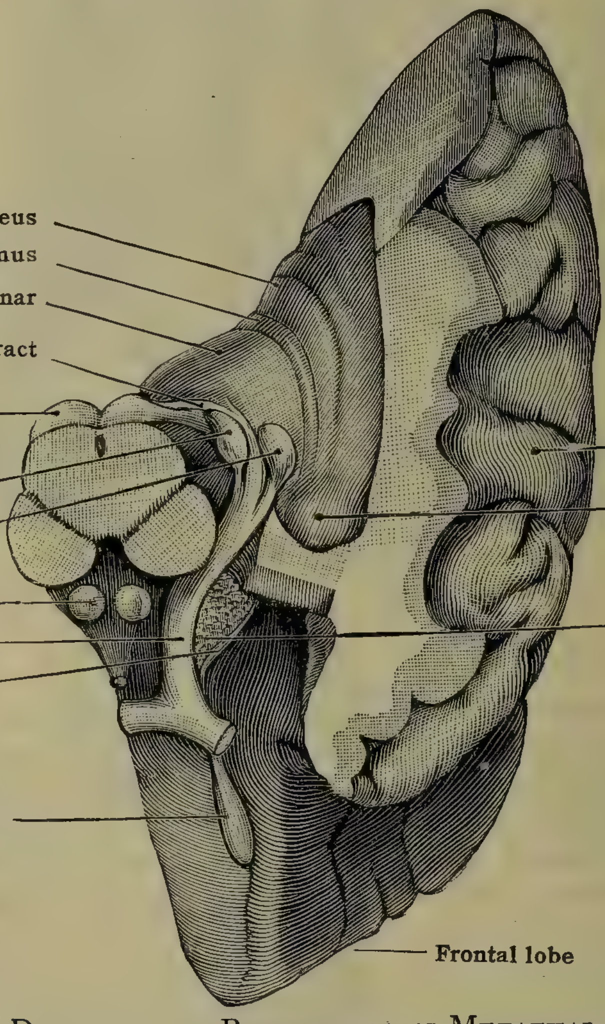


Fig. 745.—Diagram of Dissection of Brain showing Metathalamus and Pulvinar with Adjacent Structures.

They have been called the *habenulæ*, and the habenular nuclei, situated in the habenular trigone, are so called because related to them. They are continuous across the midline in the *habenular commissure*, the dorsal part of the posterior cerebral commissure, just below the neck of the pineal body (figs. 744, 773). It will be seen below that each habenula contains olfactory fibers from the fornix, the anterior perforated substance and the septum pellucidum, as well as fibers out of the thalamus, and that some of its fibers terminate in the habenular nucleus. Most of the thalamic fibers contained cross in the posterior commissure to the thalamus of the opposite side.

The inferolateral surface of the thalamencephalon is continuous into the hypothalamic tegmental region, the upward continuation of the tegmental gray substance of the mesencephalon. It is also adjacent to a portion of the internal capsule. Both these relationships, as well as the fiber connections of the diencephalon with the structures above and below it, are deferred until the discussion of the internal structure of the prosencephalon.

The **medial surface** of the diencephalon (fig. 746), allows a better view of the shape and relations of the **third ventricle.** Below the line of the massa inter-

media the ventricle is usually somewhat wider than it is along the upper margins of the thalami. This greater width is occasioned by a groove in the inferomedial surface of each thalamus, known as the **hypothalamic sulcus** (sulcus of Monro). It is along the line of this sulcus that the third ventricle is continuous with the aqueduct of the cerebrum, and thus with the fourth ventricle below, and, likewise, with the two lateral ventricles of the cerebral hemispheres at its anterior end. The latter junction occurs through a small oblique aperture, the **interventricular foramen** (foramen of Monro), one into each lateral ventricle. The upper portion of the third ventricle extends posteriorly beneath its choroid tela (velum interpositum) to form a small posterior recess about the pineal body. This is known as the **suprapineal recess.** The anteroinferior extremity of the third ventricle involves the pars optica hypothalami, which belongs to the telencephalon.

B. THE TELENCEPHALON.—External features.—The **optic portion of the hypothalamus** consists of that small central area of the basal surface of the brain which includes and surrounds the **optic chiasma,** and comprises the structures of

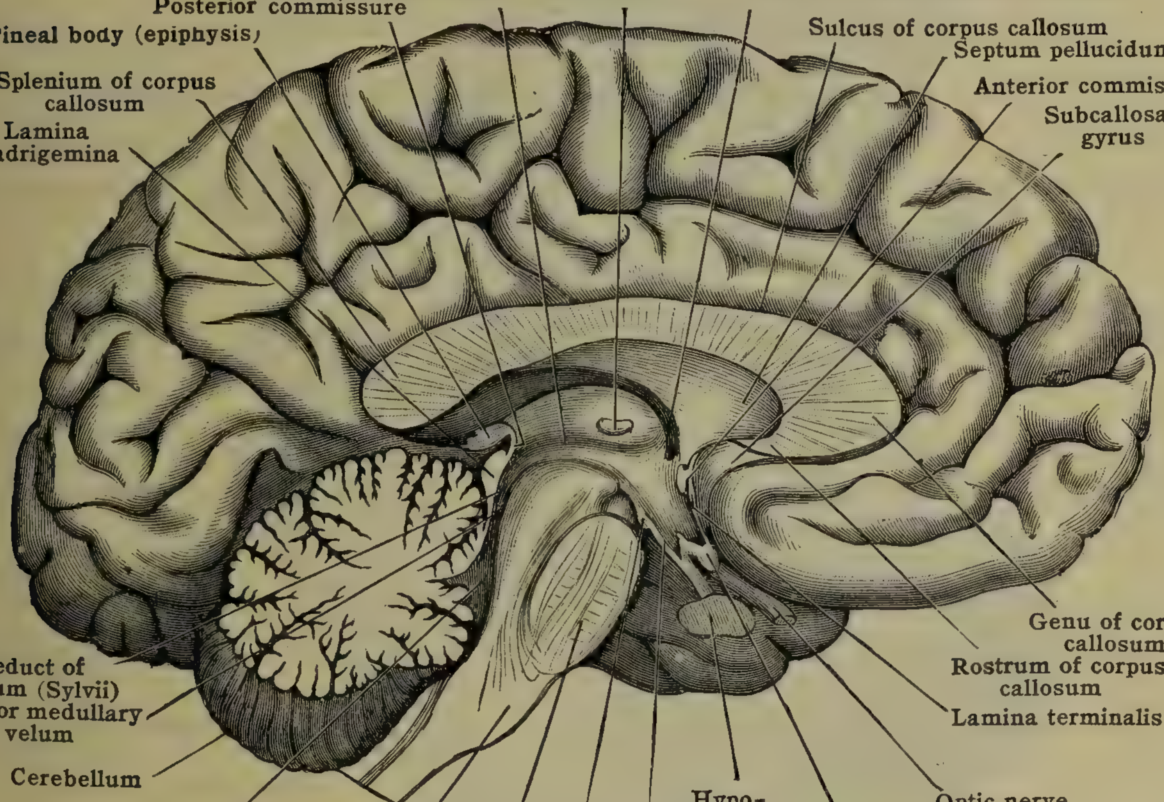


FIG. 746.—MIDSAGITTAL SECTION OF ENTIRE BRAIN, SHOWING MEDIAL SURFACE OF DIENCEPHALON AND OF TELENCEPHALON. (After Henle.)

the floor of the anterior and inferior portion of the third ventricle. The area belonging to the telencephalon extends anteriorly from the mammillary bodies in the interpeduncular fossa, and includes the **tuber cinereum** and **hypophysis** behind the optic chiasma, and some of the **anterior perforated substance** in front of it.

The most anterior portion of the third ventricle is in the form of an inferior extension. The wall of this extension is almost wholly non-nervous and quite thin, and thus the cavity of the ventricle is but thinly separated from the exterior of the brain. The front portion of this wall is the **lamina terminalis** and in the ventricular side of the upper part of this lamina the **anterior commissure** of the cerebrum is apparent.

The **optic chiasma** lies across and presses into the lower portion of the lamina terminalis, and in so doing produces an anterior recess in the cavity of the ventricle known as the **optic recess** (fig. 746). Behind the optic chiasma the floor of the third ventricle bulges slightly, giving the outward appearance known as the **tuber cinereum,** and the cavity bounded by this terminates in the **infundibular recess.**

The **tuber cinereum** then is a hollow, conical projection of the floor of the third ventricle, between the corpora mammillaria and the optic chiasma. Its wall

is continuous anteriorly with the lamina terminalis and laterally with the anterior perforated substance.

The **infundibulum** is but the attenuated apex of the conical tuber cinereum, and forms the neck connecting it with the hypophysis. It is so drawn out that it is referred to as the stalk of the hypophysis. The cavity of the tuber cinereum (infundibular recess) is sometimes maintained throughout the greater part of the length of the infundibulum, giving it the form of a long-necked funnel. Near the hypophysis the cavity is always occluded in man.

The **hypophysis cerebri** (pituitary gland) (figs. 746, 747) is an ovoid endocrine gland terminating the infundibulum. It lies in the sella turcica of the sphenoid bone, and consists of two lobes, a large *anterior lobe*, the glandular or buccal lobe,

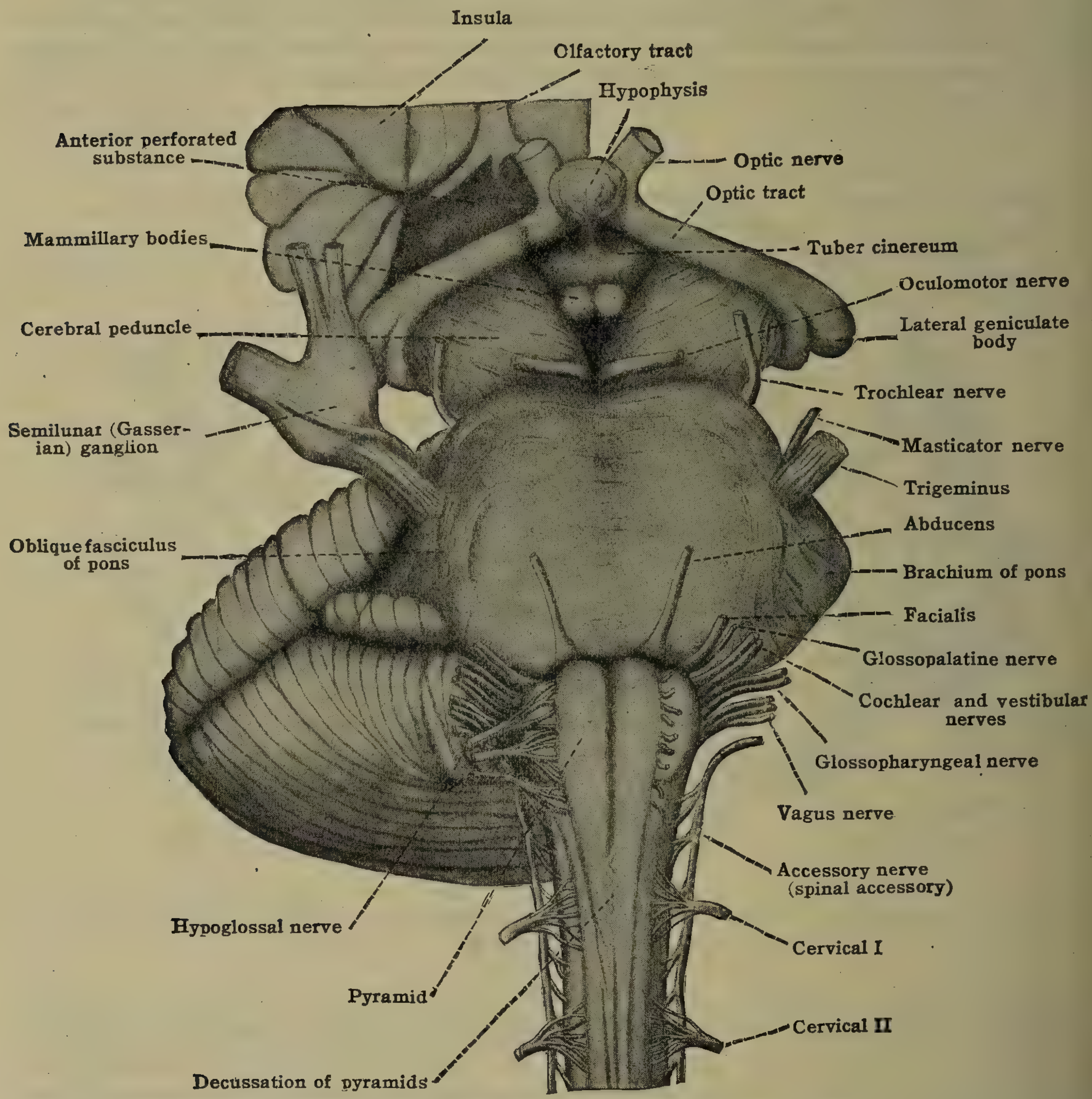


FIG. 747.—INFERIOR ASPECT OF BRAIN-STEM INCLUDING MAMMILLARY AND OPTIC PORTIONS OF THE HYPOTHALAMUS.

and a smaller *posterior* or *neural lobe*. For further details, see GLANDS OF INTERNAL SECRETION, p. 1430.

The fundaments of the **optic nerve** are derived from this portion of the telencephalon, though the nuclei of termination of its fibers are located in the thalamencephalon and mesencephalon. The optic apparatus consists of the retinæ and optic nerves, the optic chiasma, the optic tracts, the superior quadrigeminate bodies with their relations with the nuclei of the eye-moving nerves, the metathalamus, the pulvinar of the thalamus, and the visual area of the cerebral cortex of the occipital lobe. The fibers of the optic nerves arise from the cells of the ganglion-cell layer of the retinæ. The fibers which arise in the mesial or nasal halves of each retina cross in the chiasma to find their nuclei of termination in the

gray substance of the opposite side, while those from the outer or lateral halves terminate on the same side (figs. 748, 783).

The **optic chiasma** (optic commissure) is adherent upon the structures of the optic portion of the hypothalamus adjacent to it. It is formed by the approach and fusion of the two optic nerves, and is knit together by the decussating fibers from ganglion cells of the nasal halves of each retina, and, in addition, by the fibers of Gudden's commissure which is contained in it.

Beyond the chiasma the optic fibers continue as the **optic tracts** which course posteriorly around the cerebral peduncles to attain their entrance into the thalamencephalon and mesencephalon. Upon reaching the pulvinar of the thalamus each optic tract divides into two roots, a lateral and medial (figs. 745, 747, 748).

The *lateral root* contains practically all of the true visual fibers—fibers arising from the lateral half of the retina of the same side and the nasal half of the retina of the opposite side. These

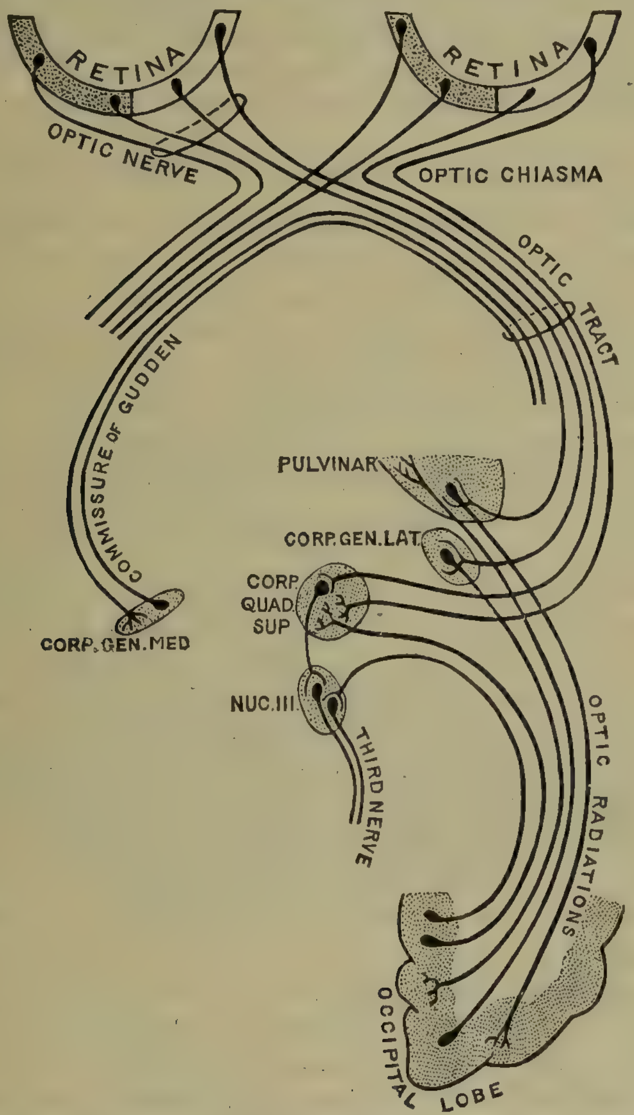


Fig. 748.—Diagram of the Principal Components of the Optic Apparatus. (After Cunningham.)

fibers are distributed to three localities:—(1) part of them terminate in the lateral geniculate body; (2) a portion pass over and around the lateral geniculate body and enter the pulvinar; (3) a portion enter the superior quadrigeminal brachium and course in it to terminate in the nucleus of the superior quadrigeminate body. The most evident function of this latter portion is to bear impulses which, by way of the neurones of the quadrigeminate body, are distributed to the nuclei of the oculomotor, trochlear, and abducent nerves, and thus mediate eye-moving reflexes. It has been suggested that the optic tracts carry a few visceral efferent fibers arising in the nuclei of the superior quadrigemina. The cells of the lateral geniculate body chiefly and the pulvinar, about which the retinal fibers terminate, give off axones which terminate in the cortex of the visual area, chiefly the gyri about the calcarine fissure of the occipital lobe. In reaching this area they curve upward and backward, coursing in a compact band of white substance known as the optic radiation (radiatio occipitothalamica, fig. 774). This band also is in part composed of fibers arising from the cells of the visual area, which pass from the cortex to the pulvinar, superior quadrigeminate bodies, and possibly some to the medulla oblongata and spinal cord. The superior quadrigeminate bodies probably send no fibers to the visual cortex, although they receive fibers from it.

Experimental and clinical evidence indicates that the great majority of the retinal fibers carrying the impulses which enter consciousness terminate in the lateral geniculate body instead of in the pulvinar of the thalamus. If so, the abundance of fibers of the lateral root which apparently pass around, over and under the lateral geniculate to reach the pulvinar may be, instead, largely fibers arising in the lateral geniculate and terminating in the thalamus to serve

in associational and reflex retinal functions. It is claimed that the pulvinar has chiefly to do with eye movements and pupillary reactions in response to light, and with stereoscopic vision and sensations of distance. In animals with monocular vision, the lateral geniculate consists of a dorsal, large-celled nucleus and a ventral one of smaller cells. The dorsal one serves as the especial nucleus of termination of fibers from the macula lutea and it contributes chiefly those fibers afferent to the visual cortex via the 'optic radiation,' while the ventral nucleus serves in light reflexes via the midbrain. In animals with complete binocular vision, including man, the dorsal or large-celled nucleus is so increased in relative size as to disperse the ventral one to loss of identity. In the latter condition it has been determined that the fibers arising from the upper or temporal half of the retina are distributed to the ventral part of the lateral geniculate body while those from the lower half terminate in the dorsal part of it.

The medial root of the optic tract contains few true visualfibers. It runs into the medial geniculate body, and neither it nor this body are appreciably affected after extirpation of both eyes. Instead, this body is concerned in the auditory apparatus. The root may be considered as largely representing the fibers of **Gudden's commissure** (inferior cerebral commissure). This commissure consists of fibers which correlate the medial geniculate bodies of the two sides with each other, and which, instead of crossing the midline through the mesencephalon, course in the optic tracts and cross by way of the posterior portion of the optic chiasma. It consists of fibers which both arise and terminate in each of the bodies, and, therefore, of fibers coursing in both directions. It is also claimed that the fibers of Gudden's commissure connect the medial geniculate body of each side with the inferior colliculus of the opposite side.

THE CEREBRAL HEMISPHERES

The cerebral hemispheres in man form by far the largest part of the central nervous system. Together, when viewed from above (fig. 756), they present an ovoid surface, markedly convex upward, which corresponds to the inner surface of the vault of the cranium. The greater transverse diameter of this surface lies posteriorly in the vicinity of the parietal eminences of the cranium. The outline of the superior aspect varies according to the form of the cranium, being more spheroidal in the brachycephalic and more ellipsoidal in the dolichocephalic. The hemispheres are separated from each other superiorly by a deep median slit, the **longitudinal fissure** (fissura interhemisphærica NK), into which fits a duplication of the inner layer of the dura mater known as the falx cerebri. The posterior or occipital extremities of the hemispheres overlap the cerebellum, and thus entirely conceal the mesencephalon and thalamencephalon. They are separated from the superior surface of the cerebellum and the corpora quadrigemina by the deep **transverse fissure** (fissura telodiencephalicaNK). This is occupied by the tentorium cerebelli, which is continuous with the falx cerebri and also with the tela chorioidea of the third ventricle (figs. 704, 765).

Each of the hemispheres is usually described as having three poles or projecting extremities, and three surfaces bounded by intervening borders. The most anterior projection is the **frontal pole.** This is near the midline and, with its fellow of the other hemisphere, forms the frontal end of the ovoid contour of the cerebrum. The **occipital pole** is the most projecting portion of the posterior and inferior end, and is more pointed than the frontal pole. The inferolateral portion of the hemisphere is separated anteriorly by the deep **lateral fissure** (fissure of Sylvius) into a distinct division, the temporal lobe, and the anterior portion of this lobe projects prominently forward and is known as the **temporal pole.**

The **surfaces** of the hemisphere are—(1) the lateral or *convex surface;* (2) the *medial surface;* and (3) the *basal surface.* The convex surface comprises the entire rounded aspect of the hemisphere visible previous to manipulation or dissection, and is the surface subjacent to the vault of the cranium. The medial surface is perpendicular, flat, and parallel with that of the other hemisphere, the two bounding the longitudinal fissure and for the most part in contact with the falx cerebri. The **superomedial border** intervenes between the convex and medial surfaces, and is thus convex and extends from the frontal to the occipital pole.

The more complex *basal surface* fits into the anterior and middle cranial fossæ, and posteriorly rests upon the tentorium cerebelli. Thus it is subdivided into—(*a*) an *orbital area*, which is slightly concave, since it is adapted to the orbital plate of the frontal bone, and is separated from the convex surface by the necessarily arched **superciliary border** and from the medial surface by the **medial orbital border,** the latter being straight and extending from the frontal pole medial to the olfactory bulb and tract; (*b*) a *tentorial area* or surface, which is arched in conformity with the dorsal surface of the cerebellum. This is separated from the convex surface by the **inferolateral border,** which runs from the occipital to the temporal pole; and from the medial surface by the **medial occipital border,** which is a more or less rounded ridge extending from the occipital pole obliquely

upward in the angle formed by the junction of the perpendicular falx cerebri and the horizontal tentorium cerebelli. This border is best seen in brains which have been hardened with the membranes *in situ*. The remainder of the basal surface includes the optic portion of the hypothalamus already considered, and the small depressed and punctate area, the anterior perforated substance, which is penetrated by the anterolateral group of the central branches of the anterior and middle cerebral arteries and into which the striæ of the olfactory trigone disappear. In addition to the orbital area, the basal surface of the hemisphere shows signs of the impress of the petrous portion of the temporal bone and of the great wing of the sphenoid.

The corpus callosum.—In their early development as lateral dilations of the anterior primary brain-vesicle, the hemispheres are connected with each other only at the anterior end of the thalamencephalon, where they are both continuous with the unpaired lamina terminalis. As development proceeds and the hemispheres extend upward, backward, forward, and laterally to conceal completely the base, and as the pallium, or cortex, thickens and its folds begin to appear, the two hemispheres become united across the midline above the thalamencephalon and the third ventricle by the intergrowth of the great cerebral commissure, the **corpus callosum.** After removal of the falx cerebri from the longitudinal fissure, the dorsal surface of the corpus callosum may be exposed by drawing apart the

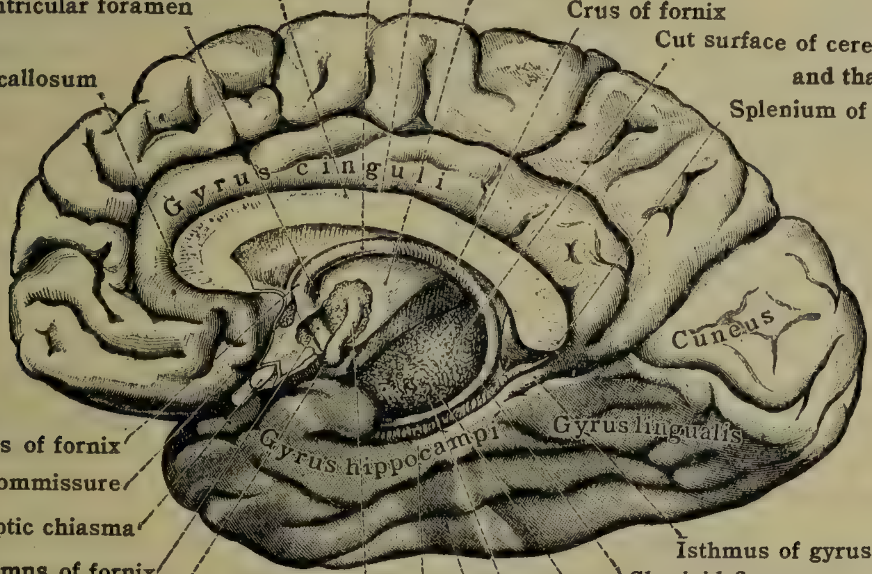


FIG. 749.—MEDIAL AND TENTORIAL SURFACES OF RIGHT CEREBRAL HEMISPHERE, VIEWED FROM THE LEFT. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

contiguous medial surfaces of the hemispheres (fig. 750). It consists of a dense mass of pure white substance coursing transversely, and arises as outgrowth from the cortical cells of both hemispheres. Thus it is the great pathway which correlates the cortex of the two sides of the telencephalon. Only the smaller middle portion of the body lies free in the floor of the longitudinal fissure, by far the greater part being concealed in the substance of the hemispheres, where its fibers radiate to and from different localities of the pallium, forming the *radiations of the corpus callosum.*

The surface of the corpus callosum shows numerous transverse markings the *transverse striæ*, which indicate the course of its component bundles of fibers. In addition there may be seen on each side of the midline two delicate, variable longitudinal bands running over its surface (fig. 750). The **medial longitudinal stria** (*stria Lancisii*) runs close to the median plane, around the anterior end from the gyrus subcallosus, and over the posterior end downward and lateralward to disappear in the hippocampal gyrus of the base of the telencephalon. The **lateral longitudinal stria** is more delicate than the mesial stria, courses lateral to the medial stria, and can be seen only within the sulcus of the corpus callosum. Both striæ are composed largely of axones having to do with the olfactory apparatus.

When severed along the median plane, it may be seen that the anterior margin of the corpus callosum is turned abruptly downward, forming the **genu,** and that

this turn continues, so that the tapering edge of the genu points posteriorly and constitutes the **rostrum** (figs. 746, 749). The rostrum is in contact with the lamina terminalis of the third ventricle below by a short, thin, frontal continuation of this lamina, known as the **rostral lamina.** The rostral lamina may be considered as beginning at the anterior cerebral commissure with the anterior aspect of which it is in contact, and extending to the rostrum. Beginning with the rostrum and genu, the corpus callosum arches backward as the **body of the corpus callosum,** and ends over the quadrigeminate region in its rounded, thickened posterior margin, the **splenium.** It is bounded above by the sulcus of the corpus callosum, and attached to its concave inferior surface are the choroid tela of the third ventricle, the fornix, and the septum pellucidum.

Each cerebral hemisphere includes—(1) a superficial and much folded mantle or *pallium,* divided into lobes and gyri, and consisting of gray substance, the *cortex,* covering an abundant mass of white substance; (2) a modified portion, the *rhinencephalon,* having especially to do with the olfactory impulses; (3) a cavity, the *lateral ventricle;* and (4) a buried mass of gray substance, the *caudate* and *lenticular nuclei,* which together with the *internal capsule* of white substance, are known as the *corpus striatum.*

Gyri, fissures and sulci.—The cerebral pallium is thrown into numerous and variable folds or *gyri* (convolutions). These are separated from each other by corresponding furrows, the deeper and most constant of which are called *fissures;* the remainder, *sulci.* All the fissures and the main sulci are named. There are, however, numerous small and shallow sulci to which names are seldom given. These occur as short branches of main sulci or as short, isolated furrows bounding small gyri which connect adjacent gyri. These small gyri are likewise seldom given individual names. They are very variable both in different specimens and in the two hemispheres of the same specimen. Collectively, they are the so-called transitory gyri [gyri transitivi]. Certain groups of them are named according to their locality, such as *orbital gyri* and *lateral occipital gyri.* Even the main gyri [gyri profundi] (and sulci) are very irregular in detail. Some of the main and deeper fissures are considerably deeper than others. Some are infoldings of the gray cortex so deep that a portion of their course may be indicated as slight bulgings in the walls of the lateral ventricles, e. g., the hippocampal and collateral fissures. While the general surface pattern is similar for all normal human brains, yet when a detailed comparison is made, the given gyri of different specimens are found to vary greatly. The main gyri of the two hemispheres of the same brain, however, are nearly alike.

Origin of the gyri.—The gyri (and sulci) are the result of processes of unequal growth—folds necessarily resulting from the surface portion of the hemispheres increasing much more rapidly than the central core. In the early periods of fetal life the surfaces of the hemispheres are quite smooth. In many of the smaller mammals this condition is retained throughout life, but in the larger mammals, including man, as development proceeds the cerebral cortex becomes thrown into folds. The absolute amount of the gray substance of the hemispheres varies with the bulk of the animal, and apparently with its mental capabilities. This is especially true of the cortex, for in the larger brains, and that of man especially, by far the greater amount of the cerebral gray substance lies on the surface. Therefore, in either the growth or evolution of a small animal into a large one the amount of cerebral gray substance is increased, and in this increase the surface area of the brain is especially enlarged. It is a geometrical law that in the growth of a body the surface increases with the square, while the volume increases with the cube of the diameter. The cerebral hemisphere is a mass the increase of whose volume does not keep the required pace with the increase of its surface area or cortical layer. The white substance of the hemisphere arises in large measure as outgrowths from the cells of the cortical layer, and thus it can only increase in a certain proportion to the gray substance. Therefore, the surface mantle of gray substance of a hemisphere, enlarged in accordance with an increased bulk of body, is greater than is necessary to comprise the surface of the geometrical figure formed by the combined white and gray substance. Consequently, in order to possess the preponderant amount of gray substance, the surface of the hemisphere is of necessity thrown into folds. It follows also that the thinner the cortical layer in proportion to the volume of the hemisphere, the greater and more folded will be the surface area. In accordance with this theory small animals have smooth or relatively smooth hemispheres, and that independently of their position in the animal scale while large animals have convoluted cortices.

The sulci in general begin to appear with the fifth month of fetal life, the larger of them, the fissures, appearing first and in a more or less regular order. Up to the fifth month the encephalon, due to its rapid growth, closely occupies the cranial capsule. During the fifth month the cranium begins to grow more rapidly than the encephalon, and a space is formed between the cerebrum and the inner surface of the cranium. This space allows further expansion of the pallium, and at the time the space is relatively greatest (during the sixth month) the form and direction of the principal gyri and sulci begin to be indicated. As growth proceeds the unrestricted expansion of the pallium results in the gyri again approaching the wall of the cranium,

and during the eighth month of fetal life they again come in contact with it. Finally, the later relative growth of the cranium results in the space found between it and the cortex in the adult. It is obvious that the relation of the cranium may be a factor in the causation of the gyri, for the increase of surface area necessitated by the increased amount of cortical gray substance might be limited by a cranial cavity of small size. It is probable that the second contact of the cortex with the cranium (during the eighth month) may at least cause a deepening and accentuation of the sulci already begun. Evidently the form of the cranium modifies the gyri, and to a certain extent probably determines their direction, for in long, dolichocephalic crania the anteroposterior gyri are most accentuated, and in the wide, brachycephalic crania the transverse gyri are most marked. At birth all the main fissures and sulci are present, but some of the smaller sulci appear later. In the growing pallium both the bottoms of the sulci as well as the summits of the gyri move away from the geometrical center of the hemisphere, the summits more rapidly, and hence the sulci or fissures first formed grow gradually deeper as long as growth continues.

The mechanical factors in the growth processes which result in the more or less regular arrangement of the gyri of the hemispheres of a given group of animals have not been satisfactorily determined. It has been suggested that the differences in arrangement of the gyri in different groups of animals may be in part dependent upon the functional importance of the various regions—the amount of gray substance of a region varying with the functional importance, and the consequent local increases being accompanied by resultant local foldings. This

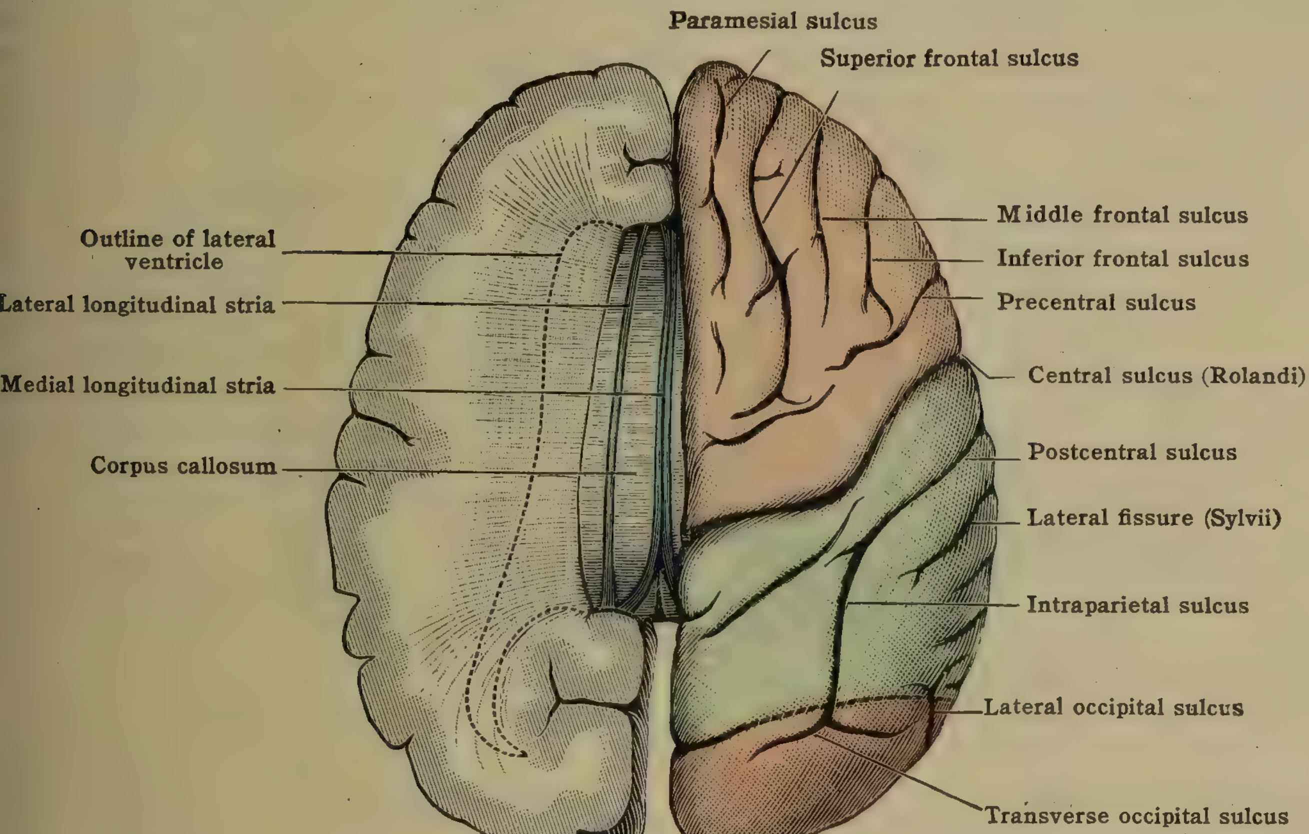


FIG. 750.—DIAGRAM OF CONVEX SURFACE OF RIGHT CEREBRAL HEMISPHERE AND UPPER SURFACE OF CORPUS CALLOSUM. (Temporal and occipital lobes red, parietal green.)

idea is supported by the fact that while the somesthetic (sensory-motor) area of the cortex varies with the bulk of the body, the frontal gyri, so much developed in man and which are one of the chief regions of the associational phenomena, are relatively independent of and do not vary with the weight of either the body or the brain.

Surface area.—The total surface area of the adult human telencephalon is about 2300 sq. cm. Of this area almost exactly one-third is contained on the outer or exposed surfaces of the gyri, while the other two-thirds is found in the walls of the sulci and fissures.

LOBES OF THE TELENCEPHALON AND THE GYRI AND SULCI

The folded pallium of each hemisphere is arbitrarily divided into lobes, partly by the use of certain of the main fissures and sulci as boundaries and partly by the use of imaginary lines (figs. 750–752). These divisions are six in number, themselves subdivided into their component gyri:

(1) Temporal lobe.
(2) Insula (Central lobe or Island of Reil).
(3) Frontal lobe.
(4) Parietal lobe.
(5) Occipital lobe.
(6) Olfactory brain or rhinencephalon (including structures comprised in the other lobes and often grouped under the names *olfactory* and *limbic lobes*.

This division of the cortex of the hemisphere is largely merely topographical. With the exception of the temporal lobe and the rhinencephalon, it has little of either morphological or functional value. The occipital lobe contains the recognized visual area of the cortex, but this area, as such, does not involve all of the lobe. In their functional significance, the frontal and parietal lobes, especially, overlap each other.

The temporal lobe.—This is the first lobe whose demarcation is indicated. During the second month of intrauterine life there appears a slight depression on the lateral aspect of the then smooth hemisphere. As the pallium further grows, this depression deepens into a well-marked fossa with a relatively broad floor. This fossa marks the beginning of the lateral cerebral fissure or fissure of Sylvius, and is, therefore, known as the *Sylvian fossa*. As the pallium continues to project outward, the folds which form the margins of the Sylvian fossa increase in size and height and begin to overlap and conceal its broad floor, which is the beginning of the insula. The overlapping folds thus become the **opercula,** and as their lips approach each other, there results the deep fissure of Sylvius, which marks off anteriorly an inferolateral limb of the pallium, termed by position the temporal lobe. As growth proceeds further, the temporal lobe thickens, the temporal pole extends further forward and becomes a free projection, thus lengthening the fissure of Sylvius and resulting in the inferior extension or stem of this fissure,

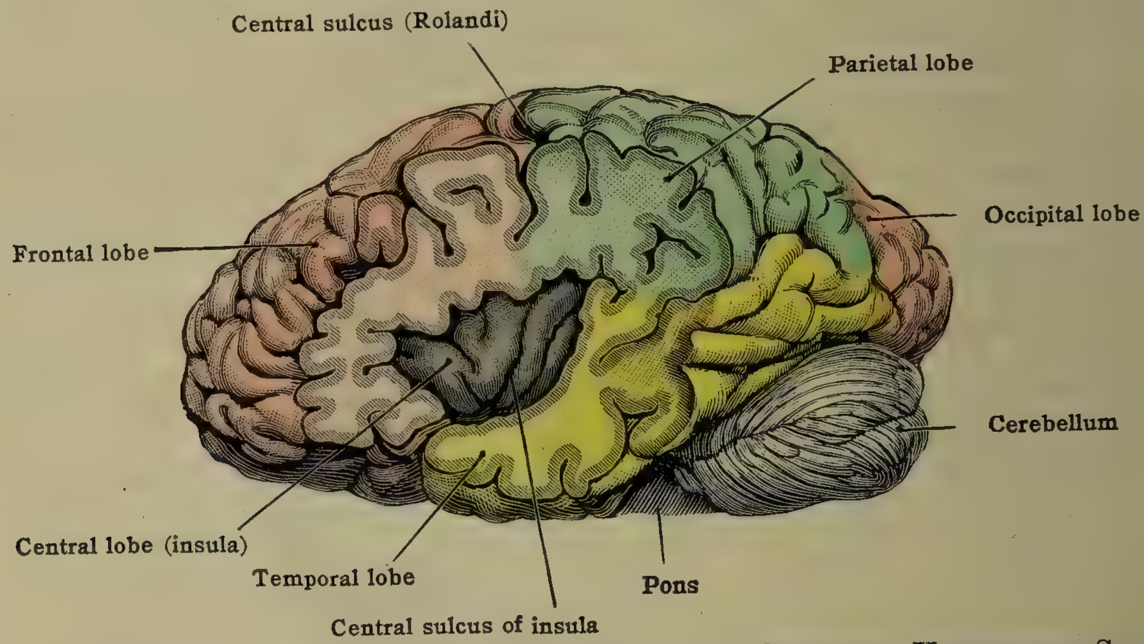


Fig. 751.—Diagram of the Convex Surface of the Left Cerebral Hemisphere Showin[g] the Five Principal Lobes of the Pallium.

The opercular regions of the frontal, parietal, and temporal lobes are removed to show the central lobe or island of Reil.

which runs between the temporal pole and the frontal lobe and curves under so a[s] to appear on the basal surface of the hemisphere (fig. 758). Finally the cortex o[f] the temporal lobe itself is thrown into folds or gyri. Its posterior end is neve[r] marked off from the lobes above and behind, except by arbitrary lines which wil[l] be mentioned in connection with those lobes.

The temporal lobe forms part of the lateral convex and tentorial surfaces of th[e] hemisphere, and its anterior portion is adapted to the surface of the middl[e] cranial fossa. It thus has a lateral surface and a basal and tentorial surface[.] In these surfaces are the following gyri with their intervening and bounding sulc[i] (fig. 752):

The **superior temporal gyrus** is bounded by the posterior ramus of the latera[l] fissure, and extends from the temporal pole backward into the supramargina[l] region belonging to the parietal lobe above. The upper margin of this gyru[s] constitutes the **temporal operculum,** in that it aids in overlapping and enclosin[g] the insula in the floor of the lateral fissure (fig. 753). This margin is mostl[y] smooth, being occasionally interrupted by a few weak twigs of the lateral fissure[.] It is separated from the gyrus below by the **superior temporal sulcus,** which i[s] parallel with the posterior ramus of the lateral fissure and is frequently called th[e] *parallel sulcus*. The posterior extremity of this sulcus divides the angular gyru[s] of the parietal lobe, and its anterior end disappears in the temporal pole, some[-]times as a continuous groove, sometimes in isolated pieces.

The **middle temporal gyrus** likewise begins in the temporal pole and is con-inuous backward into the angular gyrus of the parietal lobe.

The **inferior temporal gyrus** forms the inferolateral border of the temporal obe, and is usually more broken up than the two gyri above it. It usually begins ontinuous with them in the frontal pole, and extends horizontally backward into he lateral gyri of the occipital lobe. It is separated from the middle gyrus by the niddle **temporal sulcus,** which likewise is never so continuous a furrow as the uperior temporal sulcus. Frequently this sulcus occurs in detached portions ınd often terminates within the temporal lobe.

The **fusiform gyrus** is in the basal and tentorial surface of the temporal lobe fig. 754). Its usual somewhat spindle-shape suggests its name, and it is con-inuous backward into the occipital gyri, or its posterior end may be completely solated by a union of the *inferior temporal sulcus* and the **collateral fissure,** vhich two furrows separate it from its neighbors on either side. Anteriorly the usiform gyrus runs into the common substance of the other three gyri at the emporal pole.

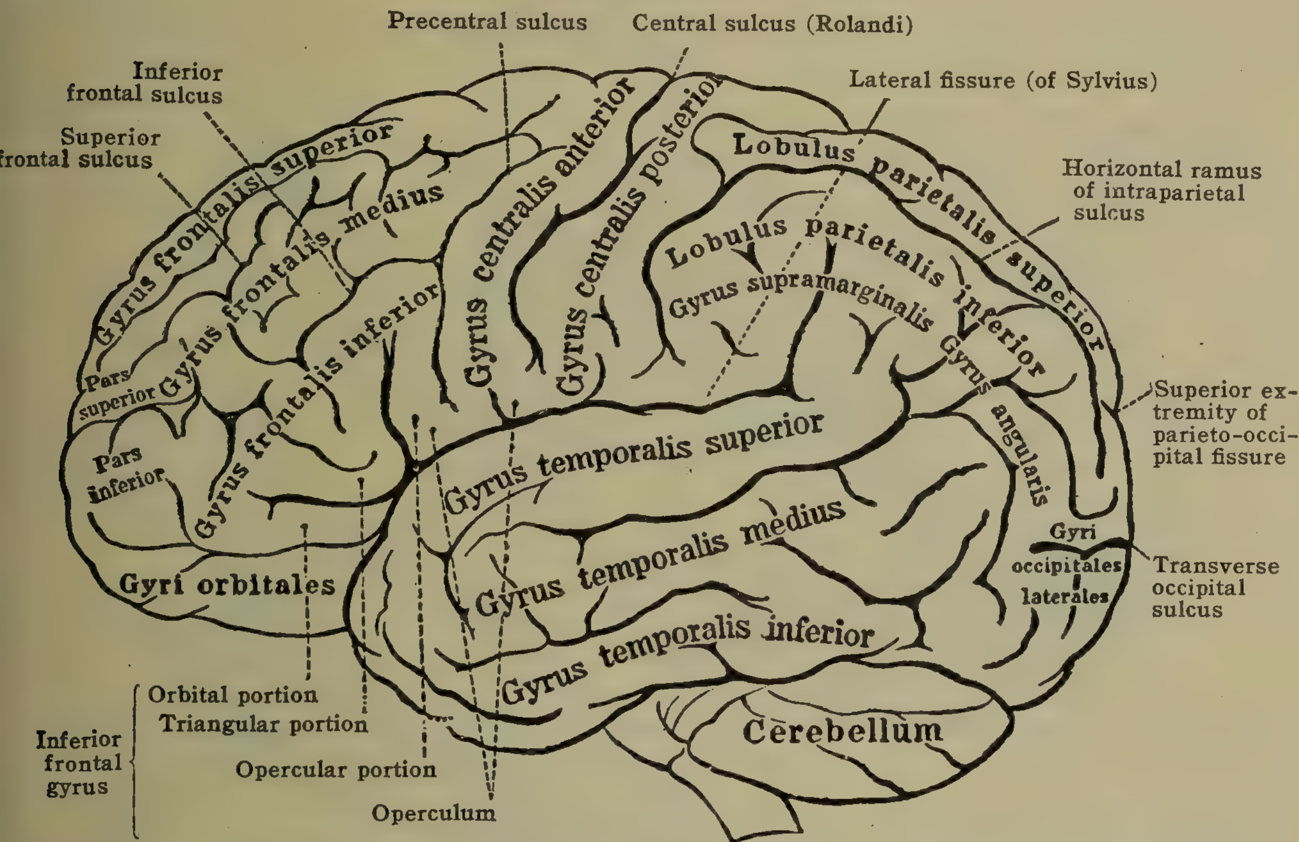


FIG. 752.—OUTLINE DRAWING OF CONVEX SURFACE OF LEFT CEREBRAL HEMISPHERE. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The **lingual gyrus** (fig. 754) is usually included in the tentorial surface of the emporal lobe, though some regard it as a part of the occipital lobe. Its larger, osterior portion lies within the boundaries of the occipital lobe. Bounded aterally by the collateral fissure, it is continuous anteriorly into the hippocampal yrus of the rhinencephalon.

All of the sulci give off occasional lateral twigs (*transverse temporal sulci*) which hemselves may or may not branch, and which tend to divide the main gyri into **ransverse temporal gyri.**

The lateral fissure (fissure of Sylvius) (vallecula cerebri lateralis NK).—On ccount of its origin by the overlapping and enclosing of the broad floor of the Sylvian fossa by the adjacent folds of the pallium, the lateral fissure is the deepest ınd most conspicuous fissure of the cerebral hemisphere (figs. 752–754). Its nain divisions are a short stem and three main branches. The **stem** lies in the asal surface of the hemisphere, where it begins in a depression in the anterior erforated substance, the *vallecula Sylvii,* and passes forward and upward between ınd separating the temporal pole and the superciliary border of the frontal lobe. It corresponds in direction with the posterior border of the lesser wing of the phenoid bone, which projects backward into it, and it contains the middle erebral artery, the Sylvian vein, and the sinus alæ parvæ. It coincides on the ateral surface with a point known in cranial topography as the *Sylvian point,* vhere it divides into its three main branches (fig. 752):

(1) The **posterior ramus** is the linear continuation of the fissure, and runs horizontally backward and upward to terminate in the supramarginal gyrus of the parietal lobe.

(2) The **anterior ascending ramus** passes upward for about 10 mm., subdividing the inferior gyrus of the frontal lobe.

(3) The **anterior horizontal ramus** passes forward from the stem of the fissure about 10 mm., and likewise into the inferior frontal gyrus, but parallel with the superciliary border.

These branches, together with certain smaller collateral twigs, divide the overlapping or opercular portions of the adjacent pallium into (*a*) the *temporal operculum*, which lies below the posterior ramus; (*b*) the frontoparietal operculum, or *operculum proper*, which lies above and behind the anterior ascending ramus; (*c*) the *frontal operculum*, between the latter and the anterior horizontal ramus; (*d*) and the *orbital operculum*, below the anterior horizontal ramus. Collectively the opercula are known as the *opercula of the insula.*

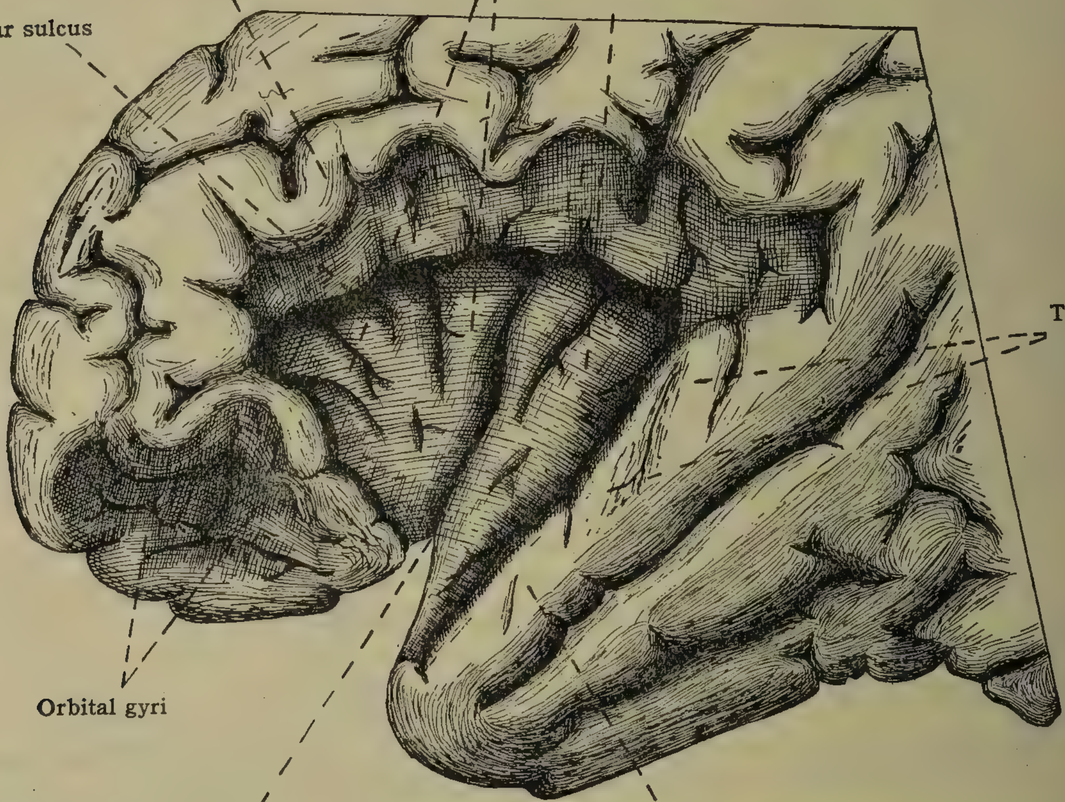


Fig. 753.—The Insula with its Gyri and Sulci. (Shown by widely separating the opercula.)

The insula (central lobe).—The insula or island of Reil (figs. 751, 753) is a triangular area of the cerebral cortex lying in the floor of the lateral fissure, and concealed by the opercula. Of these, the temporal operculum overlaps the insula to a greater extent than either the frontal or parietal. More than half of it may, therefore, be exposed, by gently pressing away the temporal lobe. The insula corresponds to the broad floor of the Sylvian fossa of the fetal brain. In the developed condition its surface is convex lateralward and is itself folded into gyri. The apex of the triangle appears upon the basal surface of the hemisphere (fig. 754), and is the only portion which may be seen without disturbing the specimen. The apex appears as the end of a small gyrus under the temporal pole, and in close relation with the anterior perforated substance and the vallecula Sylvii, and is known as the **limen of the insula.** In the folding process by which the opercula accomplish the overlapping and enclosing of the island, there results a deep sulcus which surrounds its entire area except at the limen insulæ. This is known as the **circular sulcus**, or limiting sulcus of Reil. The gyri (and sulci) of the insula radiate from the apex of the triangle. The **central sulcus** of the insula is the deepest. It runs from below backward and upward, parallel with the central sulcus (of Rolando) above and divides the insula into a larger anterior and

a longer posterior portion. The anterior portion consists of from three to five short irregular **gyri breves** or precentral gyri, separated by **sulci brevis**; the posterior portion consists of a single, slightly furrowed gyrus, which is long and arched and extends from the apex to the base of the triangle, the **gyrus longus.**

In a thorough study of the insula of more than 200 human brains, including a few of idiots and paralytics and a series of young fetuses, Nelidoff finds that the left island is more deeply marked by sulci and averages 11 mm. longer than the right; that, of the sulci in the island, the central sulcus is the first to appear, is the most persistent sulcus in defective brains, though occasionally absent in microcephalic idiots, and that on the average it is more pronounced in males than in females.

The frontal lobe (figs. 750–757).—This is the most anterior of the lobes of the hemisphere and, like the two lobes behind, it has a convex or lateral, a basal, and a medial surface. The convex surface begins with the frontal pole, and is bounded posteriorly by the *central sulcus* (*Rolandi*). The basal surface extends backward to the stem of the lateral fissure which is covered by the frontal pole. The medial surface is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the subfrontal part of the **sulcus cinguli** (callosomarginal fissure), and from the parietal lobe by a line drawn perpendicular from the upper extremity of the central sulcus (Rolandi) to the sulcus cinguli. These surfaces include the following, gyri and sulci:—

	Gyri.	Sulci.
Convex surface	Anterior central gyrus.	Precentral sulcus { Superior. Inferior.
	Superior frontal gyrus.	
	Middle frontal gyrus { Superior portion. Inferior portion.	Superior frontal sulcus. Middle frontal sulcus.
	Inferior frontal gyrus { Opercular portion. Triangular portion. Orbital portion.	Inferior frontal sulcus. Anterior ascending ramus of lateral fissure. Anterior horizontal ramus of lateral fissure.
Basal surface	Orbital gyri { Lateral. Anterior. Posterior. Medial.	Orbital sulci { Lateral Medial. Transverse.
	Gyrus rectus	Olfactory sulcus.
Medial surface	Superior frontal gyrus. Marginal gyrus. Paracentral lobule (anterior part).	Rostral sulci.

Many of the sulci, especially the superior frontal and the rostral sulci, often give off twigs or are broken into short furrows which give rise to small folds [gyri transitivi], too inconstant to be given special names.

The **anterior central gyrus** (ascending frontal convolution) is the only gyrus of the frontal lobe having a vertical direction. It lies parallel to the central sulcus (Rolandi), and thus extends obliquely across the convex surface from the posterior ramus of the lateral fissure (frontal operculum) to the superomedial border, and is continuous on the medial surface with the anterior portion of the *paracentral lobule.* It comprises the larger part of the motor portion of the somesthetic (sensory-motor) area of the cerebral cortex. It is separated from the horizontal frontal gyri in front of it by the **precentral sulcus**

This sulcus is developed in three parts, but the upper and middle parts in the fetal brain usually fuse together, so that in the later condition it consists of a superior and an inferior segment. The superior cuts the superomedial border of the hemisphere and appears on the medial surface in the paracentral lobule. On the convex surface it is usually connected with the posterior end of the superior frontal sulcus (fig. 752).

The **superior frontal gyrus** is a relatively broad, uneven convolution, comprising the anterior portion of the superomedial border of the hemisphere and therefore extends horizontally from the precentral sulcus to the frontal pole. It is sometimes imperfectly divided into a superior and an inferior part by a series of detached, irregular furrows, spoken of collectively as the *paramedial sulcus.* The resulting transitory gyri are of considerable interest in that they are peculiar to the human brain, and are said to be more marked in the higher than in the lower types.

The **middle frontal gyrus** is likewise a broad strip of pallium extending from the precentral sulcus to the temporal pole. It is separated from the superior frontal gyrus by the **superior frontal sulcus,** which is usually continuous into the

superior segment of the precentral sulcus and thence extends horizontally to the frontal pole. The middle frontal gyrus is in most cases subdivided anteriorly into a *superior* and an *inferior portion* by a **middle frontal sulcus.** This sulcus begins above and runs into the frontal pole, where, upon reaching the superciliary border, it frequently bifurcates into a transverse furrow, known as the *fronto-marginal sulcus.*

The **inferior frontal gyrus** forms the superior wall of the lateral fissure, and is separated from the middle frontal gyrus by the **inferior frontal sulcus.** This sulcus usually begins continuous with the inferior section of the precentral sulcus, and extends, very irregularly and frequently interrupted, toward the frontal pole. The gyrus abuts upon the anterior central gyrus, and its posterior portion is divided into three parts (the frontal opercula) by the anterior ascending and horizontal rami of the lateral fissure. The part behind the anterior ascending

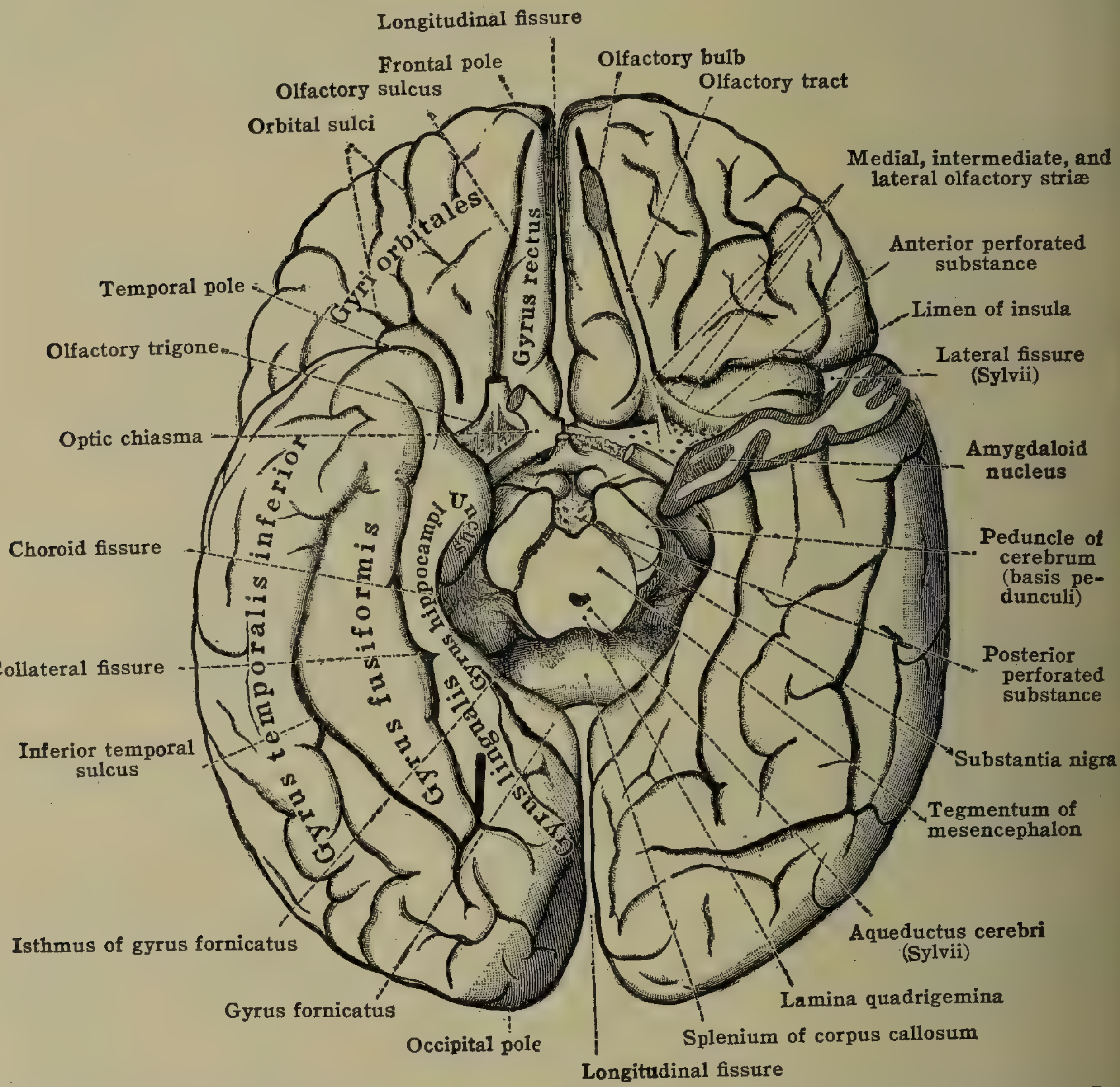


FIG. 754.—BASAL SURFACE OF THE CEREBRAL HEMISPHERES. TIP OF LEFT TEMPORAL LOBE REMOVED. (After Toldt, 'Atlas of Human Anatomy,' The Macmillian Company.)

ramus is the **opercular portion** (a part of the frontoparietal operculum or operculum proper), sometimes referred to as the *basilar portion.* In most brains this part is traversed by a short oblique furrow, the **diagonal sulcus.** The part between the two anterior rami of the lateral fissure is the cone-shaped **triangular portion.** This portion frequently involves one and sometimes two descending twigs of the inferior frontal sulcus. The part below the anterior horizontal ramus is by position the **orbital portion.**

It is seen that the inferior frontal gyrus gives rise to the whole of the frontal operculum and the anterior half of the frontoparietal operculum. The opercular portion is of special interest in that in the left hemisphere it constitutes the historic **convolution of Broca,** the motor area for the function of speech. The area controlling speech, however, involves that part of the triangular portion bounding the anterior ascending ramus of the lateral fissure as well, and both these parts often appear more developed on the left hemisphere. The development of the opercula of the inferior frontal gyrus is a distinctive characteristic of the human brain.

This gyrus does not develop opercula even in the highest varieties of apes. The development of the function of speech in man no doubt has influenced the development of the frontal opercula.

On the *basal surface* (fig. 754) of the frontal lobe is the orbital area and the gyrus rectus. The more pronounced of the **orbital sulci** are often so joined with each other as to form an H-shaped figure standing parallel to the medial plane, and thus they comprise a *medial*, a *lateral* and a *transverse orbital sulcus*. This figure naturally divides the orbital area into four gyri:—(1) The **lateral orbital gyrus** is the basal continuation of the inferior frontal gyrus, and is thus related to the orbital portion of the frontal operculum; (2) the **anterior orbital gyrus** is continuous at the pole with the middle frontal gyrus; (3) the **posterior orbital gyrus** is closely related to the limen insulæ and the stem of the lateral fissure, and its outer part is in relation with the orbital portion of the operculum; (4) the **medial orbital gyrus** is continuous over the superciliary border with the superior frontal gyrus. It frequently contains one or two short, isolated sulci. Its medial boundary is the straight **olfactory sulcus**, in which lie the olfactory bulb and tract of the rhinencephalon. This sulcus marks off a narrow straight strip of cortex between it and the medial border of the lobe known as the **gyrus rectus.** The posterior portion of the gyrus rectus comprises a part of the **parolfactory area** or Broca's area, which functionally belongs to the rhinencephalon. As an area or field, this appears mesially lying between the anterior and posterior parolfactory sulci.

On the *medial surface* (fig. 757) of the frontal lobe the superior frontal gyrus is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the well-marked **sulcus cinguli.** Anteriorly the superior frontal gyrus is subdivided by the main stem of the **rostral sulci** into a **marginal gyrus,** and what may be termed a **submarginal gyrus.** The marginal gyrus is usually broken into smaller parts by twigs of the rostral sulci, most of which are perpendicular to the main stem, while the submarginal gyrus is less frequently interrupted. Posteriorly the superior frontal gyrus constitutes the anterior portion of the *paracentral lobule*, a part of the somesthetic area of the medial surface of the hemisphere. This lobule is usually marked off anteriorly by a vertical twig from the sulcus cinguli.

The **sulcus cinguli** (callosomarginal fissure) is the longest and one of the most prominent sulci on the medial surface of the hemisphere. It divides the anterior portion of the medial surface into a marginal part above and a callosal part below —in other words, it separates the superior frontal gyrus from the gyrus cinguli. Its **subfrontal portion** begins below the rostrum of the corpus callosum and curves forward and upward around the genu, and then turns backward above the body of the corpus callosum. Before it reaches the level of the splenium, it turns upward and cuts and terminates in the superomedial border of the hemisphere, as the next sulcus behind the upper termination of the central sulcus. This upward turn is the **marginal portion** of the sulcus cinguli. It is sometimes an abrupt curve and sometimes curves gradually, but its marginal relation to the upper end of the central sulcus is so constant that it serves as a means by which either of the sulci may be identified. The marginal portion separates the paracentral lobule from the precuneus (quadrate lobule), and is wholly within the parietal lobe. One of the most constant twigs of the sulcus cinguli is that which marks off the paracentral lobule from the superior frontal gyrus. Another sometimes divides the paracentral lobule into its frontal and parietal portions.

The sulcus cinguli is developed from two and sometimes three (anterior, middle, and posterior) separate furrows, which later extend and fuse into continuity. This method of its development may explain the irregularities frequently met with and the fact that sometimes in the adult the sulcus occurs in separate pieces.

The **central sulcus** (fissure of Rolando) (figs. 752, 755, 756) is one of the principal landmarks of the convex surface of the hemisphere. It separates the frontal from the parietal lobe, and likewise divides the somesthetic area of the pallium. Its upper end terminates in and usually cuts the superomedial border of the hemisphere immediately in front of the termination of the marginal portion of the sulcus cinguli. Thence it pursues an oblique though sinuous course forward across the convex surface of the hemisphere, forming on the average an angle of about 72° with the superomedial border (**Rolandic angle**), and terminates in the frontoparietal operculum immediately above the posterior ramus, and about 2.5 cm. behind the point of origin of the two anterior rami of the lateral fissure. It rarely cuts

through the frontoparietal operculum. In its sinuous course, varying from the line of its superomedial end, two bends are marked (fig. 755):—(1) The **superior genu** occurs at about the junction of the upper and middle thirds of the sulcus and is concave forward. It accommodates the greater part of that portion of the cortex which is the motor area for the muscles of the leg and trunk, and the development of this area in man probably aids in producing it. (2) The **inferior genu** occurs below, is concave forward and is commonly a little more marked than the superior genu. It is probably in part a result of the superior genu—the turn of the sulcus in resuming its general course, but it may further result from the development of the shoulder and arm area of the cortex which occupies its concavity.

The central sulcus (Rolandi) appears in the pallium of the fetus during the latter part of the fifth month. It then consists of a lower longer and an upper shorter part. Usually these two parts become continuous before birth; very rarely do they remain separate in the adult. The point of their fusion is sometimes manifest within the depth of the sulcus. If the lips of the sulcus be pressed widely apart at about the region of the junction of its middle and upper thirds, it will be found that the opposing walls give off a number of protuberances or lateral gyri, which dovetail into each other when the sulcus is closed. Sometimes two of these lateral gyri appear fused across the floor of the sulcus, so as to form a bridge of gray substance known as the **deep annectant gyrus**. This interruption of the continuity of the sulcus, when present, represents the point at which the two parts of the sulcus in the fetal brain joined each other without the continuity becoming wholly completed in the adult. The genua of the adult sulcus may often be due to the precedent parts not being in line at the time of their fusion.

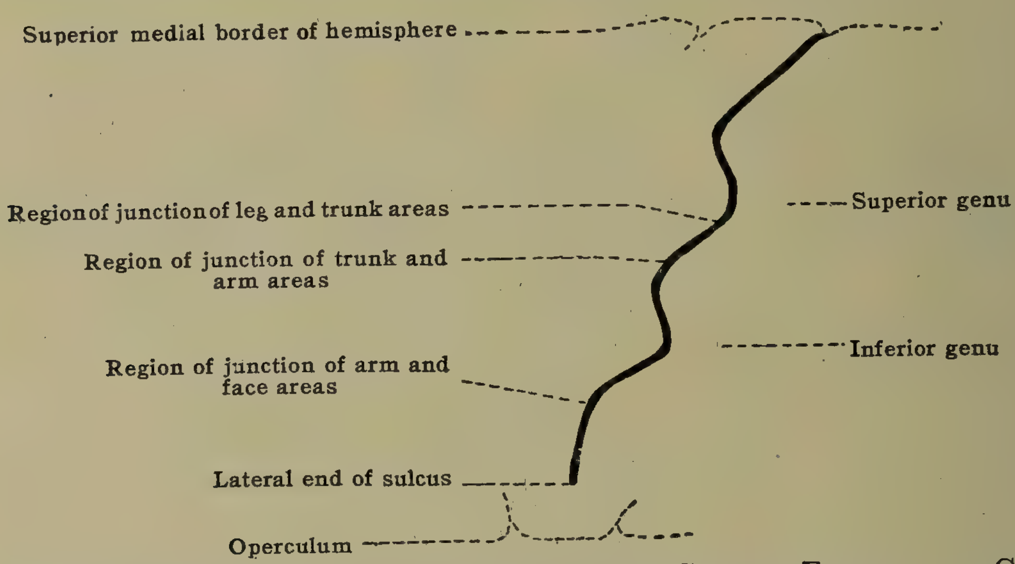


Fig. 755.—Diagram Representing the Most Common Form of the Central Sulcus and Indicating the Regions of Junction upon it of the Areas of the Precentral Gyrus Devoted to the Different Regions of the Body (Symington and Crymble).

From a special study of the central sulcus of 237 normal adult hemispheres, Symington and Crymble (1913) give the following details: (1) that the most common course of the sulcus is that illustrated in fig. 755, above; (2) that it varies in depth both in a given specimen and in different specimens—the greatest variations in depth reported for a given sulcus being from 22 to 12 millimeters, the shallowest part being in the region of the deep annectant gyrus; (3) that the average length from the superomedial border of the hemisphere to the opercular end of the sulcus is about 9 cm. in direct line and 10.4 cm. following the curves of the sulcus. The average length of the curved floor is 7.9 cm. (4) From the superomedial end of the sulcus to the points of junction of the general areas of the precentral gyrus, direct line measurements give averages, (a) to the junction of leg and trunk areas, 3.5 cm.; (b) to junction of trunk and arm areas, 4.5 cm.; (c) junction of arm and face areas, 7.5 cm.

The parietal lobe.—The parietal lobe (figs. 749–752, 756, 757) occupies a somewhat smaller area of the human telencephalon than either the frontal or the temporal lobe. It has a lateral convex and a medial surface, but no basal surface. It is separated from the frontal lobe in front by the central sulcus; from the occipital lobe behind, on the medial surface by the *parietooccipital fissure*, and, on the convex surface, by an arbitrary line drawn transversely around the convex surface of the hemisphere from the superior extremity of this fissure to the inferolateral border, and it is separated from the temporal lobe below by the horizontal part of the posterior ramus of the lateral fissure, and by a line drawn in continuity with this horizontal part to intersect the transverse line drawn to limit it from the occipital lobe.

The preoccipital notch.—*In situ*, the inferolateral border of the posterior portion of the hemisphere rests over a small portion of the parietomastoid suture of the cranium, and upon this suture occurs a fold or vertical thickening of the dura mater, which slightly indents the

inferolateral border of the hemisphere. This indentation occurs about 4 cm. from the occipital pole, and is considered one of the points of limitation of the parietal from the occipital lobe, and is therefore called the preoccipital notch. While during late fetal life and early childhood it is well marked, it is usually very slight in the adult brain, and is, as a rule, evident only in brains hardened *in situ.* When it is visible, the arbitrary transverse line from the superior extremity of the parietooccipital fissure, used as a boundary between the convex surfaces of the parietal and occipital lobes, should be so drawn as to bisect the preoccipital notch.

The *convex surface* of the parietal lobe comprises the following gyri and sulci:—

The **posterior central gyrus** (ascending parietal) extends obliquely across the hemisphere parallel with the anterior central gyrus of the frontal lobe, from which it is separated by the central sulcus. Its inferior end is bounded by the posterior ramus of the lateral fissure, and constitutes the posterior or parietal portion of the frontoparietal operculum. Its upper end takes part in the superomedial border of the hemisphere, and is bounded posteriorly by the tip end of the marginal portion of the sulcus cinguli. Its posterolateral boundary consists of the two

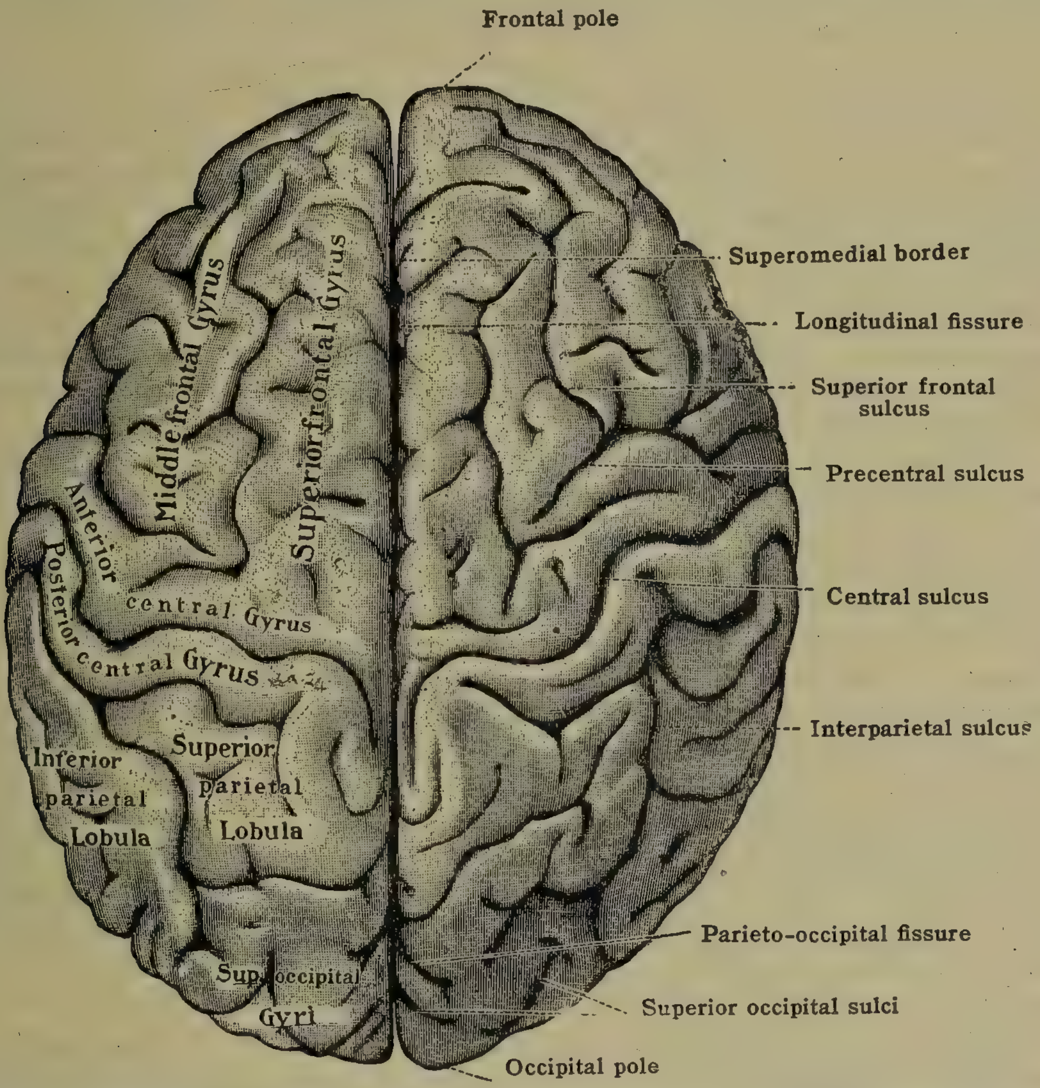


FIG. 756.—CONVEX SURFACE OF THE CEREBRAL HEMISPHERES AS VIEWED FROM ABOVE. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

more or less vertical rami or factors of the interparietal sulcus, viz., the inferior and superior portions of the *postcentral sulcus*, either continuous with each other or detached.

The **interparietal sulcus** (intraparietal) is often the most complicated sulcus of the pallium. Its development usually begins as four different furrows in the fetal brain, and the difficulty with which it is traced in the adult brain depends upon the extent to which these four factors become continuous in the later development. When continuity of the furrows is well established, the entire sulcus may be described as consisting of an anterior end and a convex *horizontal ramus*, which gives off a few short collateral twigs and whose either end is in the form of an irregular, reclining ⊣. The transverse bar of the anterior end arises from two of the four factors of the entire sulcus:—(1) an inferior furrow, the *inferior postcentral sulcus*, commencing above the posterior ramus of the lateral fissure and ascending as the boundary of the lower half of the posterior central gyrus, and (2) a superior furrow, the *superior postcentral sulcus*, lying behind the upper portion of the posterior central gyrus, and which, upon approaching the superomedial

border, may turn backward a short distance parallel with the horizontal ramus, as in fig. 752. When confluent, these two factors form together a continuous **post-central sulcus.** In the adult the superior of the two is always continuous with the horizontal ramus; when confluent, the two join so as to form the transverse bar of the anterior end of this ramus. The horizontal ramus, which represents the third of the primary furrows, is continued backward past the superior extremity of the parietooccipital fissure into the occipital lobe, where it usually joins the *occipital ramus*, the fourth of the primary furrows. This ramus divides shortly into two branches which run at right angles to the stem, forming the *transverse occipital sulcus*, and thus arises the transverse bar of the posterior end of the interparietal sulcus.

The occipital ramus may, however, consist of little more than the transverse bar, which may or may not be joined by the horizontal ramus. The occipital ramus is more frequently separate from the horizontal than is the postcentral sulcus. In their development the inferior postcentral sulcus appears first (during the latter part of the sixth month), the occipital ramus second, the horizontal ramus third, and last, the superior postcentral sulcus.

The **superior parietal lobule** (*gyrus*) is the area of the superomedial border of the parietal lobe (figs. 752, 756). It is limited in front by the superior postcentral sulcus, below by the horizontal ramus of the interparietal sulcus, and posteriorly it is continuous around the superior end of the parietooccipital fissure into the cortex of the occipital lobe. It is a relatively wide area (lobule), always invaded by collateral twigs of its limiting sulci, and usually contains a few short, isolated furrows. When the parieto-occipital fissure is considerably prolonged over the superomedial border (*external parietooccipital fissure*), the continuation of the lobule about the end of this fissure presents the appearance described as the **parietooccipital arch.**

The **inferior parietal lobule** is limited in front by the inferior postcentral sulcus, and above by the horizontal ramus of the interparietal sulcus (fig. 752). It is continuous with the cortex of the temporal lobe, and with that of the occipital lobe behind, and is therefore invaded by the ends of the sulci belonging to these lobes. Its anterior portion is separated from the temporal lobe by the horizontal portion of the posterior ramus of the lateral fissure. The upturned end of this ramus invades the anterior portion of the lobule and the broad fold, arched around this end and continuous behind it into the superior temporal gyrus, is known as the **supramarginal gyrus**—an area to which auditory word- and tone-images are attributed. The **angular gyrus** is the portion which embraces the posterior end of the superior temporal sulcus, and is continuous behind this into the middle temporal gyrus and in front usually with the superior temporal gyrus. It is the area for visual word images. Its shape is usually such as to suggest its name. The most posterior part of the inferior parietal lobule, when arching about the end of the middle temporal sulcus and continuous with the temporal gyri on its either side, is known as the **postparietal gyrus.** This is a smaller area than either of the other two, and, owing to the variability of the end of the middle temporal sulcus, is not always evident.

The *medial surface* of the parietal lobe is divided into two parts by the marginal portion of the sulcus cinguli. The anterior and smaller part is the medial continuation of the posterior central gyrus, and comprises the posterior portion of the **paracentral lobule** (fig. 757). It is limited from the part of this lobule belonging to the frontal lobe by a vertical line drawn from the marginal extremity of the central sulcus. The **precuneus** (*quadrate lobule*) is the posterior and larger part of the medial surface of the parietal lobe. It is separated from the cuneus of the occipital lobe by the parietooccipital fissure, and is imperfectly separated from the gyrus cinguli (limbic lobe) below by the *subparietal sulcus* (postlimbic fissure), branches of which invade it extensively.

The occipital lobe.—This is a relatively small, trifacial, pyramidal segment, comprising the posterior extremity of the hemisphere, its apex being the occipital pole. Though one of the natural divisions of the cerebral hemisphere, it is very indefinitely marked off from the lobes anterior to it. Though it contains the cortical area of the visual apparatus, only in the brains of man and the apes does it occur as a well-defined posterior projection of the hemisphere. In most of the mammalia it is not differentiated at all. Its three surfaces comprise a convex, a medial, and a tentorial surface.

Its *convex surface* is separated from that of the parietal and temporal lobes by the superior and external extremity of the parietooccipital fissure and by an arbitrary line drawn transversely from this extremity to the inferolateral border of the hemisphere, or so drawn as to bisect the preoccipital notch when this is evident. The sulci which occur on the convex surface may be described as two, though both of these are very variable in their extent and shape, and their branches are inconstant both as to number and length. (1) The **transverse occipital sulcus** is the most constant in shape. It extends a variable distance transversely across the superior portion of the lobe, and, as noted above, it is frequently continuous with the interparietal sulcus through its occipital ramus, and when so, it appears as the posterior terminal bifurcation of this sulcus (fig. 752). When detached, it often occurs merely as a definite furrow with few rami, and sometimes the ramus by which it otherwise would join the interparietal sulcus is entirely absent. (2) The **lateral occipital sulcus** is always short, and has its deepest portion below the transverse sulcus. It usually has a somewhat oblique course toward the superomedial border. Sometimes it occurs in several detached pieces, then known collectively as the *lateral occipital sulci.*

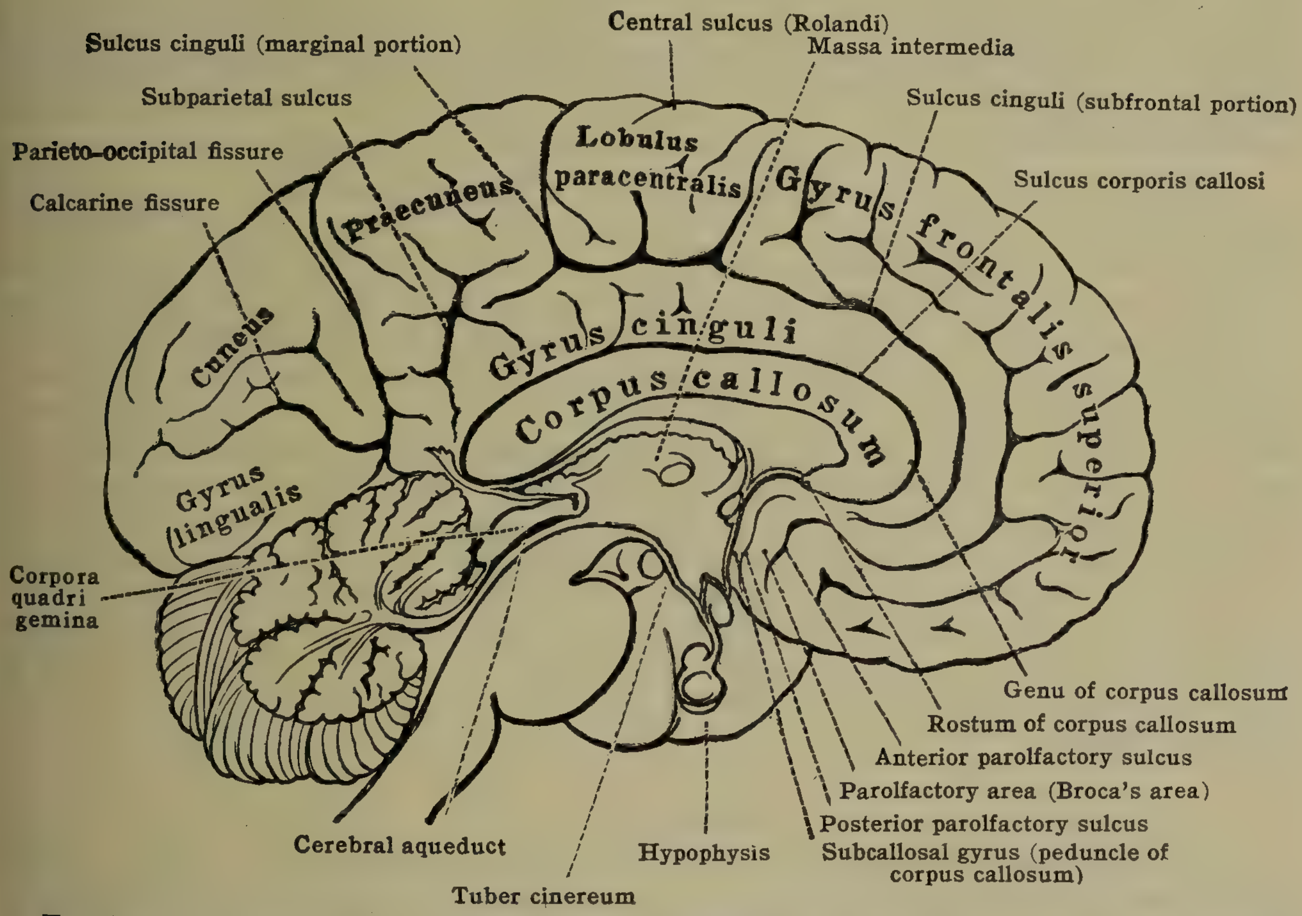


FIG. 757.—OUTLINE DRAWING OF MEDIAL SURFACE OF LEFT CEREBRAL HEMISPHERE. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

Therefore, the gyri of the convex surface of the lobe are also variable. They are not sufficiently constant to merit individual names. The lateral occipital sulcus or sulci roughly divide them into an inferior and lateral area, known as the **lateral occipital gyri,** and into a superior area, the **superior occipital gyri.** The lateral area is continuous into the gyri of the temporal lobe, while the superior area is continuous into the gyri of the parietal lobe.

The *medial surface* of the occipital lobe is separated from that of the parietal lobe (precuneus) and from the gyrus cinguli of the limbic lobe by the well-marked parietooccipital fissure. It comprises the constantly defined, wedge-shaped lobule known as the **cuneus,** and the posterior and medial extremity of the **lingual gyrus.** Since the greater portion of the length of the lingual gyrus is involved in the basal surface of the temporal lobe, this gyrus as a whole has been considered as belonging to the temporal lobe (see figs. 749, 754). The cuneus is separated from the lingual gyrus by the posterior portion of the **calcarine fissure,** which always terminates in a bifurcation, one limb of which invades the cuneus near the superomedial border. In addition the cuneus may contain other twigs from both the fissures bounding it, and also, when wide, may contain one or more short, detached **sulci cunei.**

The **calcarine fissure** and the **parietooccipital fissure** are almost invariably joined in the human brain, forming a **Y**-shaped figure, the prongs of which give the cuneus its shape. The calcarine fissure begins on the tentorial surface in the posterior portion of the hippocampal gyrus of the limbic lobe, below the splenium of the corpus callosum, and extends backward across the medial occipital border of the hemisphere. It then bends downward and proceeds to its terminal bifurcation in the polar portion of the occipital lobe. The stem or hippocampal portion of the fissure is deeper than the posterior or occipital portion. It produces a well-marked eminence in the medial wall of the posterior cornu of the lateral ventricle, known as the *calcar avis* or *hippocampus minor.* It is developed separately from the posterior portion, which itself first appears as two grooves. All three parts are usually continuous with each other before birth.

The **parieto-occipital fissure** usually appears from the first as a continuous groove. It begins in the superomedial border of the hemisphere, rarely extending into the convex surface more than 10 mm. (*external parieto-occipital fissure*), thence it extends vertically downward across the mesial surface (*internal parieto-occipital fissure*), and terminates by joining the calcarine fissure at the region of the downward bend of the latter, or at about the junction of its anterior and middle thirds. In certain of the lower apes and in the brain of the chimpanzee there is no junction between the two fissures, they being kept apart by a narrow neck of cortex, the **gyrus cunei.** Neither are they joined in the human fetus. If in the adult human brain the region of their junction be opened widely, there will be found a submerged transitory gyrus (deep annectant gyrus), which is the gyrus cunei, superficial in the fetus. In the higher apes and in microcephalic idiots this gyrus may be on the surface or partially submerged. Two other transitory gyri (annectant gyri) are to be found by pressing open the calcarine fissure, and they mark the points at which its three original grooves became continuous during its development into a boundary between the cuneus and the lingual gyrus. Of these, the **anterior cuneolingual gyrus** crosses the floor of the calcarine fissure on the posterior side of its junction with the parietooccipital fissure, and therefore near the gyrus cunei. The **posterior cuneolingual gyrus** occurs near the region of the terminal bifurcation of the fissure.

The *tentorial surface* of the occipital lobe is blended intimately with that of the temporal lobe, from which it is separated only by an arbitrary line drawn from the line of demarcation for the convex surface, at the region of the preoccipital notch, and thence to the isthmus of the gyrus fornicatus—the narrow neck of cortex connecting the gyrus cinguli with the hippocampal gyrus, just below the splenium of the corpus callosum (see fig. 749). The gyri blending the occipital and temporal lobes across this line are the *lingual gyrus,* already mentioned, and the **fusiform gyrus** (occipitotemporal convolution). In fact, the tentorial surface of the lobe may be considered as nothing more than the posterior extremity of the fusiform gyrus, and the inferior portion of the same extremity of the lingual gyrus. The former is often somewhat broken up and is then continuous into the lateral occipital gyri. These two gyri are separated by the *collateral fissure,* the posterior end of which extends into the occipital lobe. The fusiform gyrus is bounded laterally by the inferior temporal sulcus, which sometimes is continuous by a lateral twig, across the posterior end of this gyrus, with the collateral fissure.

The Rhinencephalon

The rhinencephalon or *olfactory brain* includes those portions of the cerebral hemisphere which are chiefly concerned as the central components of the olfactory apparatus. Owing to the preponderant development of the other divisions of the hemisphere, the parts comprising this division appear relatively but feebly developed in the human brain. In most of the mammals the sense of smell is relatively much more highly developed, and in many of the larger mammals the parts comprising the rhinencephalon are of greater absolute size than in man, though their cerebral hemispheres may be considerably smaller. In the human fetus the parts of the rhinencephalon are relatively much more prominent than after the completed differentiations into the adult condition. In the broader sense of the term the rhinencephalon includes those parts of the hemisphere usually classed as comprising two lobes, viz., the **olfactory lobe** and the **limbic lobe.** Neither of these is a 'lobe' in the sense of comprising a definite segment of the hemisphere, as do the other lobes, and therefore the rhinencephalon cannot be called a distinct lobe. It is so strung out that by one or the other of its parts it is either in contact or continuity with each of the other lobes of the hemisphere. Morphologically, the olfactory lobe and adjacent structures form the *anterior division,* and the limbic lobe forms the *posterior division* of the rhinencephalon.

The **anterior division**—the *olfactory lobe* proper—belongs almost wholly to the base of the encephalon, and consists of the following parts:—

(1) The **olfactory bulb** is an elongated, oval enlargement of gray substance which lies upon the lamina cribrosa of the ethmoid bone, and, practically free, it

is pressed into the anterior end of the olfactory sulcus in the basal surface of the frontal lobe. The numerous thin filaments of non-medullated axones of the *olfactory nerve* enter the cranium through the foramina of the lamina cribrosa and pass into the inferior surface of the bulb to form synapses with its cells.

(2) The **olfactory tract** is a triangular band of white substance which arises in the olfactory bulb, and continues backward about 20 mm. to the region of the anterior perforated substance. It appears triangular in transverse section from the fact that its upper side fits into the olfactory sulcus. It becomes somewhat broader at its posterior end. In the human fetus and in the adult of many of the lower vertebrates the tract retains considerable gray substance.

(3) The **olfactory trigone** (*olfactory tubercle*) is the small triangular ridge, the posterior continuation of the olfactory tract joining the anterior perforated substance. In it the olfactory tract breaks up into three roots, the *lateral, intermediate*, and *medial olfactory stria* (*gyri*). The lateral olfactory stria emphasizes the lateral portion of the trigone into the **lateral olfactory gyrus,** a portion of which is directly continuous into the *limen insulæ* (figs. 754, 758).

While a few of the fibers of the lateral stria penetrate this region, the greater mass of them pass obliquely lateralward over it and gradually disappear in the anterolateral portion of the anterior perforated substance, in which some of them terminate, but through which most of them pass to curve into the anterior end of the hippocampal gyrus and terminate there, chiefly in the uncus. In most of the mammals the lateral stria is so strong that it appears as a superficial white band passing directly into the uncus. In the early fetus it is seen to enter the

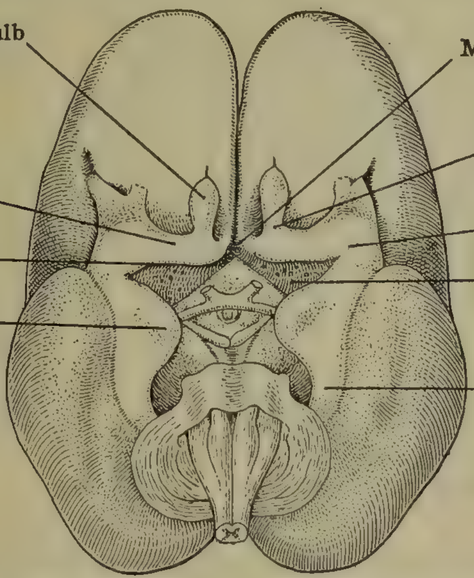


Fig. 758.—Brain of Human Fetus of 22.5 Cm. (Beginning of Fifth Month), showing the Parts of the Developing Rhinencephalon Apparent on the Basal Surface. (After Retzius.)

uncus in two branches, forming the medial **semilunar gyrus** and the lateral **gyrus ambiens** upon the uncus. A portion of the *limen insulæ* belongs to the rhinencephalon.

(4) The **parolfactory area** (Broca's area) (area adolfactoria NK) involves the mesial extension of the olfactory trigone, and is concerned with the *medial olfactory* stria. On the basal surface of the hemisphere this area involves the posterior extremity of the gyrus rectus—a portion of which is sometimes separated from the remainder of the gyrus by a ventral prolongation of the *anterior parolfactory sulcus* of the medial surface (figs. 757, 762). This prolongation when present has been called the **fissura serotina.** On the medial surface the parolfactory area appears as a definite gyrus. In front this is separated from the superior frontal gyrus by the *anterior parolfactory sulcus*, and from the subcallosal gyrus behind by the deeper *posterior parolfactory sulcus* (fig. 757). It is continuous above into the gyrus cinguli of the limbic lobe, a portion of the posterior division of the rhinencephalon.

A large portion of the fibers of the medial stria are lost in the parolfactory area, and are known to terminate about the cells there. This stria or root of the olfactory tract forms a slight ridge on the ventral surface of the area, which is frequently prominent enough to retain the name **medial olfactory gyrus** applied to it in the fetal brain (fig. 758).

(5) The **subcallosal gyrus** (peduncle of the corpus callosum) is the narrow fold of the pallium which lies between the posterior parolfactory sulcus and the rostral lamina and the ventral continuation of the latter into the lamina terminalis. It begins above, in part fused to the rostrum of the corpus callosum, and in part

continuous with the gyrus cinguli, and ventrally it goes over lateralward and posteriorly into that portion of the anterior perforated substance known as the *diagonal band* of Broca, and in this way it extends into the uncus. Medially, it approaches its fellow of the opposite side so closely that the groove separating the two is known as the *median subcallosal sulcus* of Retzius. Some fibers of the medial olfactory stria disappear in the substance of the subcallosal gyrus.

(6) The **anterior perforated substance** (area olfactoria NK) must be considered with the rhinencephalon, but, like the limen insula, it can only be considered as belonging in part to this division of the brain. It comprises the basal region between the optic chiasma and optic tract and the olfactory trigone. Usually the posterior parolfactory sulcus (*fissura prima* of the embryo) is sufficiently evident to separate it more or less distinctly from the latter. Its posterolateral area is occupied by the *diagonal band* of Broca. A few fibers from the medial stria are known to disappear within its depths, and, as mentioned above, many fibers from the lateral stria also pass into it. The intermediate *olfactory stria* is always much the weakest of the three striæ, and in many specimens is apparently absent. The fibers of this stria run almost straight backward and plunge directly into the anterior area of the anterior perforated substance, where some of them are known to terminate, while others continue into the uncus.

On embryological grounds, the subcallosal gyrus and the anterior perforated substance are classed with the posterior part of the 'olfactory' lobe or anterior division of the rhinencephalon. The olfactory bulb and tract arise as a hollow outgrowth from the lower and anterior part of the anterior of the three primary vesicles. It is a tubular structure at first, and in many of the mammals the cavity maintains throughout life as the *olfactory ventricle*. In man the cavity becomes occluded and the ependyma and gelatinous substance which line it become the gray core of the bulb and tract of the adult.

The gray cortical substance persists and develops chiefly in the bulb, and in fact produces it as such. It is much thicker on the inferior surface of the bulb than on the superior surface, and in section shows definite layers. From within outward, the principal of these layers are—(1) the layer of large cells whose shape suggests their name, *mitral cells;* (2) large dendrites of the mitral cells project toward the inferior surface of the bulb and there break up into numerous telodendria which copiously form synapses with like telodendria of the entering fibers of the olfactory nerve, thus forming rounded, much tangled glomeruli and the layer containing these, the *glomerular layer;* (3) the superficial layer, or *olfactory layer*, consists of the fibers of the olfactory nerve which form a dense interlacement with each other on the inferior surface of the bulb before they pass into its interior. The superior surface of the bulb becomes formed almost wholly of the fibers which arise as axones of the mitral cells and pass backward to form the olfactory tract, and thence to their localities of termination, chiefly by way of the three striæ. Along the dorsal, covered, aspect of the olfactory tract the gelatinous substance of the core may show through as a gray ridge.

The posterior division of the rhinencephalon or the so-called **limbic lobe** (a name introduced by Broca in 1878) takes part in both the medial and tentorial surfaces of the hemisphere (fig. 759). Seen from the medial surface, it forms an irregular elliptical figure which encloses the corpus callosum and the extremities of which approach each other at the anterior perforated substance, where they are continous with the structures of the anterior division of the rhinencephalon. The figure is bounded externally by the sulcus cinguli above, by the subparietal sulcus (postlimbic sulcus) and the anterior limb of the calcarine fissure behind, and by the collateral fissure below. These respectively separate it from the frontal, parietal, occipital, and temporal lobes. It comprises the following structures which are either wholly or in part devoted to the functions of the olfactory apparatus:—

1. Gyrus fornicatus
   - Part of gyrus cinguli and cingulum.
   - Isthmus of the gyrus fornicatus.
   - Hippocampus
     - hippocampal gyrus.
     - uncus.
     - dentate gyrus (fascia).
     - fimbria.
2. The medial and lateral longitudinal striæ upon the corpus callosum.
3. The fornix.
4. The mammillary body, the mammillothalamic fasciculus to the anterior nucleus of the thalamus and the mammillopeduncular fasciculus.
5. Part of anterior cerebral commissure.
6. Part of septum pellucidum.
7. Part of medullary stria of thalamus.
8. Most of habenular nucleus.

The **gyrus fornicatus** comprises the greater mass of the limbic lobe. As seen above, it is a term used to represent collectively a number of conjoined structures. Being an incomplete ellipse in form, its two ends are united to form a closed ring by means of the connection of the parolfactory area with the gyrus cinguli and the connection of the anterior perforated substance with the uncus of the hippocampal gyrus. It is best described in terms of its three component parts indicated above:

The **gyrus cinguli** begins in junction with the area parolfactoria below the anterior end of the corpus callosum, and curves above so as to embrace entirely the upper surface of the latter It is separated from the frontal lobe by the sulcus cinguli (callosomarginal fissure), from the parietal lobe by the subparietal sulcus, and from the corpus callosum below by the **sulcus of the corpus callosum.** By the latter it is separated from the longitudinal stria of the upper surface of the corpus callosum.

The gyrus cinguli covers over, and its cells are closely associated with, the **cingulum,** a well-marked arcuate band of white substance, which follows the gyrus in its bend around the rostrum and backward to turn around the splenium of the corpus callosum in the isthmus of the gyrus fornicatus, and then to course forward into the hippocampal gyrus and the uncus. The cingulum is largely an association fasciculus between the gyri of the temporal lobe and those gyri on the

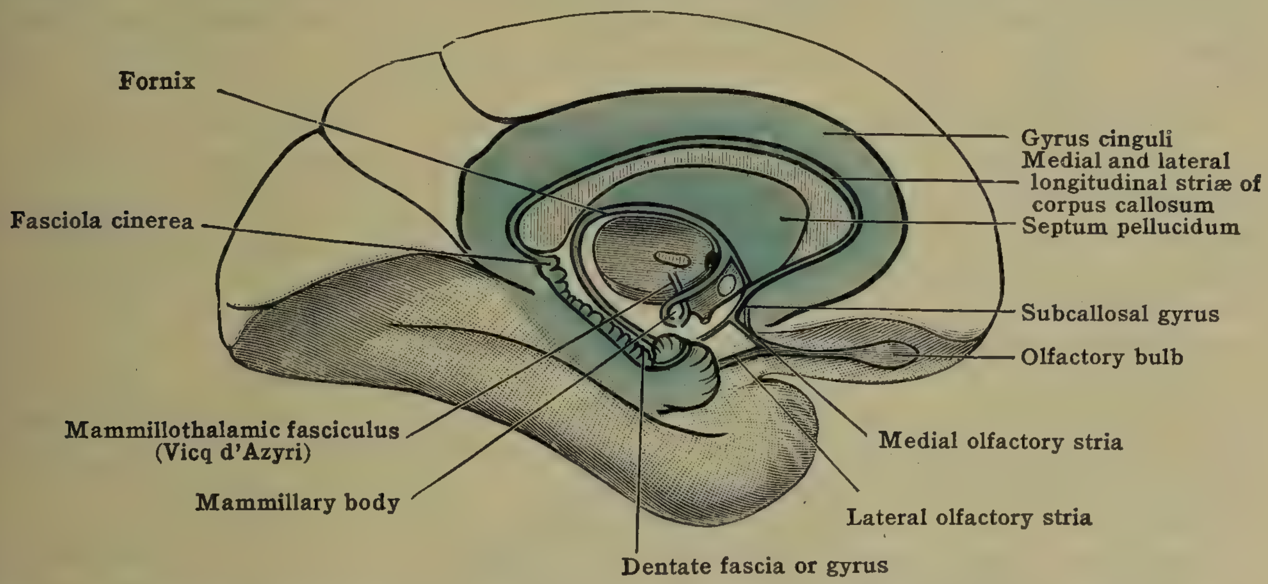


Fig. 759.—Diagram showing Position of Structures Comprising the Limbic Lobe as Seen from the Medial Aspect of the Cerebral Hemisphere.

medial surface of the cerebral hemisphere in which it runs, its fibers for the most part running short courses, being continually added to it and continually leaving it. However, it contains olfactory axones running in two directions: (1) fibers from the medial olfactory stria and fibers arising in the parolfactory area, the gyrus subcallosus and the anterior perforated substance which course posteriorly for distribution in the cortex of the gyrus cinguli and hippocampal gyrus; (2) fibers arising in the hippocampal gyrus, especially the uncus, to course dorsalward through the isthmus and forward as association fibers. Some fibers arising from the cortical cells of the gyrus cinguli pass inferiorly through the cingulum, through the corpus callosum and, anteriorly, through the septum pellucidum to join the fornix below (*perforating fibers of the fornix*).

The **isthmus of the gyrus fornicatus** is the constricted portion connecting the posterior end of the gyrus cinguli with that of the hippocampal gyrus (figs. 749, 754). It is bounded externally by the anterior end of the calcarine fissure, and incloses the posterior turn of the cingulum.

The **hippocampus** is the name applied to the curved appearances produced in the floor of the lateral ventricle by the peculiar foldings of this part of the cerebral cortex. The *hippocampal gyrus* (gyrus of the hippocampus) is the main gyrus of the tentorial surface of the limbic lobe. Externally it is separated from the fusiform gyrus by the collateral fissure, and it is bounded internally by the **hippocampal** or, more inclusive, the **choroid fissure.** Posteriorly it is partially divided by the calcarine fissure into the lingual gyrus (of the temporal lobe) and the isthmus of the gyrus fornicatus. Its anterior extremity is hooked backward and is known as the **uncus** (*gyrus uncinatus*). This is almost entirely separated from the temporal lobe by a groove, the **temporal notch.** If the hippocampal fissure be opened up, the **dentate gyrus** or fascia and the *fimbria* will be seen. These lie side by side, separated by the shallow **fimbriodentate sulcus** (fig. 766).

The free edge of the dentate gyrus presents a peculiarly notched appearance, produced by numerous parallel grooves cutting it transversely. Its posterior end, sometimes called the *fasciola cinerea*, continues backward over the splenium of the corpus callosum, and upon the upper surface of the corpus callosum appears as a thin strip of gray substance which contains embedded in it the ends of the *medial* and *lateral longitudinal striæ*. This strip is called the supracallosal gyrus (*gyrus epicallosus, induseum griseum*), and is thought to represent a vestigial part of the hippocampal gyrus. Closely beneath the splenium of the corpus callosum, on the superomedial side of the hippocampal gyrus and medial to the dentate gyrus, there sometimes occur suggestions of round or oval elevations of the gray substance which have been called the 'callosal convolutions' or *gyri Andreæ Retzii*. Rarely are they strongly developed, but when so they often produce a spiral appearance.

The **fimbria** is but the fimbriated, free border of the posterior end or origin of the fornix, so folded as to project into the hippocampal fissure, parallel with the dentate gyrus (fig. 766). It is a conspicuous band composed almost entirely of white substance, continuous laterally with the thick stratum covering the ventricular surface of the hippocampus. It begins anteriorly in the hook or recurved extremity of the uncus. Traced backward, it is seen to curve upward, and within the ventricle it becomes part of the general accumulation of the white substance (*alveus*) of the ventricular surface of the hippocampus, which accumulation is the beginning of the fornix. The free border of the fimbria (seen in section) is known as the *tenia fimbriæ*, or better, *tenia fornicis*. The fimbria is separated from the cerebral peduncles by the **choroid fissure,** the thin, non-nervous floor of which alone intervenes between the exterior of the brain and the cavity of the lateral ventricle within.

The hippocampal fissure attains its greatest depth between the dentate gyrus and the hippocampal gyrus, and the resulting eminence produced in the floor of the lateral ventricle is known as the **hippocampus major** (figs. 764, 765), as distinguished from the lesser eminence produced posteriorly by the end of the calcarine fissure and known as the *hippocampus minor* [calcar avis]. The collateral fissure may likewise produce a bulging in the wall of the ventricle, the *collateral eminence*. In transverse sections of the hippocampus major, the layers of gray and white substance present a coiled appearance known as the **cornu ammonis.** Externally the medial surface of the hippocampal gyrus adjoining the dentate gyrus has reflected over it a delicate reticular layer of white substance known as the *substantia reticularis alba* (*Arnoldi*).

The fornix (figs. 760–762) is the great association pathway of the limbic lobe, and appears to be wholly concerned in the apparatus of the rhinencephalon. It is a bilateral structure arched beneath the corpus callosum, with which it is connected anteriorly by the septum pellucidum. Posteriorly it passes in contact with the splenium. It consists of two prominent strips of white substance, one for each hemisphere, the ends of which are separate from each other, while their intermediate parts are fused across the midline. These fused parts run above the choroid tela of the third ventricle, and their lateral edges (*teniæ fornicis*) rest, on each side, along the line of the tenia chorioidea. The posterior, separate ends are known as the posterior pillars or crura of the fornix; the fused, intermediate portion is the body, and the separate, anterior ends are the anterior pillars or columns of the fornix.

The crura (posterior pillars) of the fornix.—When seen from the medial aspect of the hemisphere, the fused portion of the fornix, in the separation of the hemispheres, is split along the midline (fig. 749). The half under examination may be seen to course obliquely lateralward under the splenium of the corpus callosum, and then, continuous into the fimbria, to curve forward and ventralward toward the uncus. The greater mass of the fibers coursing in the fornix arise as outgrowths of the cells of the uncus, hippocampal gyrus, and dentate gyrus. They accumulate as a dense stratum on the ventricular surface of these gyri, termed the **alveus,** which crops outward as the fimbria and which passes backward and upward; upon reaching the region of the splenium it turns obliquely forward under the latter and approaches the midline, to fuse with the like bundle from the gyri of the hippocampus of the opposite side. The bundles thus arising from the two sides are the crura (posterior pillars) of the fornix. They appear as two flattened bands of white substance which come in close contact with and even adhere to the splenium.

The angle formed by the mutual approach of the crura of the fornix is crossed by a lamina of commissural fibers connecting the hippocampal gyri of the two hemispheres (fig. 761).

This lamina is the **hippocampal commissure** or *transverse fornix.* Like those of the fornix, its fibers arise from the cortex of the hippocampal gyri, but they serve as commissural fibers between the hippocampal gyri of the two hemispheres. Being of a different functional direction, it should not be considered a part of the fornix. The angle formed by the two crura of the fornix as traversed by the hippocampal commissure gives a picture named the **psalterium** or **lyra.** Usually the hippocampal commissure and the crura are in close contact with the under surface of the splenium. When occasionally they do not adhere, the space between is known as **Verga's ventricle.** According to recent studies of brains with degenerated corpus callosum (Shimazono), further commissural fibers between the limbic lobes course in the posterior angle of the septum pellucidum, transverse to the body of the fornix.

The body of the fornix [corpus fornicis] appears as a triangular plate of white substance produced by the fusion of the pillars. Its base or widest portion is behind. It is not always bilaterally symmetrical. Its upper surface is attached by the septum pellucidum to the lower surface of the corpus callosum. Below, it lies over the choroid tela of the third ventricle, which separates it medially from the cavity of the third ventricle and laterally from the upper surfaces of the thalami. Its sharp lateral edge or margin (tenia fornicis) projects into the lateral ventricle of either side in relation with the choroid plexus of that ventricle, and thus the lateral portion of its upper surface forms part of the floor of the lateral ventricle—an arrangement to be expected, since the crura arise from the floor of the ventricle, viz., the hippocampus. The ventricular portion is covered by a layer of ependyma in common with that lining the rest of the ventricle.

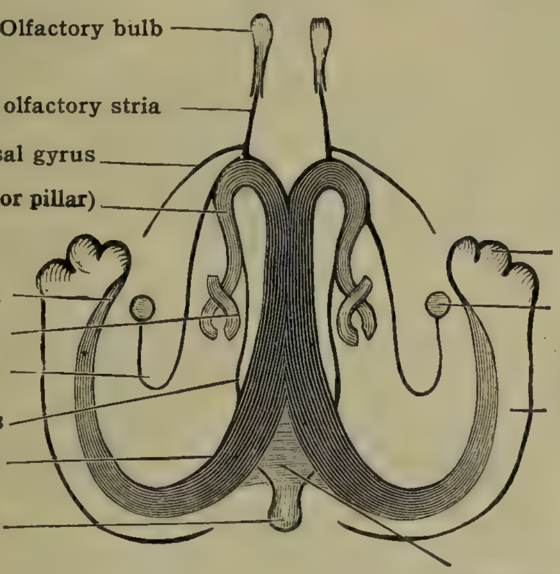


Fig. 760.—Diagram Showing Fornix and its Connections as Seen from Above.

Along its body the fornix receives fibers arising from the cells of the cortex of the gyrus cinguli and fibers from the longitudinal stria upon the dorsal surface of the corpus callosum. These pass through the latter and are the **perforating fibers of the fornix** (fig. 762). In their ventral course, they pass obliquely forward through the corpus callosum and, anteriorly, through the posterior angle of the septum pellucidum to join the fornix and course in its functional direction. The fibers arising in the cortex of the gyrus cinguli may course short distances in the cingulum before perforating the corpus callosum.

The columns (anterior pillars) of the fornix [columnæ fornicis] are two separate, cylindrical bundles which pass forward from the apex of the body of the fornix and then turn sharply downward along the anterior boundary of the third ventricle, just behind the anterior cerebral commissure. A part of each column, the *free porticn* [pars libera], forms the anterior boundary of the interventricular foramen (Monroi). Thence the *covered portion* [pars tecta] sinks into the gray substance of the lateral wall of the third ventricle, and passes downward to the base of the brain, where it appears on the exterior as the **mammillary body** [corpus mammillare] (fig. 749).

Some fornix fibers are interrupted in the nuclei of the mammillary body; probably most of them merely double back, forming the genu. From the mammillary body the fibers are disposed in at least three ways: (1) The greater part perhaps pass directly upward and are lost in the *anterior nucleus of the thalamus,* where they ramify freely and terminate about its cells. These fibers form the bundle known as the **mammillothalamic fasciculus,** or bundle of Vicq d'Azyr; (2) A portion of the fibers go to form a **mammillomesencephalic fasciculus** (*tegmentomammillary fasciculus, mammillopeduncular fasciculus*). This begins in the mammillary body and passes caudalward into the mesencephalon to terminate about cell-bodies in, or in the region of, the so-called *nucleus of the medial longitudinal fasciculus and posterior commissure.* Fibers given by these cell-bodies may convey impulses by way of the medial longitudinal fasciculus or the gen-

eral reticular formation to the nuclei in the mesencephalon, rhombencephalon and perhaps into the spinal cord. Some of this portion of the fibers from the mammillary body are said to pass caudalward through the mesencephalon without interruption there. (3) A portion of the fibers decussate in the superior parts of the mamillary bodies and are distributed to both the thalamus and the mesencephalon of the opposite side. This decussation is the **supramammillary commissure.**

As seen above, the fornix as a whole is composed of longitudinally directed fibers, some of which, however, cross the midline in the region of its body and course in the columns of the opposite side. For the greater part, its fibers rise from the cells of the hippocampal gyri, but it is known to contain some fibers which arise in the anterior perforated substance and subcallosal gyrus and course through the fornix to the hippocampal gyri.

The **medial and lateral longitudinal striæ** upon the corpus callosum consist of olfactory fibers coursing in both directions: (1) fibers arising in the parolfactory area, the subcallosal gyrus and the anterior perforated substance (diagonal band of Broca) course posteriorly and

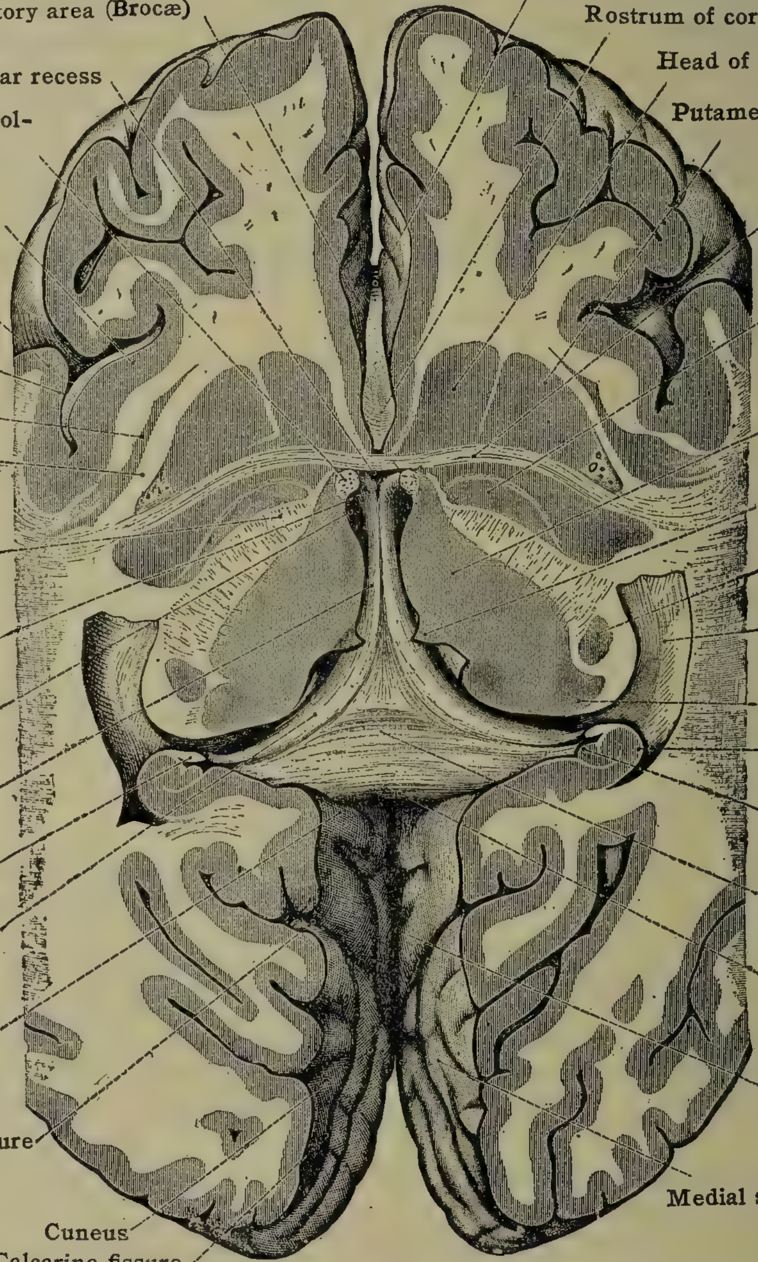


FIG. 761.—HORIZONTAL SECTION OF TELENCEPHALON SHOWING BODY OF FORNIX AND HIPPOCAMPAL COMMISSURE AS SEEN FROM BELOW AND THE ANTERIOR COMMISSURE, IN SECTION. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

then inferiorly in them to the gray substance of the gryi of the hippocampus; (2) and chiefly, fibers from the hippocampal gyri course in them anteriorly and inferiorly around the rostrum of the corpus callosum, through the ventral part of the septum pellucidum, to join the fornix. It is suggested that the stria, especially the medial, may be considered as a part of the fornix detached upon the dorsal surface of the corpus callosum during the projection of the latter between the cerebral hemispheres. The medial stria is often called the *stria Lancisii.* The two striæ are sometimes called the *dorsal fornix.*

The anterior cerebral commissure is largely concerned in the rhinencephalon; the remainder includes commissural fibers connecting the two temporal lobes. It forms one of the five commissures of the telencephalon, the other four being the corpus callosum, the hippocampal, inferior cerebral, and supramammillary commissures. It is a bundle of white substance with a slightly twisted appearance,

which crosses the midline in the anterior boundary of the third ventricle between the lamina teminalis and the columns of the fornix (figs. 749 and 761), just below the interventricular foramen (foramen of Monro). In each hemisphere its main or temporal portion passes lateralward and slightly backward beneath the head of the caudate nucleus and through the anterior end of the lenticular nucleus, and thence is dispersed to the gray substance of the temporal lobe and hippocampal gyrus.

It contains fibers both to and from the temporal lobe of each side. In addition to these fibers, the anterior commissure carries in its frontal side three sets of fibers belonging to the olfactory apparatus:—(1) fibers arising in the olfactory bulb of one side, which pass by way of the medial olfactory stria through it to the olfactory bulb of the opposite side; (2) fibers which pass through it from the medial stria (olfactory bulb) of one side to the uncus of the opposite side; (3) commissural fibers between the hippocampal cortex, especially the uncus, of the two sides.

The anterior commissure is a more primitive commissure than the corpus callosum, in that it is present in the lower forms when the latter is absent, and diminishes in relative size and importance as the corpus callosum appears and increases in size. In man the appearance of the anterior commissure precedes but little that of the corpus callosum. During the fifth month the lamina terminalis, which then alone unites the anterior ends of the two hemispheres, develops a thickening of its dorsal portion. In a part of this thickening, transverse fibers begin to appear and their increase in number results in the partial separation posteriorly of the part containing them from the rest of the lamina, and then follows the differentiation of this part into the anterior commissure. The remainder of the thickening of the lamina continues to increase in size with the increase of the hemispheres; its upper edge is directed posteriorly, and fibers begin to appear in it which arise in the cortex of one side and cross over to that of the other side. These fibers form the corpus callosum.

The corpus callosum, a growth of fibers in the upper, expanded portion of the lamina terminalis, thus bridges over a portion of the longitudinal fissure between the hemispheres. In the mean time, the *fornix* arises as two bundles of fibers, one from the hippocampus of each side. In the complex mechanics of the development of the cerebrum these two bundles approach each other under the corpus callosum, fuse for a certain distance, and together arch the cavity of the third ventricle and come to acquire their adult position. There results from these processes of growth a completely enclosed space, a portion of the longitudinal fissure, the roof of which is the corpus callosum, its floor, the body of the fornix, and its lateral walls, portions of the mesial surfaces of the two cerebral hemispheres. The lateral walls of this space do not thicken as do the other regions of the pallium, but remain thin and constitute the *septum pellucidum* of the adult, the space itself being the so-called *fifth ventricle* or cavity of the septum pellucidum.

The **septum pellucidum** is a thin, approximately triangular, vertically placed partition which separates the anterior portions of the two lateral ventricles from each other. Its widest portion lies in front, bounded by the genu and rostrum of the corpus callosum, the rostral lamina, and the anterior portion of the fornix, to all of which it is attached. Prolonged backward under the body of the corpus callosum, it narrows rapidly and terminates at the line of adherence between the posterior portion of the fornix and the splenium of the corpus callosum. It consists of two thin layers, the **laminæ of the septum pellucidum,** arrested developments of mesial portions of the cerebral pallium. The laminæ enclose a narrow median cavity known as the **fifth ventricle** [cavum septi pellucidi]. This cavity is of very variable size, is completely closed, and does not merit the term 'ventricle,' as applied to the other cavities of the brain, in that it has no communication with the ventricular system and has a different lining from the other ventricles.

Each lamina of the septum pellucidum consists of a layer of undeveloped gray substance next to the fifth ventricle and a layer of white substance next to the lateral ventricle, the latter covered by a layer of ependyma common to that ventricle. The white substance consists in part of fibers belonging to the general association systems of the hemispheres, and in part of four varieties of fibers concerned with the rhinencephalon:—(1) fibers from each medial olfactory stria are known to reach the septum pellucidum and thence go by way of the fornix to the hippocampus major; (2) fibers are thought to be contributed by the fornix to the septum pellucidum, and through it reach the subcallosal gyrus and perhaps the parolfactory area and even the olfactory bulb; (3) the posterior angle of the septum pellucidum is perforated by some commissural fibers passing from the body of the fornix and by some perforating fibers of the fornix, passing from above through it to the fornix below; (4) anteriorly, some fibers from the longitudinal stria upon the corpus callosum pass through its posterior portion to join the fornix.

The medullary stria of the thalamus [stria medullaris thalami] (*stria pinealis, tenia thalami, habenula*), already described as to position, receives fibers from three sources, the majority at least of which belong to the rhinencephalon: (1) fibers from the fornix nearby and thus from the cortex of the hippocampal gyrus and gyrus cinguli (a corticohabenular tract); (2) fibers from the parolfactory area and the anterior perforated substance, through the septum pellucidum and lamina terminalis (a more direct olfactohabenular tract); (3) fibers arising from the cell-bodies in the thalamus, supposedly chiefly from its anterior (olfactory) nucleus. These latter fibers make a thalamohabenular tract.

The majority of the fibers of the medullary stria terminate in the **habenular nuclei**, situated at the two sides of the stalk of the pineal body. Most terminate in the habenular nucleus of the same side. Some cross in the *habenular commissure* (dorsal part of the posterior cerebral commissure) and terminate in the nucleus of the opposite side. A few are claimed to pass to the nuclei of the quadrigeminate bodies and a few others to join the association tracts of the mesencephalon. Axones given off by the cells of the habenular nucleus curve anteriorly, inferiorly, and then course posteriorly (fasciculus retroflexus) to terminate in the *interpeduncular nucleus* (*habenulopeduncular tract*), and fibers arising in this latter nucleus pass to the cells about the central gray substance of the mesencephalon (an interpedunculotegmental tract). The two mesencephalic paths here noted and the mammillomesencephalic fasciculus noted above give three anatomical possibilities for olfactory reflex activities, visceral (or sympathetic) and somatic, involving the motor cranial nerves and possibly the spinal nerves. Fibers arising in the cortex of the hippocampal gyrus, uncus especially, may pass by way of the cingulum and thence by any suitable association fasciculus of the cerebral hemisphere to the motor area of the cerebral cortex; also fibers may arise from the anterior nucleus of the thalamus and pass to the motor cortex by way of the internal capsule. From the motor cortex, the descending pyramidal fibers give the possibilities for any higher cortical reactions induced by smell.

A more direct mesencephalic path has been suggested by Wallenberg, namely, that cells in the olfactory trigone and anterior perforated substance, about which terminate fibersaof the olfactory tract, send axones directly posteriorly, around the tuber cinereum, to termin te in the mammillary body and thence the impulses may go to the mesencephalon. Such fibers, if they exist, would form an *olfactomammillary tract*. A path is described in the hedge-hog

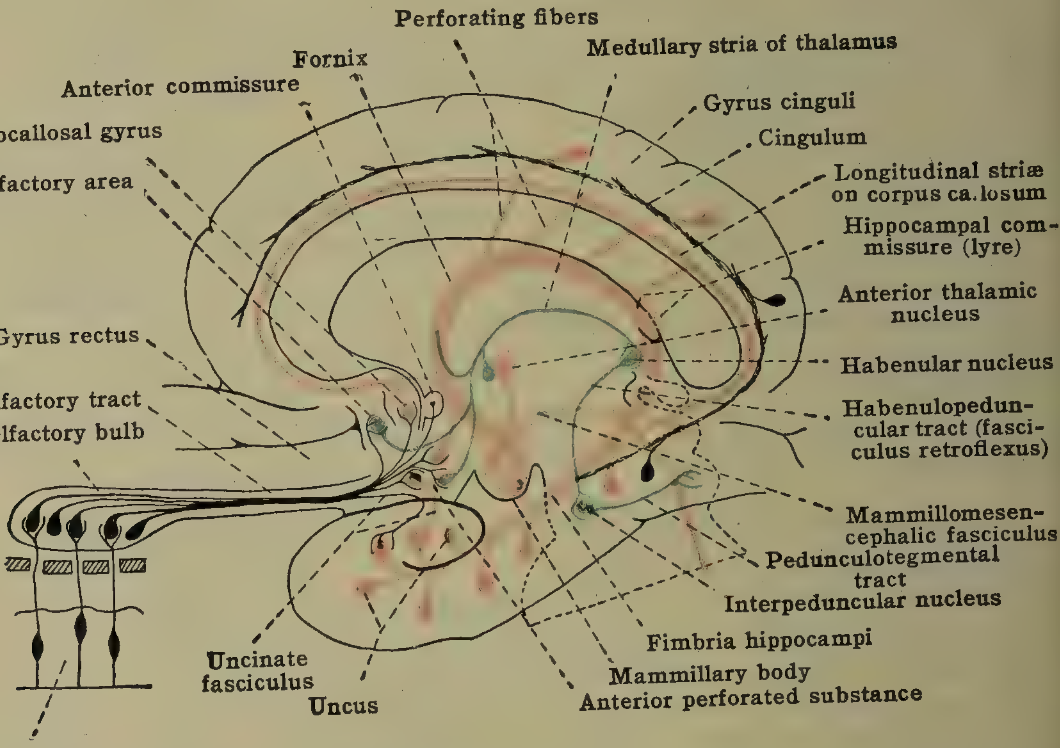


FIG. 762.—DIAGRAM SHOWING SOME OF THE PRINCIPAL TRACTS AND SYNAPSES OF THE OLFACTORY APPARATUS.

which arises from cells in the olfactory trigone and passes directly posteriorly to terminate in the gray substance of the mesencephalon—an *olfactomesencephalic tract*.

To the complicated central connections of the sense of smell, Dejerine adds yet another path, namely, a portion at least of the **terminal stria** [stria terminalis] of the thalamus. This contains fibers arising from cells in the anterior perforated substance and in the septum pellucidum and fibers from the opposite side by way of the anterior commissure. It runs a crescentic course posteriorly, bounding the thalamus from the caudate nucleus, turning downward and then anteriorly in the wall of the inferior cornu of the lateral ventricle to terminate in the amygdaloid nucleus, which latter is a more or less detached bit of the cortex of the extreme anterior portion of the hippocampal gyrus (uncus). The stria is said also to contain fibers which arise in the amygdaloid nucleus and course in it forward to be given off to the thalamus and probably to the internal capsule and thence to the cerebral cortex above. For a more detailed description of what may be called the fornix-system of fibers, the work of Shimazono may be consulted.

SUMMARY OF THE OLFACTORY APPARATUS

I. Peripheral part.

(1) Olfactory area of nasal epithelium containing the cell-bodies and peripheral processes of olfactory neurones (*olfactory ganglion*).

(2) Non-medullated central processes of olfactory neurones, the *olfactory nerve*, passing as numerous filaments through the cribriform plate of the ethmoid, to terminate in contact with the dendrites of the 'mitral cells' (stratum glomerulosum) in the olfactory bulb.

II. The rhinencephalon.

A. The anterior division.

(1) Olfactory bulb, olfactory tract, olfactory trigone (tubercle), lateral olfactory stria (gryus), medial and intermediate olfactory stria.

(2) The parolfactory area, subcallosal gyrus, anterior perforated substance including the diagonal band of Broca.

B. The posterior division.

(1) Part of anterior commissure, septum pellucidum, uncinate fasciculus, hippocampal gyrus (uncus especially), dentate gyrus, gyrus cinguli and cingulum.

(2) Fimbria, hippocampal commissure, fornix, longitudinal striæ upon corpus callosum, mammillary body, mammillothalamic fasciculus, mammillomesencephalic fasciculus.

(3) The anterior nucleus of the thalamus.

(4) The medullary stria of the thalamus, habenular nucleus, fasciculus retroflexus, interpeduncular nucleus, and interpedunculotegmental tract.

(5) Probably an olfactomammillary and an olfactomesencephalic tract, and a part of the terminal stria of the thalamus with the amygdaloid nucleus.

THE LATERAL VENTRICLES

Two of the four cavities of the ventricular system of the brain are in the telencephalon. From their position, one in each cerebral hemisphere, they are known as the **lateral ventricles** (figs. 763–766). They arise as lateral dilations of the cavity of the anterior of the primary vesicle, and, just as the fourth ventricle remains in communication with the third by way of the aqueduct of the cerebrum, so the lateral are connected with the third by the two interventricular foramina (Monroi). The whole ventricular system, including the central canal of the spinal

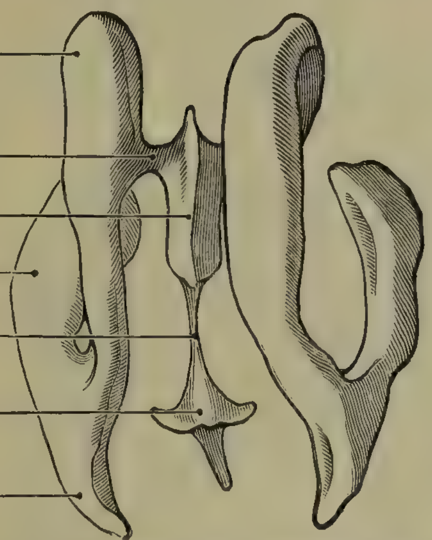


Fig. 763.—A Cast of the Four Ventricles of the Encephalon. (After Welcker.)

cord, is lined by a continuous layer of ependyma and contains a small quantity of liquid known as the cerebrospinal fluid.

Each lateral ventricle is of an irregular, horseshoe shape. It consists of a *central portion* or body and three cornua, which correspond to the three poles of the hemisphere. The portion projecting into the frontal lobe is known as the *anterior cornu*, that projecting into the occipital lobe is the *posterior cornu*, and the portion which sweeps anteriorly downward into the temporal lobe is the *inferior cornu*. The ventricles of different individuals vary considerably in capacity, and the cavity of a given ventricle is not uniform throughout. In some localities the space may be quite appreciable, while in other places the walls may be approximate or even in apposition. Each lateral ventricle is a completely closed cavity except at the interventricular foramen. However, a strip of the floor of the inferior cornu is separated from the exterior of the brain by only the thin, non-nervous lamina forming the floor of the choroid fissure.

The **interventricular foramen** (foramen of Monro), by which the lateral ventricle is continuous with the cavity of the third ventricle, is a small, roundish channel, 2 to 4 mm. wide, which opens into the mesial side of the posterior end of the anterior cornu. It is bounded in front by the free portion of the columns (anterior pillars) of the fornix, and behind by the anterior tubercle of the thalamus. That the greater part of the lateral ventricle is posterior to it is due to the backward extension of the hemispheres during their growth and elaboration. Through the two foramina indirectly, the cavities of the two lateral ventricles are in communication with each other by way of the cavity of the third ventricle.

The walls of the lateral ventricle.—The **anterior cornu** (recessus frontalis NK) is a bowl-like cavity, convex forward and extending downward and medialward into the frontal lobe. Above and anteriorly it is bounded by the lower surface of the corpus callosum and the radiations of its genu into the substance of the

frontal lobe. Its medial boundary is the septum pellucidum; the head of the caudate nucleus (part of the corpus striatum) gives it a bulging, inferolateral wall, and the remainder of its floor is formed by the white substance of the orbital part of the frontal lobe.

The **central portion** or body of the ventricle is more nearly horizontal. It lies within the parietal lobe and extends from the interventricular foramen to the level of the splenium of the corpus callosum. Its roof is formed by the inferior surface of the body of the corpus callosum, and its medial wall consists of the posterior part of the septum pellucidum, attaching the fornix to the lower surface of the corpus callosum. Like the anterior horn, it is given an oblique, inferolateral wall by the narrower, middle part of the caudate nucleus. Several structures contribute to its floor:—(1) the stria terminalis of the thalamus, a line of white substance conforming to the genu of the internal capsule within, and constituting the boundary between the caudate nucleus and the thalamus, and containing (2) the vena terminalis (vein of the corpus striatum); (3) the lamina affixa, a medial continuation of the stria terminalis upon the surface of (4) the lateral part of the thalamus; (5) the medial edge of the lamina affixa, the tenia chorioidea, and the choroid plexus continuing under (6) the edge (tenia) of the body and the beginning crura (posterior pillars) of the fornix (fig. 765).

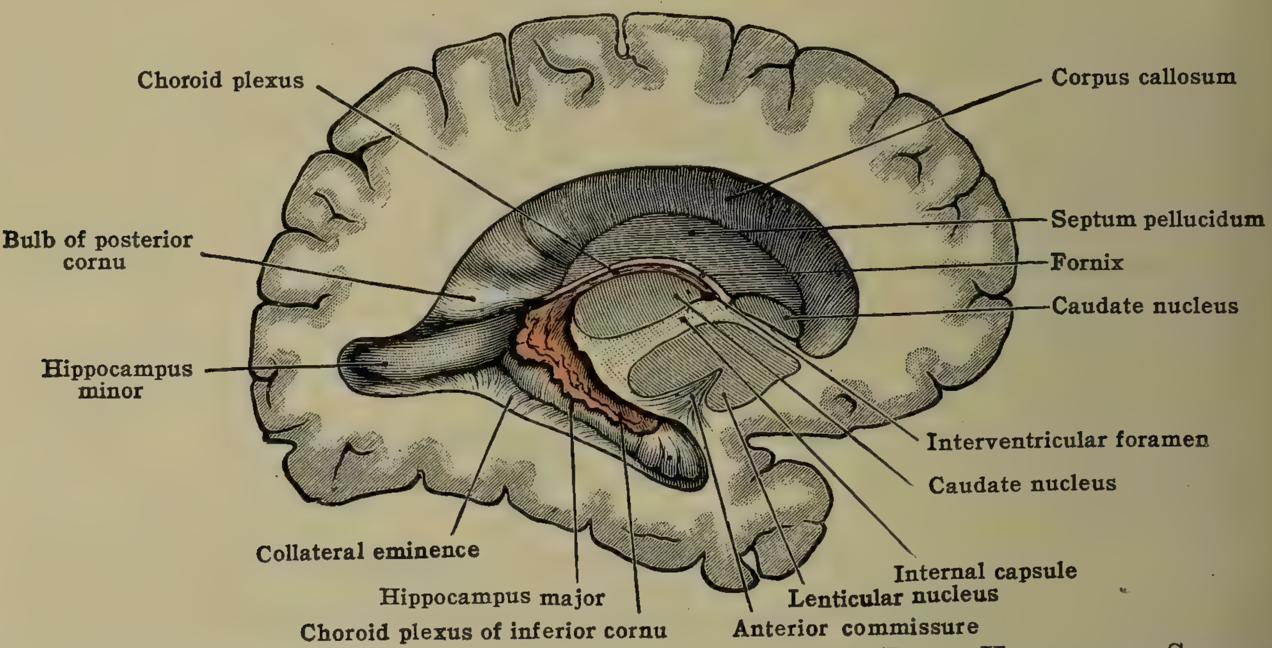


FIG. 764.—DIAGRAM OF LATERAL SAGITTAL SECTION THROUGH RIGHT HEMISPHERE SHOWING LATERAL VENTRICLE FROM THE MESIAL SIDE OF THE SECTION.

The choroid plexus of the lateral ventricles (figs. 765, 799) is continuous with that of the third ventricle. The choroid tela of the third ventricle (velum interpositum) continues under the tenia of the fornix into the lateral ventricle, and there, along the line of the tenia chorioidea, becomes elaborated into a varicose, convoluted, villus-like fringe, rich in venous capillaries and lymphatics. This fringe is the choroid plexus. It is continuous anteriorly, at the interventricular foramen, with the corresponding plexus of the opposite lateral ventricle and with the choroid plexus of the third ventricle. The latter consists of two similar but smaller fringes, which project close together into the cavity of the third ventricle from the medial portion of the ventral surface of its choroid tela. Behind, the choroid plexus of the lateral ventricle curves posteriorly and inferiorly into the inferior cornu, being especially well developed at the region of its entrance into the latter, into what is called the **choroid glomus.** It extends into neither posterior nor anterior cornu.

Though apparently lying free in the ventricle, the choroid plexus is invested throughout by a layer of ependyma, the **epithelial choroid lamina,** which is adapted to all its unevennesses of surface and which is a continuation of the ependymal lining of the remainder of the ventricle —continuous, on the one hand, with that of the lamina affixa and thalamus, and, on the other, with the epitheloid covering upon the upper surface of the tenia of the fornix and fimbria.

The **posterior cornu** (recessus occipitalis NK) of the lateral ventricle is a crescentic cleft of variable length, convex lateralward, which is carried backward from the posterior end of the body of the ventricle and, curving medialward, comes to a point in the occipital lobe. Its *roof* and *lateral wall* are formed by a

portion of the posterior radiation of the corpus callosum, which forms a layer, from its appearance known as the **tapetum.** In transverse sections of the occipital lobe (fig. 774) the tapetum appears as a thin lamina of obliquely cut white substance immediately bounding the cavity, while lateral to the tapetum occurs a thicker layer of more transversely cut fibers, the occipitothalamic radiation. In the medial or *inner wall* of the posterior cornu run two variable longitudinal eminences:—(1) The superior of these is the **bulb of the posterior cornu,** and is formed by the occipital portion of the radiation of the corpus callosum (splenium), which bends around the impression of the deep parieto-occipital fissure, and, hook-like, sweeps into the occipital lobe. In horizontal sections these fibers, together with the fibers of the splenium and the similar fibers into the opposite occipital lobe, form the figure known as the **forceps major.** (2) The inferior and thicker of the eminences is the **hippocampus minor** [**calcar avis**] (cock's spur),

Fig. 765.—Horizontal Dissection of the Cerebral Hemispheres.
The fornix has been removed to show the relation of the tela chorioidea of the third ventricle to the choroid plexus of the lateral ventricles. (From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

and it is due to the anterior part of the calcarine fissure, by which the wall of the hemisphere is projected into the ventricle. The posterior cornu, like the anterior, is not entered by the choroid plexus.

The inferior cornu (pars temporalis NK).—In its inferior and slightly lateral origin from the region of junction between the body of the ventricle and the posterior cornu, the inferior cornu aids in producing a somewhat triangular dilation of the cavity, known as the **collateral trigone.** Beginning as a part of the trigone, the cavity of this cornu at first passes posteriorly and lateralward, but then suddenly curves anteriorly and inferiorly into the medial part of the temporal lobe nearly parallel with the superior temporal sulcus. Above, it follows the curved crura (posterior pillars) of the fornix and fimbria; below, it does not extend to the temporal pole by from 2 to 3 cm. Its *roof* and *lateral wall* are, for the most part, like those of the posterior cornu, formed by the tapetum, but

medialward a strip of the roof is formed by the attenuated, inferior prolongation, or tail, of the caudate nucleus, together with the inferior extension of the stria terminalis of the thalamus.

At the end of the inferior cornu the roof shows a bulging, the **amygdaloid tubercle,** situated at the termination of the tail of the caudate nucleus. This bulging is produced by the *amygdaloid nucleus*, an accumulation of gray substance continuous with that of the cortex of the hippocampal gyrus, and which gives origin to part of the longitudinal fibers coursing in the stria terminalis of the thalamus.

In the *medial wall* and floor of the inferior cornu the following structures are shown:—(1) In the posterior or trigonal part of the floor is the longitudinal **collateral eminence,** a bulging, very variable in development in different specimens, produced by the collateral fissure. This is often pronouncedly in two parts, a posterior prominence corresponding to the middle portion of the collateral fissure and an anterior prominence (less frequent) produced by the anterior part of the fissure. (2) Medial to this eminence lies the inferior extension of the **choroid plexus,** usually more voluminous than the part in the body of the ventricle. (3) Partly covered by the choroid plexus is the **hippocampus major,** a prominent,

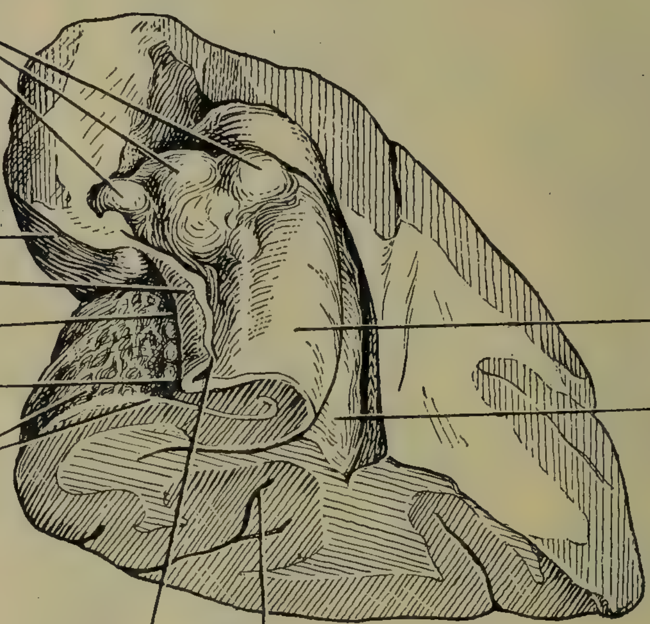


Fig. 766.—Dissection of Right Temporal Lobe Showing the Medial Wall of the End of the Inferior Horn of the Lateral Ventricle. (From Spalteholz.)

sickle-like ridge corresponding to the indentation of the hippocampal fissure. It begins as a narrow ridge posteriorly, at the end of the body of the ventricle, as the extension of the crus of the fornix, and expands anteriorly as the ventricular surface of the uncus. Its surface is not regular, but, shows a concave medial margin as distinguished from a wider, convex, lateral surface. Its termination in front (*pes hippocampi*) is divided by two or three flat, radial grooves into a corresponding number of short elevations known as the *hippocampal digitations*. It is covered by a thick stratum of white substance, the *alveus*, arising from its depths and continued mesially into the fimbria. (4) The **fimbria** is so folded that its margin, *tenia fimbriæ*, lies in the cavity of the inferior cornu attached to the choroid plexus and the thin, non-nervous floor of the choroid fissure.

The caudate nucleus (fig. 767).—As realized in the study of the lateral ventricle, the caudate nucleus is a comma-shaped mass of gray substance with a long, much-curved, and attenuated tail. Its *head* forms the bulging lateral wall of the anterior cornu; thence it proceeds posteriorly in the lateral wall of the body of the ventricle and, at the collateral trigone, curves downward and its *tail* becomes a medial portion of the roof of the inferior cornu. It is separated from the thalamus adjacent to it by the stria terminalis of the thalamus (tenia semicircularis). The end of its tail extends anteriorly below to the level of the anterior horn of the ventricle above. Owing to its much curved shape, both horizontal and coronal sections of the hemisphere passing through the inferior cornu may contain the nucleus cut at two places (figs. 768, 773).

The caudate nucleus is the intraventricular of the two masses of gray substance which together are sometimes referred to as the **basal ganglia.** The extraventricular of these masses is the *lenticular nucleus,* which is buried in the substance of the hemisphere, lateral and inferior to the caudate nucleus. The two masses are separated by the *internal capsule,* a thick band of nerve-fibers continuous into the cerebral peduncles, and connecting the gray cortex of the hemisphere with the structures inferior to it. Anteriorly and below, the two nuclei become continuous. The white substance of the internal capsule, in separating them posteriorly, contributes to their striated appearance in sections, known collectively as the *corpus striatum* (figs. 769–773). The corpus striatum as such is described below.

INTERNAL STRUCTURE OF THE PROSENCEPHALON

From the above examinations of their external and ventricular surfaces, it is apparent that the cerebral hemispheres consist of a folded, external mantle of gray substance, the cortex cerebri, spread more or less evenly over an internal mass of white substance which contains embedded within it certain masses of gray substance, the chief of which are known as the caudate and lenticular nuclei of the corpus striatum. In addition, the hemispheres of the telencephalon overlie and are in functional connection with the structures of the diencephalon below, the chief of which are the thalamencephalon and the bases of the cerebral peduncles.

The gray substance of the telencephalon.—The gray substance is in intimate relation with the white substance, and in fact its cells give origin to the greater part of the fibers composing the white substance. The accumulations of gray substance to be considered are the cerebral cortex, with its variations in thickness and arrangement, the corpus striatum, the claustrum, and the amygdaloid nucleus.

The cerebral cortex [substantia corticalis] is distributed over the entire surface of each hemisphere except the peduncular region of the base and the region of the corpus callosum and fornix of the medial surface. Numerous measurements have been made to determine its average thickness. These have shown that the mantle is not uniformly distributed:—(1) that it is thicker on the convex surface than on the basal and medial surfaces; (2) that on the convex surface it is thicker on the central region of the hemisphere, somesthetic area, than at the poles; (3) that in the average normal specimen it averages somewhat thicker on the left than on the right hemisphere; (4) that its average thickness varies greatly in different individuals, and that the thickness decreases with old age; (5) that it is probably somewhat thicker in males than in females, and (6) that in a given specimen it averages thicker on the summits of the gyri than in the floors of the corresponding sulci.

In the normal adult it averages about 4 mm. thick on the anterior and posterior central gyri, in the somesthetic area, while it attains its mimimum thickness of about 2.5 mm. on the basal surface of the occipital and frontal lobes. Its total average thickness is about 2.9 mm. The lamina of the septum pellucidum and the practically non-nervous floor of the third ventricle and that of the choroid fissure are very much thinner. The cortex of the (more ancient) rhinencephalon is termed the **archipallium;** while the remaining cortex of the telencephalon is the **neopallium.**

The cerebral cortex consists of layers of the cell-bodies of neurones, chiefly of the pyramidal type (fig. 684), which receive impulses from the structures below and from other regions of the cortex by way of fibers reaching them through the internal mass of white substance, and which in turn contribute fibers to the white substance. Certain fibers of shorter course and numerous collateral branches of fibers passing out of the cortex are devoted to the association of the region of their origin with the cortex of the immediate vicinity of their origin, and most of these course within the gray cortex itself. In certain gyri, such as the anterior central gyri and those of the medial surface of the occipital lobe, these short association fibers accumulate into strata, and in vertical sections give the cortex a stratified appearance. Two such strata of white substance may be noted in the above localities, one lying about midway in the thickness of the cortex and one slightly internal to this. They are known as the inner and outer **stripes of Baillarger.** In addition, a thin, superficial or *tangential layer* of fibers may often be distinguished lying in the surface of the cortex. Transverse sections through the anterior end of the hippocampus show a coiled arrangement of the layers of white substance, to which has been given the name *cornu ammonis.* The peculiar structure and appearance of the olfactory bulb and tract, parts of the cortex, have already been mentioned.

The corpus striatum is so called on account of the appearance in section of its component parts, the caudate and lenticular nuclei (basal ganglia) and the internal capsule between them. The two nuclei are directly continuous with each other at their anterior ends (fig. 767), and in addition they are connected by

numerous small bands of gray substance which pass from one to the other through the internal capsule, especially its anterior part. Also each nucleus contributes numerous fibers to, and receives fibers from, the internal capsule. These bundles of fibers both arising and terminating within the nuclei, together with the gray substance among the fibers of the capsule, produce the ribbed and striped appearance suggesting the name, corpus striatum. The **caudate nucleus**—the intraventricular part of the corpus striatum—lies with its thicker anterior part (head) closely related to the internal capsule, but its tail passes posteriorly around the posterior border of the capsule and curves downward and anteriorly into the roof of the inferior cornu of the lateral ventricle.

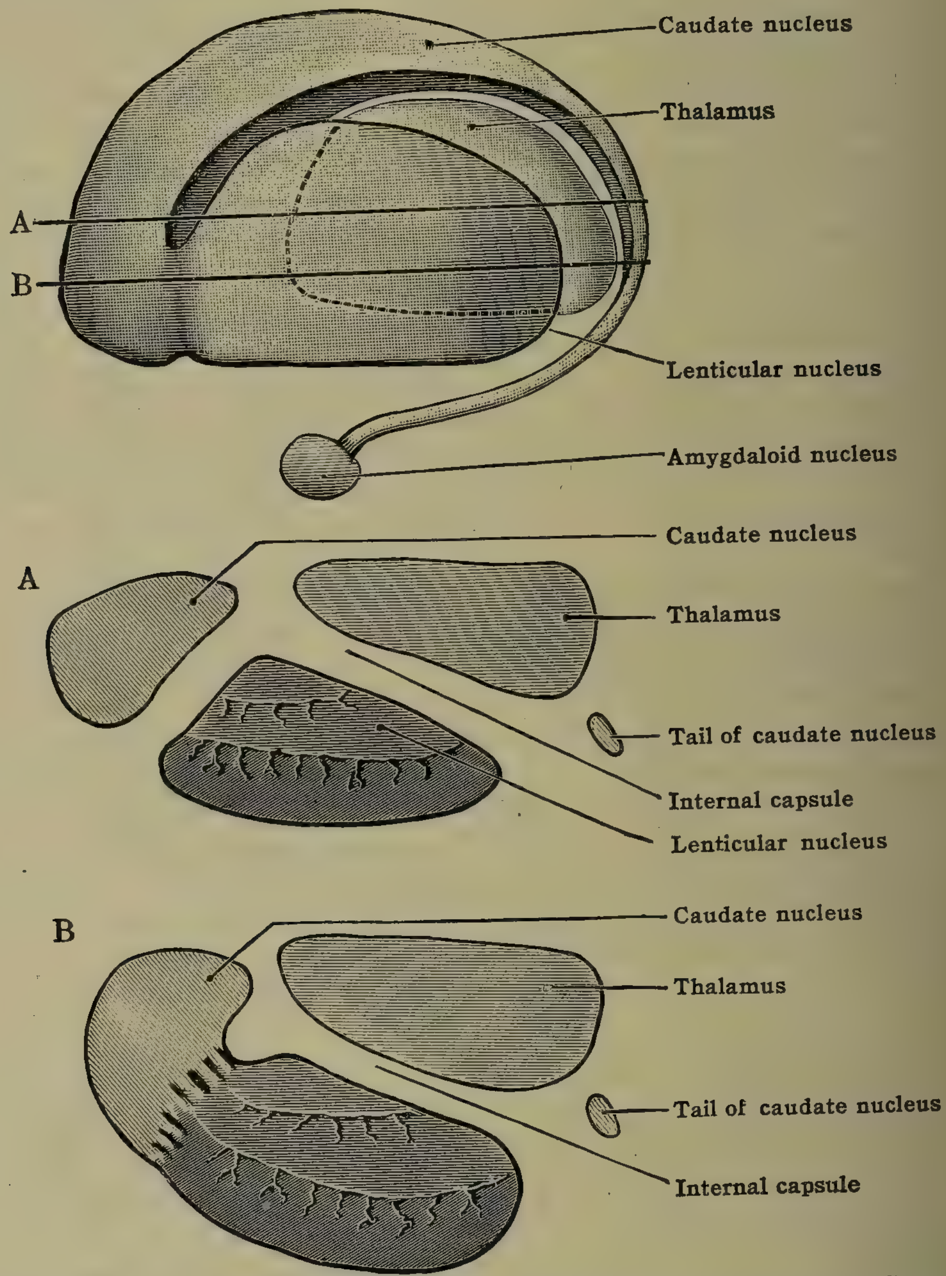


Fig. 767.—Diagrams of Lateral View and Horizontal Sections of the Corpus Striatum and Thalamus With Position of the Internal Capsule.

A and B below represent horizontal sections along the lines A and B in the figure above. The figure also shows the relative position of the thalamus and the amygdaloid nucleus.

The lenticular nucleus [nucleus lentiformis]—the extraventricular part of the corpus striatum—is embedded in the white substance of the cerebral hemisphere. It is somewhat pyriform in shape, not being so long as the caudate nucleus, and neither having a tail nor extending so far anteriorly. Its lower surface is separated from the inferior cornu of the lateral ventricle by the white substance of the roof of that cornu and by the tail of the caudate nucleus, and, further forward, the anterior commissure passes through its base. Its lateral surface is rounded and conforms both in extent and curvature with the surface of the insula, from which it is separated by the fibers of the external capsule and the intervening claustrum. Its oblique superior and medial surface is adapted to the lateral surface of the internal capsule, and it comes to a rounded apex in the angle formed by the internal capsule and a plane parallel with the base of the hemisphere. In both horizontal and coronal (transverse) sections through its middle

it resembles a compound biconvex lens. Internally this appearance is produced by two vertically curving lamina of white substance, an **external** and an **internal medullary lamina**, which divide its substance into three zones:—the two medial zones together form an area, triangular in section, known as the **globus pallidus** (pars pallida NK); the lateral, larger and more gray, concavoconvex zone is the **putamen** (figs. 769, 770). Radiating fibers from the medullary lamina extend into the zones, especially those of the globus pallidus, rendering it a paler gray. These zones disappear in transverse sections of the anterior portion of the lenticular nucleus on account of the fact that the larger putamen alone comprises this portion and alone becomes continuous with the caudate nucleus. (See figs. 767, 771.)

Phylogenetically, the globus pallidus, the most primitive portion of the striate body, is referred to as the *paleostriatum*, with the hypothalamic nucleus and substantia nigra sometimes included in the term. In contrast, the name, *neostriatum*, is used for the putamen and the caudate nucleus. The latter two nuclei are really but a single mass of gray substance separated largely and imperfectly by the invasion of the internal capsule. They increase progressively as the mammalian scale is ascended, reaching their greatest relative size in the primates.

Connections.—Both nuclei of the corpus striatum become continuous with the cortex in the region of the anterior perforated substance, and the putamen of the lenticular nucleus may blend with the anterior part of the base of the claustrum. The following are the principal fiber connections:—(1) Fibers arising in the nuclei which join the internal capsule to reach the cerebral cortex, and fibers arising in the cortex which descend by the same course to the cells of the nuclei. (2) Fibers which pass in both directions between the thalamus and the corpus striatum (caudate nucleus especially). These are more abundant anteriorly, and necessarily pass in the internal capsule. (3) The **ansa lenticularis**, or striosubthalamic radiation, a usually distinct lamina, composed largely of fibers passing inferiorly between the thalamus and lenticular nucleus. It passes from the basal aspect of the anterior tubercle and middle nuclei of the thalamus and curves below through the internal capsule to the basal surface of the lenticular nucleus, and there its fibers are distributed upward through its medullary lamina to the globus pallidus and putamen. Some enter the internal capsule and reach the cortex, chiefly that of the temporal lobe. The ansa lenticularis also contains fibers from the cortex of the temporal lobe to terminate in the inferior and medial parts of the thalamus. The fibers associating the thalamus with the temporal lobe belong to the so-called *inferior peduncle of the thalamus.* (4) Fibers connecting both nuclei (chiefly the lenticular) with the red nucleus and substantia nigra of the mesencephalon. These pass through the hypothalamic region and along the cerebral peduncle.

No definitely localized functions have been with certainty ascribed to either nucleus of the corpus striatum. They serve as relays in the pathways associating the cortical gray substance with the structures below. It is held that some of the descending motor fibers arising from the cells of the cortex give off collaterals, in passing, to the cells of the nuclei and these give fibers which join the internal capsule and cerebral peduncles, increasing the number of fibers bearing impulses from the cortex to the mesencephalon, rhombencephalon and spinal cord. This would make the functions of the nuclei subsidiary to those of the cerebral cortex. In lower vertebrates, the corpus striatum is an important reflex center. It has been established that fibers from the globus pallidus exert control over skeletal muscular activity (S. A. K. Wilson), via the red nucleus (striorubral tract). More recently considerable interest has been directed toward the entire striate body. Research as to the possible extent of striate associations has been done with the hope to obtain anatomical explanations for certain long known and very pronounced nervous symptoms. The investigations have resulted in the fairly well supported assumption of a structural complex referred to as the extrapyramidal system, discussed below (fig. 776).

The claustrum is a triangular plate of gray substance which is embedded in the white substance between the lenticular nucleus and the cortex of the insula. Its medial surface is concave, conforming to the convexity of the putamen. The sheet of white substance intervening between it and the putamen is known as the **external capsule** (pars lateralis of the capsula nuclei lentiformis NK).

The lateral surface of the claustrum shows ridges in section which conform to the neighboring gyri of the insula, and it is spread through a region which quite closely coincides with the area of the insula. Below and anteriorly it becomes continuous with the cortex of the anterior perforated substance and with the lenticular nucleus at the region of the junction of these. Above and posteriorly it gradually becomes thinner, and finally disappears in the white substance about it. In origin it is thought to be a detached portion of the cortical gray substance of the insua.

The amygdaloid nucleus [nucleus amygdalæ] is represented by the amygdaloid tubercle, which has already been described in the extremity of the inferior cornu of the lateral ventricle (fig. 767). It is an almond-shaped mass of cells joined to the tail of the caudate nucleus, continuous above with the putamen and anteriorly continuous with the cortex of the hippocampal gyrus.

The chief connections of the amygdaloid nucleus by way of the *stria terminalis of the thalamus* are noted above under the description of the posterior division of the rhinencephalon. The

amygdaloid nucleus, like the claustrum, is thought to represent a detached portion of the cortex, it being detached from the uncus. Considering this and its chief connections, it, with the stria terminalis of the thalamus, are concerned in the central portion of the olfactory apparatus.

The thalamus and hypothalamus.—The external features of these portions of the prosencephalon have been described previously, but inasmuch as they contain the chief relays between the telencephalon and the divisions of the nervous system caudal to the prosencephalon, the consideration of their internal structure has been deferred until now. The principal gray masses to be considered are the thalamus and the hypothalamic nucleus. The structures comprising the metathalamus and epithalamus have already been mentioned in their relations with the mesencephalon and the optic and auditory apparatus.

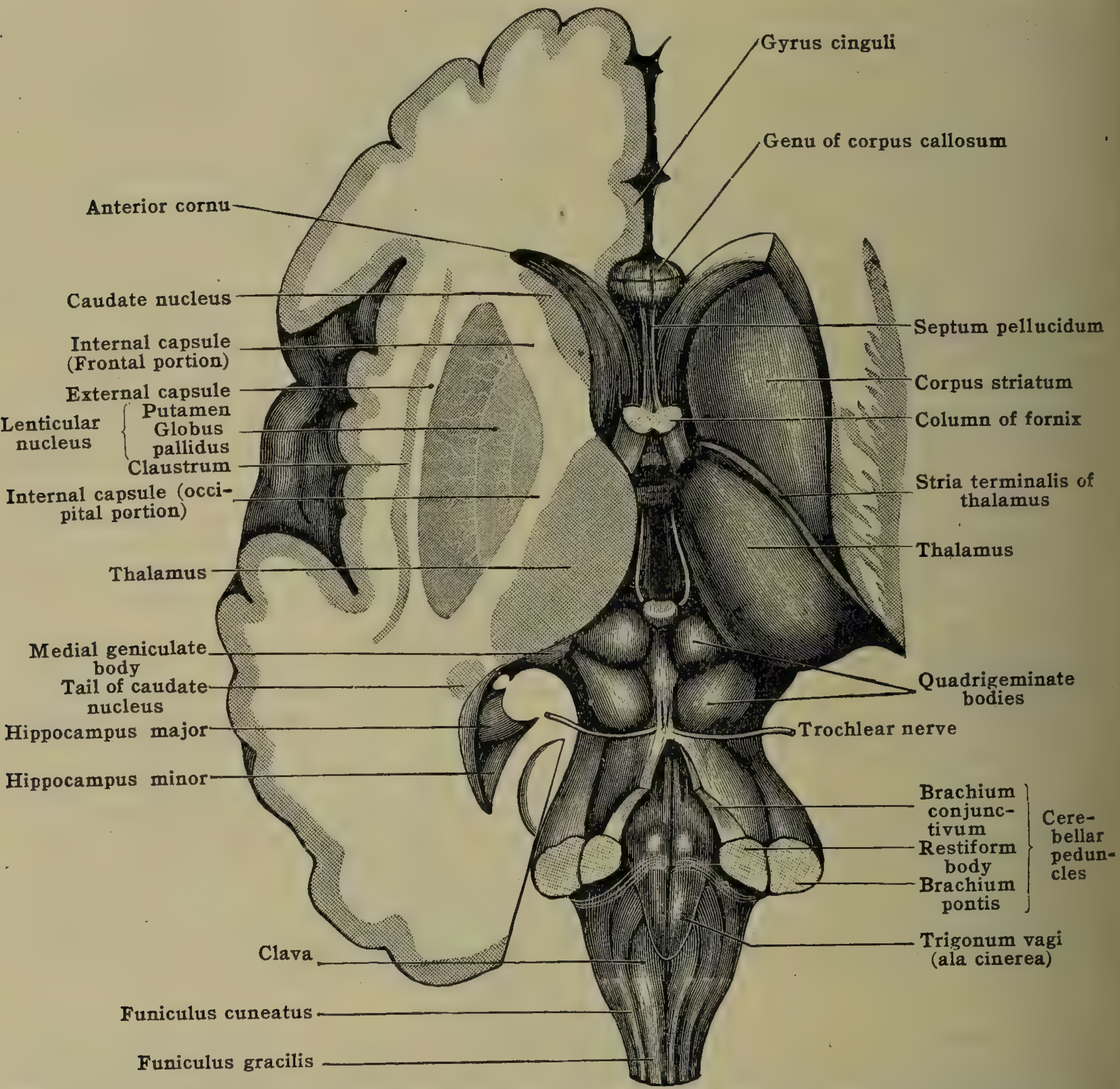


FIG. 768.—HORIZONTAL DISSECTION SHOWING THE GRAY AND WHITE SUBSTANCE OF THE TELENCEPHALON BELOW THE CORPUS CALLOSUM AND THE RELATIVE POSITION OF THE THALAMENCEPHALON. (After Landois and Stirling.)

The thalamus has upon its upper surface, under its ependyma, a thin **stratum zonale** of white substance, derived in part from the incoming fibers but chiefly from its own cells. Its oblique lateral surface conforms to the medial surface of the internal capsule; its vertical medial surface forms the lateral wall of the third ventricle, and below it is continuous into the hypothalamic (tegmental) region and the hypothalamic nucleus. Its upper surface shows a middle, an anterior, and a posterior prominence or tubercle. The **anterior tubercle** (nucleus) forms the posterior boundary of the interventricular foramen; the posterior tubercle is the cushion-like **pulvinar** which projects backward over the lateral geniculate body and the brachium of the superior quadrigeminate body.

A horizontal section through the superomedial edge, splitting the stria medullaris of the thalamus and thus passing above the massa intermedia, shows the gray mass of the thalamus divided into segments or nuclei by a more or less distinct

internal medullary lamina. This extends the whole length of the thalamus, dividing its middle and posterior portion into the **medial** and the **lateral nucleus.** Anteriorly the lamina bifurcates into a medial limb, extending to the medial surface of the thalamus, and a lateral limb, extending forward to join the genu of the internal capsule (figs. 770, 771). This bifurcation results in a cup-like sheet of white substance which encloses the **anterior nucleus.** On the lateral surface of the section, next to the internal capsule, usually there may be distinguished an **external medullary lamina,** separated from the white substance of the capsule by a *reticular layer* of mixed white and gray substance.

The anterior nucleus, lying partially encapsulated in the bifurcation of the internal medullary lamina, is somewhat wedge-shaped and points backward between the anterior portions of the lateral and medial nuclci.

It is composed chiefly of large cells, and constitutes the anterior tubercle of the superior aspect. Its principal connection from below is with the nuclei of the mammillary body of the same and opposite sides, and chiefly with uninterrupted fibers derived from the fornix. The fibers from both sources enter it by way of the *mammillothalamic fasciculus* (figs. 749 and 770). The significance of this connection is mentioned in the description of the limbic lobe.

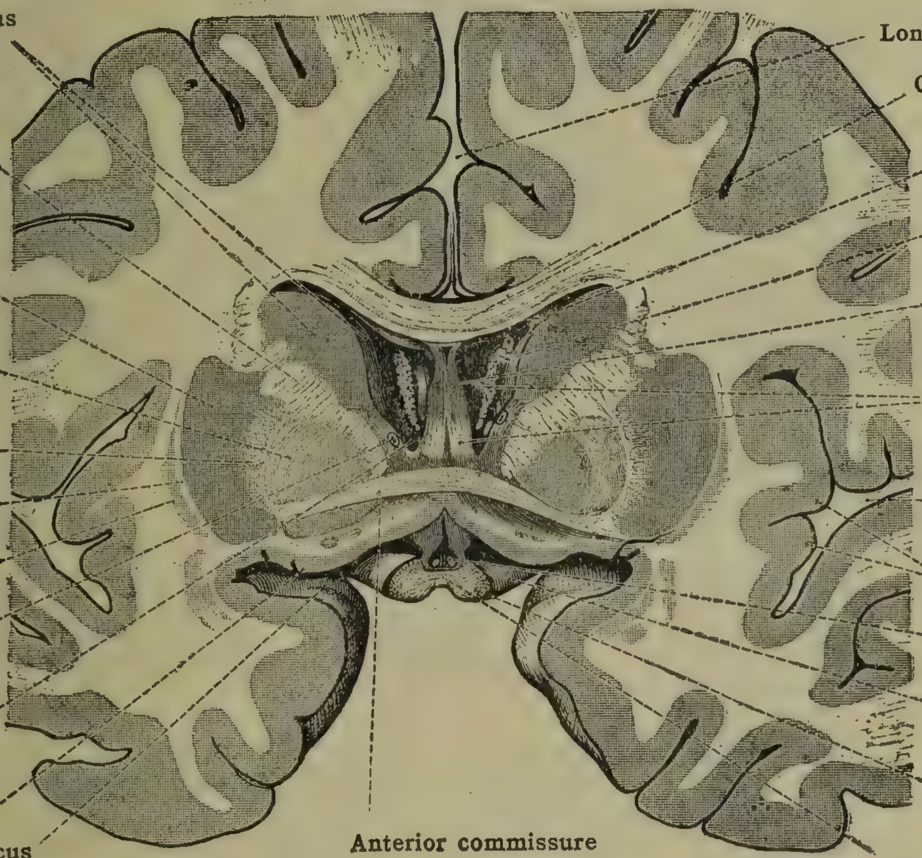


FIG. 769.—CORONAL SECTION OF TELENCEPHALON THROUGH THE ANTERIOR COMMISSURE, OPTIC CHIASMA AND BODY OF CORPUS CALLOSUM. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The lateral nucleus, lying between the external and internal medullary laminæ, extends posteriorly to include the **pulvinar,** which latter, however, is often called the posterior nucleus of the thalamus.

The neurones of the anterior portion of the lateral nucleus (lateral nucleus proper), together with the entire inferolateral gray substance of the thalamus, receive the terminations of the spinal, medial and trigeminal lemnisci and thus serve as the third links in the neurone chains bearing sensory impulses from the general body to the cerebral cortex. The lateral nucleus also especially receives fibers inferiorly from the red nucleus and from the brachium conjunctivum direct. The pulvinar, as already noted, together with the lateral geniculate body, constitutes the prosencephalic nucleus of termination of the optic tract, and the stratum zonale upon the surface of this nucleus might be called its stratum opticum.

The medial nucleus lies medial to the internal medullary lamina and forms the posterior portion of the lateral wall of the third ventricle (fig. 771). It is shorter than the lateral nucleus, and is less extensively pervaded by fibers.

Its inferior part is thought to receive fibers from the three lemnisci, trigeminal especially, and to send fibers to the cortex. Its dorsal part receives fibers from the olfactory areas of the cortex and contributes fibers to the medullary stria of the thalamus and probably some to the cortex. It is usually continuous across the third ventricle with the opposite medial nucleus by the massa intermedia.

In comparative anatomy, the nuclei of the thalamus have been variously subdivided by the different investigators. All the nuclei are connected with the lenticular nucleus by fibers passing between the two through the internal capsule directly, and by fibers curving from below, chiefly from the anterior, lateral and medial nuclei, and passing in the ansa lenticularis.

The cortical connections of the thalamus are abundant. They consist of fibers both to and from the cortex of the different lobes of the hemisphere, the greater part arising in the thalamus and terminating in the cortex. These fibers collect in the internal and external medullary lamina and the stratum zonale; most of them enter the internal capsule and thence radiate to the different parts of the cortex. Carrying sensory impulses to the cortex received from sensory neurones below, these thalamocortical fibers are the *sensory projection fibers* of the brain.

They form the so-called peduncles of the thalamus, which have been distinguished both by the Flechsig method of investigation, by the degeneration method and by direct dissection. The anterior or **frontal peduncle** passes from the lateral and anterior part of the thalamus through the frontal portion of the internal capsule, and radiates to the cortex of the

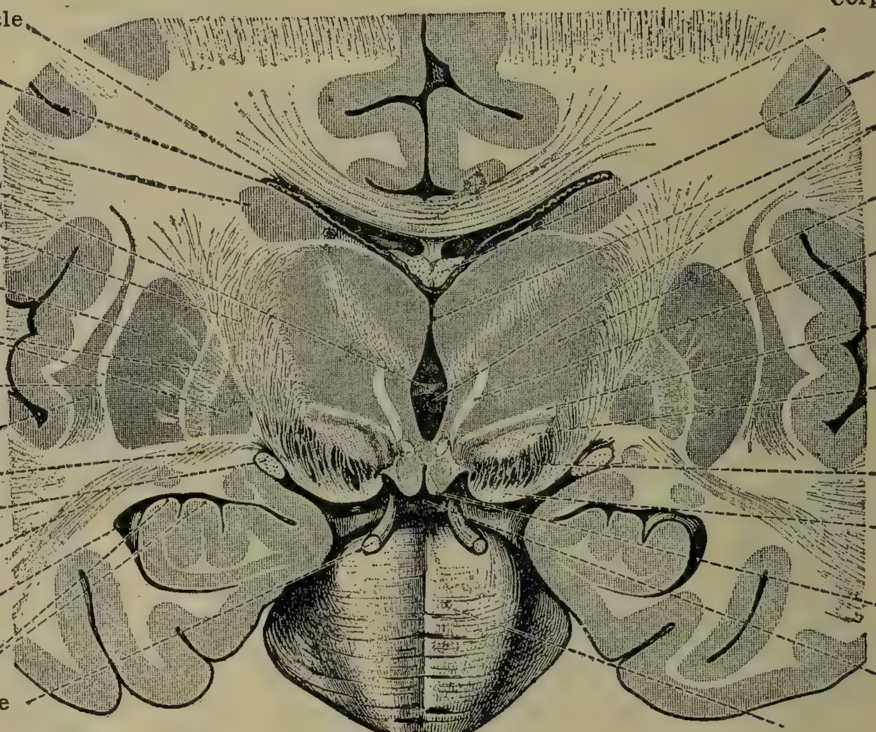


Fig. 770.—Coronal Section of Prosencephalon through Thalamencephalon at Region of Corpora Mammillaria. (Seen from in front.) (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

frontal lobe (fig. 775). The middle or **parietal peduncle** passes from the lateral surface of the thalamus through the intermediate part of the internal capsule, and upward to the cortex of the parietal lobe. The posterior or **occipital peduncle** passes chiefly from the pulvinar, through the occipital portion of the internal capsule, and radiates backward to the occipital lobe by way of the occipitothalamic (optic) radiation (fig. 774). The **inferior peduncle** passes from the medial and basal surface of the thalamus (from the anterior and medial nuclei chiefly), turns outward to course beneath the lenticular nucleus, and radiates to the cortex of the temporal lobe and insula. The fibers of this peduncle course chiefly in the ansa lenticularis (fig. 770). Some turn upward in the external capsule to reach the cortex above the insula; others pass upward through the medullary laminæ of the lenticular nucleus.

The nuclei of the thalamus without doubt serve chiefly as relays in the sensory paths, both general and special, from the periphery of the body to the cerebral cortex. By the several terminal branches of each of the ascending visiting fibers making synapses with the thalamic neurones, the sensory impulses are not only reinforced by the transfer but also the number of neurones bearing them to the cortex is increased in the thalamus.

From the viewpoint of comparative anatomy, the larger, lateral portion of the thalamus, or *neothalamus*, including the pulvinar and the lateral and medial geniculate bodies (detached portions of the thalamus), is considered especially concerned in such relays. In the lower forms, having little or no cerebral cortex, the medial portion of the thalamus persists and serves for the mediation of primitive reflex activities. In man, clinical evidence collected by Head and Holmes and others seem to suggest that some of these primitive reflex functions may be retained in the medial portion; but further, the interesting inference is possible that some activities usually classed as conscious may be mediated by the thalamus, the cerebral cortex not being essential for them. In other words, the thalamus divorced from the cerebral cortex by destructive lesions, seems able to mediate activities in response to sensations of pleasure and pain. The participation of the cerebral cortex, however, seems especially necessary for all analytical, or so-called intellectual and voluntary activities. Such functions of the thalamus give the thalamospinal fasciculus greater functional significance than is usually attributed to it.

The hypothalamic nucleus (body of Luys, subthalamus) (fig. 770) is a biconvex plate of gray substance situated on the basal aspect of the lateral and anterior nuclei of the thalamus, and between these and the basis of the cerebral peduncle. It is the anterior continuation of the substantia nigra, which is spread upon the dorsal surface of the peduncle, and which, though greatly diminished, extends into the hypothalamic region. It is referred to as the hypothalamic nucleus as far

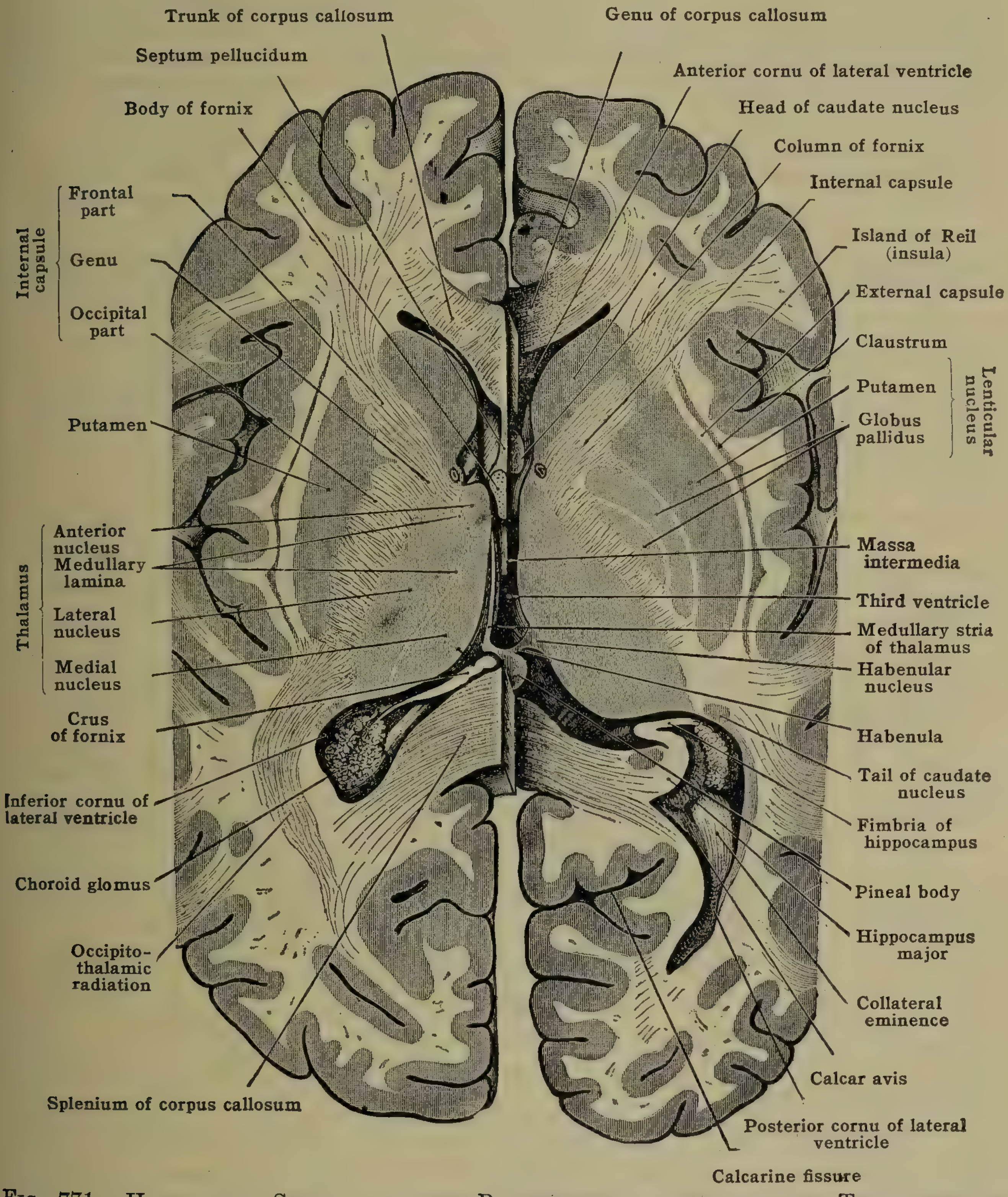


FIG. 771.—HORIZONTAL SECTIONS OF THE PROSENCEPHALON THROUGH THE THALAMUS AND CORPUS STRIATUM.

The plane of the section of the left hemisphere splits the medullary stria of the thalamus about 15 mm. above the plane through which the right hemisphere is cut. (After Toldt.)

posteriorly as the posterior commissure. It presents a brownish-pink color in fresh material, due to pigment in its cells and to its abundant blood-capillaries.

It is enclosed by a thin capsule of white substance, some of the fibers of which seem to decussate with those of the opposite side in the floor of the third ventricle, above and just behind the region of the corpora mammillaria. It is said to receive fibers descending from the cortex and fibers from the thalamus and nuclei of the corpus striatum. Most of the fibers arising from it join the cerebral peduncle. Such relations would suggest that the hypothalamic nucleus serves as a relay in certain paths from the cortex and striate body to the structures below. On the other hand, formerly it was considered the chief nucleus of termination of the medial lemniscus.

The *habenular nucleus* and the *fasciculus retroflexus* of Meynert have been noted in the description of the rhinencephalon. The **habenular nucleus**, a part of the epithalamus, is a small group of nerve cells situated in the habenular trigone just inferolateral to the pineal body. Some fibers of the medullary stria of the thalamus (habenula) terminate about its cells. A small bundle of fibers crossing the midline under the pineal body in the superior aspect of the posterior cerebral commissure is called the *commissure of the habenulæ*, from the fact that it contains fibers correlating the habenular nuclei of the two sides.

The **fasciculus retroflexus (Meynerti)** (tractus habenulopeduncularis) is a relatively strong bundle of fibers which runs downward and then turns caudalward from the habenular nucleus toward the inferior portion of the interpeduncular fossa. It has been shown that many, at least, of the fibers of this bundle arise from the cells of the habenular nucleus. In its slightly caudal course, the bundle passes obliquely through the red nucleus, entering the medial superior aspect and makes its exit from the medial side of the inferior extremity of this nucleus. In the

Fig. 772.—Oblique Frontal Section through the Brain in the Direction of the Cerebral Peduncles and the Pyramids. (Seen from in front.) (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

animals in which it has been studied, the bundle ends in the *interpeduncular nucleus* (ganglion), a group of nerve cells lying in the floor of the interpeduncular fossa at the level of the inferior quadrigemina. In man, the interpeduncular nucleus is not definitely assembled and the bundle seems to disappear in the posterior perforated substance. However, the microscope shows cells dispersed among the fibers of the bundle and these cells probably represent the nucleus. Impulses borne by the fasciculus are presumably transmitted to the cranial and spinal nerves.

The white substance of the telencephalon.—A horizontal section through the upper part of the body of the corpus callosum will pass above the basal gray substance of the corpus striatum, and, aided by the corpus callosum, each hemisphere in such a section will appear as if consisting of a solid, half-oval mass of white substance, bounded without by the gray layer of the cortex (fig. 750). As seen at this level, the white substance of each hemisphere is known as the **centrum semiovale.** Horizontal sections passing below the body of the corpus callosum involve the corpus striatum and thalamus, and the appearance of the white substance is modified accordingly (fig. 768).

In the white substance of the cerebral hemispheres as a whole three main systems of fibers are recognized:—projection fibers, commissural fibers, and association fibers. The *projection fibers* are those of a more or less vertical course, which pass to and from the cortex of the hemisphere, associating it with the structures below the cortex and the confines of the hemisphere. The *commissural fibers* are those of a transverse or horizontal course, which cross the midline and functionally correlate the two hemispheres with each other. The *association fibers* are those which neither cross the midline nor pass beyond the bounds of the hemisphere in which they arise, but instead associate the different parts of the same hemisphere—lobes with lobes and gyri with gyri. The fibers which associate the cortex with the nuclei of the corpus striatum must also be classed as association fibers, since these masses of gray substance are a part of the telencephalon, while by definition those which associate the thalamus and hypothalamus with the cortex belong to the projection system. Some of the fiber bundles of the above systems have already been described in connection with the parts with which they are concerned.

The projection fibers of the hemisphere comprise both ascending and descending fibers between the cerebral cortex and structures below the bounds of the hemisphere proper, i.e., some arise in the structures below and terminate in the cortex; others arise from the cortical cells and terminate in the structures below, including the gray substance of the thalamencephalon, mesencephalon, rhombencephalon, and spinal cord. The projection fibers are given different names in the hemisphere according to their arrangement and the appearances to which they contribute in the dissections. Beginning with the pyramidal fasciculi and the basis of the peduncle, they contribute fibers (both sensory and motor)—(1) to the *internal capsule* and some to the *external capsule* and (2) to the *corona radiata*.

The internal capsule [capsula interna] (pars medialis of the capsula nuclei lentiformis NK) is a band of white substance, consisting of the ascending fibers from the nuclei of the thalamus, hypothalamus, and corpus striatum, reinforced by the descending fibers from the cortex to these nuclei and by those descending in the cerebral peduncle to terminate in the mesencephalon, rhombencephalon and spinal cord. It is a broad, fan-like mass of fibers, which increases in width from the base of the hemisphere upward, and which is spread between the lenticular nucleus on its lateral aspect and the caudate nucleus and thalamus on its medial side. To reach the cortex above, the course of its fibers necessarily intersects that of the radiations of the corpus callosum, and thus, together with the corpus callosum, these fan-like bands of the two hemispheres form a capsule containing the thalami, the third ventricle, the caudate nuclei, and the anterior and central portions of the lateral ventricles. In horizontal sections, each internal capsule appears bent at an angle, the **genu** (genu capsulæ NK), which approaches the cavity of the lateral ventricle along the line of the boundary between the thalamus and the caudate nucleus. Along the genu runs the stria terminalis of the thalamus, and through the genu the capsule receives fibers from the internal medullary lamina of the thalamus, from the stratum zonale of the thalamus and from that of the caudate nucleus. At the genu each capsule is separable into two parts:—(1) the **anterior (frontal) portion** (crus frontale NK), spreading between the caudate and lenticular nuclei; (2) the **posterior (occipital) portion** (crus occipitale NK), between the lenticular nucleus and the thalamus (fig. 775).

Functionally, the internal capsule may be divided into a frontal, a frontoparietal and an occipital part.

The **frontal part** consists of (1) an *anterior segment*, carrying chiefly fibers coursing in both directions between the thalamus and the cortex of the frontal lobe, and (2) a *posterior segment* carrying the frontopontile tract.

The **frontoparietal part** may be considered in four segments:—(1) An anterior segment, the *genu*, carrying impulses from the cortex to the nuclei of the motor cranial nerves; (2) posterior to this is the *corticospinal segment for the arm and thorax*, descending cortical fibers to the spinal cord; also the *corticorubral tract;* (3) next is the *corticospinal segment for the lower extremity;* (4) a posterior segment carrying the *general sensory path* ascending from the ventrolateral part of the thalamus and the red nucleus to the cortex. All the segments of the frontoparietal part carry in addition, fibers in both directions between the cortex above and the thalamus and the nuclei of the striate body.

The **occipital part** consists (1) of an anterior segment which carries the descending *temporal and occipital pontile paths*, and (2) a posterior segment carrying the *visual fibers* between the occipital cortex and the nuclei of termination of the optic nerve. This segment also carries the

auditory fibers passing to the cortex of the superior temporal gyrus from the regions of termination of the lateral lemniscus. Thus this segment carries a visual and an auditory path.

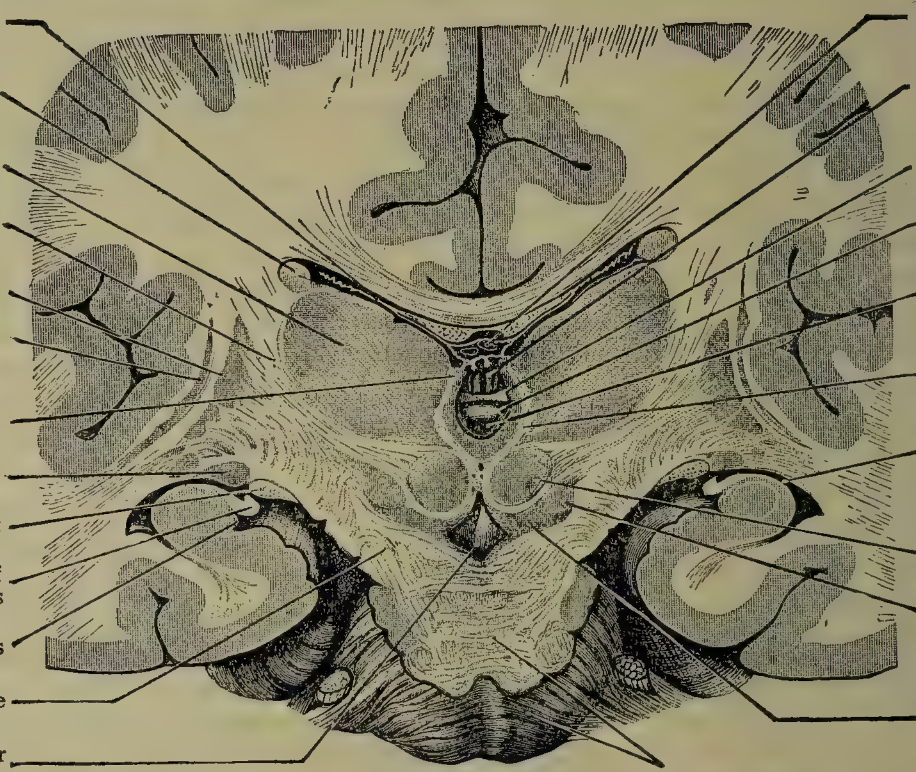


Fig. 773.—Coronal Section of Brain Passing Through the Pulvinar of the Thalamus and the Uncus of the Hippocampal Gyrus. (After Toldt.)

The corona radiata.—Above the corpus callosum and laterally joining its radiations, the fibers of the internal capsule are dispersed in all directions. The appearance known in coronal sections of the hemispheres as the corona radiata is produced by the ascending and descending fibers of the internal capsule combined

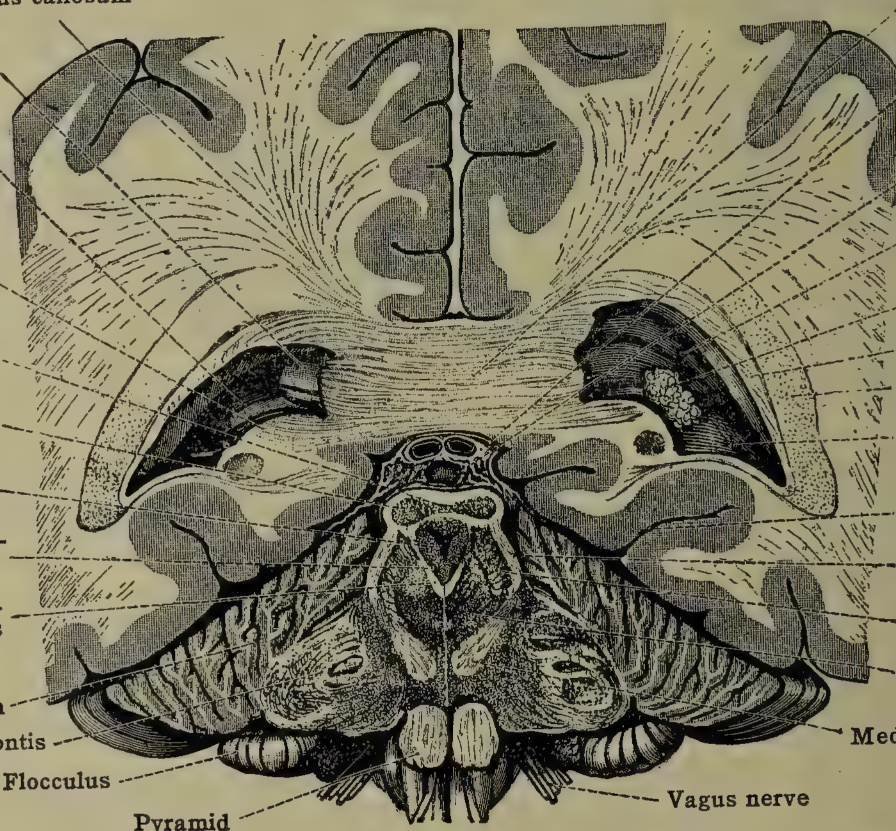


Fig. 774.—Coronal Section through the Splenium of the Corpus Callosum and the Posterior Cornua of the Lateral Ventricles. (Viewed from behind.) (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

with the radiations of the corpus callosum. The radiations related to the internal capsule may be divided into a frontal, a parietal and an occipital part, corresponding to the frontal, parietal and occipital parts of the internal capsule.

The radiation derived from the posterior segment of the occipital part of the internal capsule, the visual path, accumulates into a well-defined band of fibers which passes posteriorly into the occipital lobe, spreading in the lateral wall of the posterior cornu of the lateral ventricle immediately lateral to the tapetum. This band consists for the most part of fibers arising in the pulvinar of the thalamus and in the lateral geniculate body and going to the visual area of the occipital cortex, and of fibers arising in this cortex to terminate in the thalamus and mesencephalon. Being thus concerned with the optic apparatus, it is known as the **occipito-thalamic radiation** or **optic radiation** (fig. 774).

The external capsule is, as already noted, a thin sheet of white substance spread between the claustrum and the lenticular nucleus.

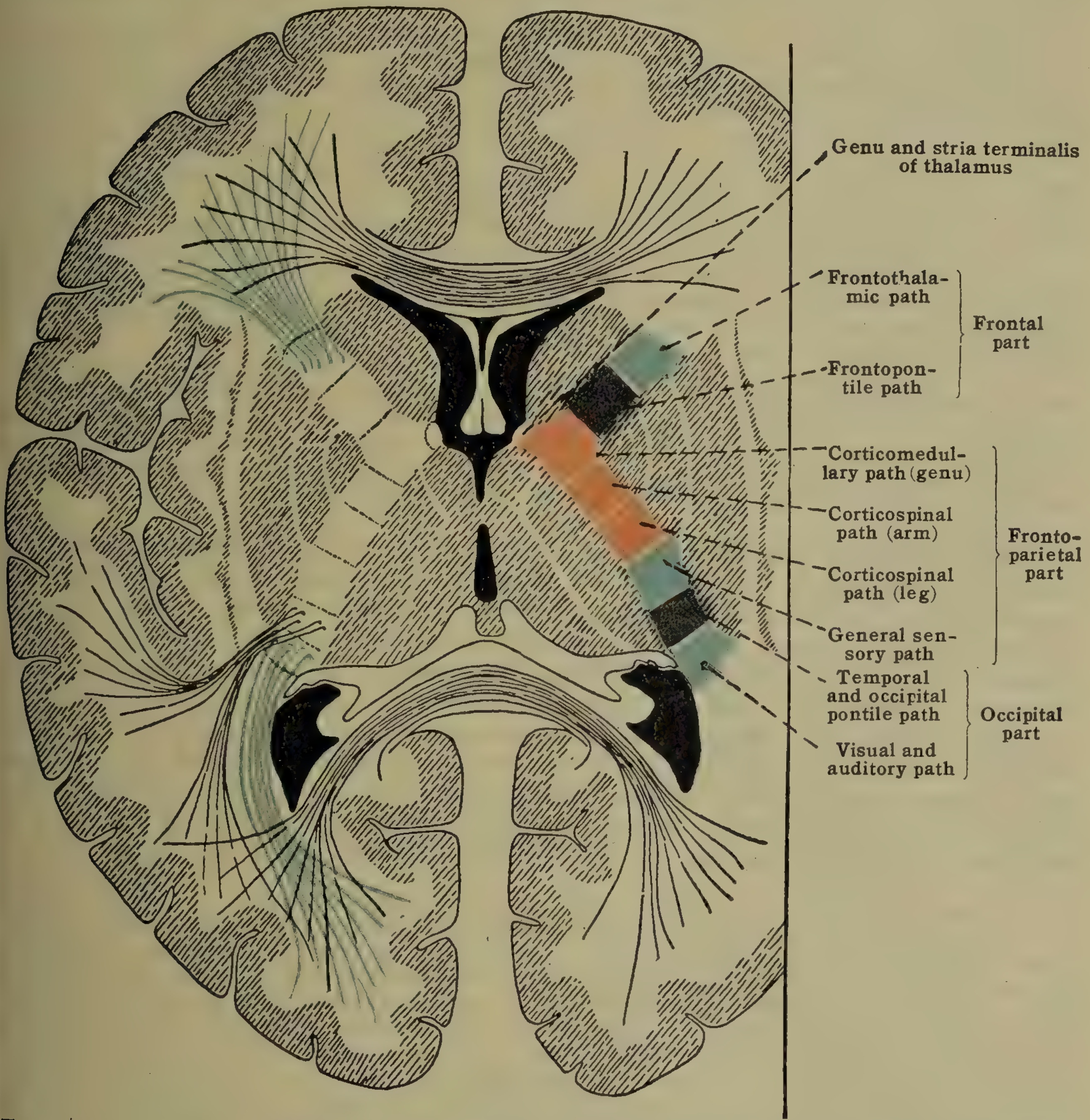


FIG. 775.—DIAGRAM TO INDICATE THE TOPOGRAPHY OF THE PROJECTION FIBERS IN THE INTERNAL CAPSULE. (In part after Villiger.)

It owes its appearance as such to the presence of the claustrum. It joins the internal capsule at the upper, posterior, and anterior borders of the putamen, and below the claustrum it is continuous with the general white substance of the temporal lobe. Thus it contributes to an encapsulation of the lenticular nucleus by white substance. Most of the fibers contained in it belong to the association system. Its projection fibers consist of those of the inferior peduncle of the thalamus, which pass from the basal surface of the thalamus and, instead of continuing below to the cortex of the temporal lobe and insula, turn upward, around the lenticular nucleus to the cortex above the insula. Some of these thalamic fibers are known to pass upward through the laminae of the lenticular nucleus instead of through the external capsule.

The ascending projection fibers arise mostly from the cells of the nuclei of the thalamus; some arise from nuclei in the mesencephalon and from the red nucleus. They may be summarized as follows:—

(1) *The terminal part of the general sensory pathway of the body.* The portion of the medial lemniscus which arises in the nuclei of the fasciculus gracilis and cuneatus, of the opposite side, and the 'spinal lemniscus' (spinothalamic fasciculi), arising in the opposite side of the spinal cord, terminate in the ventral and lateral gray substance of the thalamus. The projection fibers given off by this pass chiefly through the posterior segment of the frontoparietal part of the internal capsule and radiate to and terminate in the somesthetic area of the cortex, chiefly in the posterior central gyrus. Some few may pass outside around the lenticular nucleus, and ascend by way of the external capsule.

(2) *The terminal part of the general sensory pathway of the head and neck.* The nuclei of termination of the sensory portions of the cranial nerves of the rhombencephalon (except the nuclei of the cochlear nerve) give fibers which course upward in the medial lemniscus (fillet) and reticular substance of the opposite side and terminate in the inferolateral portions of the thalamus. Thence arise projection fibers which ascend to the somesthetic area by practically the same route as those of the general sensory system for the body. A large portion of this part of the medial lemniscus arises from the nucleus of termination of the trigeminal nerve and is known as the '*trigeminal lemniscus.*'

(3) *The terminal part of the auditory pathway.* The ventral and dorsal nuclei of termination of the cochlear nerve send impulses which, by way of the lateral lemniscus, are distributed to the inferior quadrigeminate body, the nucleus of the lateral lemniscus and, chiefly, the medial geniculate body of the opposite side. These nuclei send projection fibers through the posterior segment of the occipital part of the internal capsule, and thence by the temporal portion of the corona radiata to the cortex of the superior temporal gyrus (auditory area). Probably some of these fibers pass by way of the inferior peduncle of the thalamus. Some of the fibers arising in the nuclei of termination of the vestibular nerve are thought to convey impulses which reach the somesthetic area, but the origin of the terminal portion of this path is uncertain.

(4) *The terminal part of the visual pathway.* The cells of the lateral geniculate body and the pulvinar, serving as nuclei of termination of the optic tract, give off projection fibers which pass by way of the posterior segment of the occipital portion of the internal capsule and the occipitothalamic radiation to the cortex of the occipital lobe, chiefly the region about the posterior end of the calcarine fissure—the visual area.

(5) *The terminal ascending cerebellar pathway.* The fibers of the brachium conjunctivum, after decussating, terminate both in the red nucleus and in the lateral nucleus of the thalamus. Some fibers from the red nucleus become projection fibers direct, others terminate in the medial and anterior portion of the lateral nucleus of the thalamus. From the thalamus the projection fibers of this system pass in the peduncles of the thalamus (internal capsule) to the somesthetic area and general cortex, that of the frontal lobe especially.

The descending projection fibers arise as outgrowths of the pyramidal cells of the cerebral cortex. Practically all of them cross to the opposite side in their descent to the structures of the brain stem and spinal cord. The majority of them arise near and within the gyri in which the respective ascending fibers terminate. Those transmitting cortical impulses to the cells giving origin to the motor fibers of the cranial and spinal nerves arise chiefly from the giant pyramidal cells of the precentral (anterior central) gyrus, the paracentral lobule and the posterior ends of the superior, middle, and inferior frontal gyri. These latter occupy nearly three-fourths (the anterior three segments) of the frontoparietal part of the internal capsule and the middle three-fifths of the basis of the cerebral peduncle, and are usually called *pyramidal* fibers (fig. 775).

The principal descending projection fibers may be grouped as follows:

(1) **The pyramidal fibers to the spinal cord** (corticospinal or pyramidal fasciculi proper). These arise from the giant pyramidal cells of the upper two-thirds of the precentral gyrus, the anterior portion of the paracentral lobule and the posterior third of the superior frontal gyrus. Those for the lumbosacral region of the spinal cord arise nearest the superomedial border of the hemisphere (fig. 778). The tract descends through the two middle segments of the frontoparietal part of the internal capsule. Those carrying cortical impulses for the muscles of the arm and shoulder course in the segment anterior to the course of those for the muscles of the leg. Both continue through the cerebral peduncles and the pons and through the pyramids of the medulla, where most of them decussate and pass down the spinal cord to terminate about the ventral horn cells (the origin of the motor nerve roots) of the opposite side.

(2) **The pyramidal (cortico-medullary) fibers to the nuclei of origin of the motor cranial nerves** arise from the pyramidal cells in the inferior third of the precentral gyrus, the posterior end of the inferior frontal gyrus, the opercular margin of the posterior central gyrus, and probably some (for eye movements) in the posterior end of the middle frontal gyrus. The locality of the origin of the pyramidal fibers terminating in the nuclei of the facial and hypoglossal nerves only has been determined with certainty. The general tract passes in the genu of the internal capsule, through the cerebral peduncle, and gradually decussating along the brain stem, terminates in the nuclei of the motor cranial nerves of the opposite side.

(3) **The frontal pontile path** (Arnold's bundle) arises in the cortex of the frontal lobe, anterior to the precental gyrus, descends through the frontal part of the corona radiata and posterior segment of the frontal portion of the internal capsule into the frontomedial portion of the cerebral peduncle, and terminates in the nuclei of the pons.

(4) **The temporal pontile path** (Türk's bundle) arises in the cortex of the superior and middle temporal gyri, passes through the anterior segment of the occipital part of the internal capsule, enters the cerebral peduncle posterolateral to its pyramidal portion, and terminates in the nuclei of the pons. An occipitopontile path is described as arising in the occipital cortex and

joining the temporal pontile path in the internal capsule to pass to the nuclei of the pons.

(5) The occipitomesencephalic path (Flechsig's secondary optic radiation) arises in the cortex of the visual area of the occipital lobe (cuneus and about the calcarine fissure), passes forward through the occipitothalamic radiation, downward in the posterior segment of the occipital portion of the internal capsule, and terminates in the nucleus of the superior quadrigeminate body and the lateral geniculate body. It is probable that some of its fibers terminate directly in the nuclei of the eye-moving nerves.

(6) Those fibers of the fornix which arise in the hippocampus may terminate in the corpus mammillare or pass through to the anterior nucleus of the thalamus of the same and opposite side (mammillothalamic fasciculus) or continue into the mescencephalon and probably to structures lower down.

In the frontal part of the internal capsule fibers are said to course in both directions between the medial nucleus of the thalamus and the cortex of the frontal lobe. And in the frontoparietal part of the capsule a tract is claimed to descend from the motor area of the cortex to terminate in the red nucleus—a *'corticorubral tract.'* In addition, as noted in preceding paragraphs, some

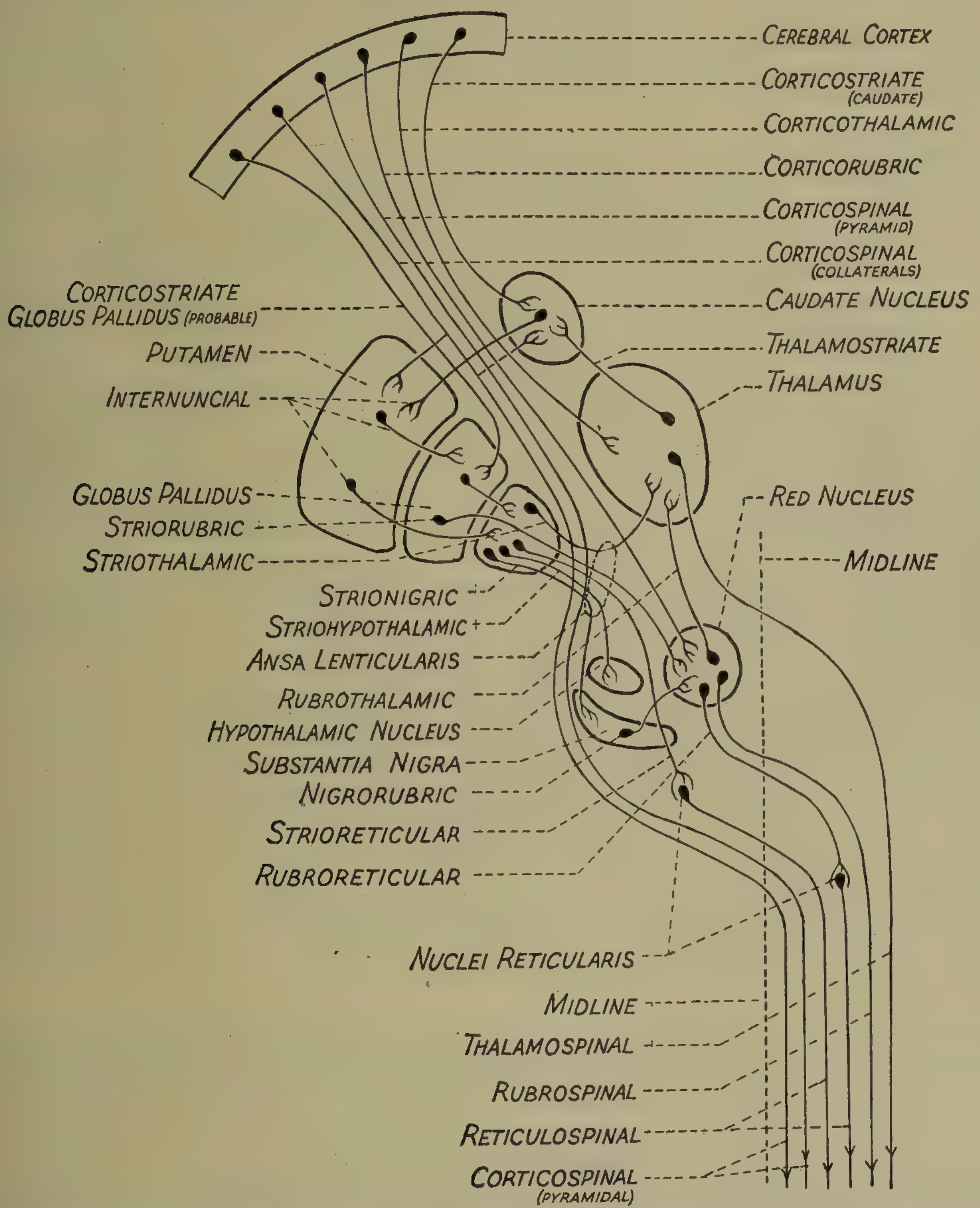


FIG. 776.—DIAGRAM OF THE KNOWN AND SOME OF THE PROBABLE PATHS COMPRISING THE EXTRAPYRAMIDAL SYSTEM.

of the fibers descending from the cortex are described as making synapses in the corpus striatum (basal ganglia), thalamus, hypothalamic nucleus, and substantia nigra. These cortical fibers are claimed for the most part to give off collaterals which terminate in these masses of gray substance instead of terminating wholly within them. Descending fibers arising from these masses have acquired much clinical importance from experimental evidence and from pronounced nervous symptoms found to be associated with pathological lesions involving them, especially the caudate and the lenticular nuclei. These descending fibers, together with the descending cortical fibers concerned, are collectively named the extrapyramidal system.

(7) **The extrapyramidal system.**—Actual structural proof is lacking for anatomical explanations of all the experimental phenomena and all the symptoms associated with pathological lesions which are usually attributed to the extrapyramidal paths. However, it is known that descending fibers do arise in the thalamus, red nucleus and some from the corpus striatum. These extrapyramidal fibers may provide a mechanism for the partial restitution of function

in cases in which lesions involving the regular pyramidal fasciculi have abolished the usual voluntary activities. Also, normally the extrapyramidal fibers are held to coördinate with the regular pyramidal fibers so as to contribute a steadying control in the activities mediated by the latter. The extrapyramidal system includes all descending cortical chains which reach the medulla and spinal cord by a circuitous route instead of following the recognized pyramidal tracts. The paths descending by the way of the cerebellum and chiefly concerned in the apparatuses of equilibration and muscle tone are usually omitted from the extrapyramidal paths. Thus the paths included in the list are:

(a) The *corticorubral* path, which arises in the cortex of the frontal lobe and makes synapses in the red nucleus. Descending fibers from the red nucleus may establish connections with the motor neurones of the brain stem and spinal cord by way of the rubrospinal tract, including the rubroreticulospinal and the rubrothalamospinal paths. (See diagram, fig. 776.)

(b) *Corticothalamic* fibers, which connect the cortex with the thalamus of the same side. Thence the thalamospinal fasciculus serves as intermediate links between the thalamus and the motor neurones of the spinal cord. A thalamostriate path is claimed to exist between the thalamus and caudate nucleus, and possibly the globus pallidus via the ansa lenticularis.

(c) *Corticostriate* fibers, claimed, if they exist, to be direct cortical fibers terminating in the caudate nucleus and possibly in the globus pallidus. In addition to these, there may be included in this group collaterals given off by the regular pyramidal (corticospinal) fibers in their passage through the internal capsule, which collaterals terminate in the caudate nucleus and the putamen.

Large ganglion cells are included in the lenticular nucleus, mostly in the globus pallidus, and these give rise to fibers which convey impulses out of the striate body by way of the ansa lenticularis and distribute them in the red nucleus, substantia nigra, hypothalamus, and thalamus. These are thought to be the most important of the striofugal fibers concerned with the extrapyramidal system, more important as contrasted with the incoming (striopetal) which arise elsewhere (cortex, thalamus, etc.) and terminate in the striate body. The smaller ganglion cells of the striate body are considered as giving rise to internuclear (internuncial) fibers which associate the various divisions of that body. These fibers for the most part arise in the caudate nucleus and putamen (neostriatum) and terminate in the globus pallidus. Some originate in the caudate nucleus and terminate in the putamen.

No definitely localized functions have been ascribed to any of the nuclei of the striate body. Experimental and clinicopathological evidence, in conjunction with their evolution and fiber connections, suggest that the caudate nucleus and the putamen serve as a coordinating and inhibitory center necessary in the enlarged nervous apparatus of the higher mammals. On the other hand, the globus pallidus (paleostriatum) is thought to be a motor center of long standing for the control or production of associated movements such as the coordinated swinging of the upper and lower limbs in walking.

Clinical aspects.—Diseases involving the extrapyramidal system are manifested clinically by changes in muscle tone and some form of disturbed motility, but without paralysis. The more common symptoms which have been found to be associated with lesions in the striate body are the syndromes known as Parkinson's disease and Wilson's syndrome. Parkinson's disease, commonly known as *paralysis agitans*, seems to be particularly associated with destruction of the globus pallidus. It is characterized by the familiar tremors which may cease or become less marked upon increased volition (muscular rigidity to some extent under control), a mask-like face and disturbance of automatic and associated movements. Wilson's syndrome, often referred to as *progressive lenticular degeneration*, is more associated with destruction of the caudate nucleus and putamen. It is characterized by impaired inhibitory influence upon the activities mediated by the regular pyramidal fasciculi, by marked muscular rigidity and complex tremor, often violent, which is exaggerated, instead of being controlled, by volition, the symptoms being more violent when the patient is conscious of being under observation. The rigidity is distinctly spasmodic and often there is spasmodic weeping and laughter and dysphasia. Naturally there are many varieties and degrees of these two symptom complexes involving inefficient control of muscular and joint movements.

In studying the phenomena assigned to the extrapyramidal system, its functions must always be associated with those of the cerebellum since the latter serves so largely in muscle tone and as the great central station for coördination paths in proprioceptive reactions.

The commissural system of fibers.—The commissural fibers of the telencephalon serve to connect or correlate the functional activities of one hemisphere with those of the other. They consist of three groups:—The corpus callosum, the anterior commissure and the hippocampal commissure.

(1) The **corpus callosum** is the great commissure of the brain. A general description of this with the medial and lateral striæ running over it has already been given. It is a thick band of white substance, about 10 cm. wide, which crosses between the two hemispheres at the bottom of the longitudinal fissure. Its shape is such that in a median sagittal section of the brain its parts are given the names *splenium, body, genu,* and *rostrum* (figs. 746 and 757). Its lower surface is medially joined to the fornix, in part by the septum pellucidum and in part directly. Posterolaterally, it forms the tapetum of the lateral ventricle of either side. The majority of its fibers arise from the cortical cells of the two hemispheres and terminate in the cortex of the side opposite that of their origin. In dissections, its fibers are seen to radiate toward all parts of the cortex—the radiation of the corpus callosum. These radiations may be divided into frontal, parietal, temporal and occipital parts. The occipital parts curve posteriorly in two strong bands from the splenium into the occipital lobes, producing the figure known as the

forceps major. Anteriorly, the frontal parts are two similar but lesser bands which curve from the genu forward into the frontal lobe, producing the **forceps minor.**

(2) The **anterior commissure** (commissura rostralis NK) has been described in connection with the rhinencephalon. In addition to the olfactory fibers coursing through it from the olfactory bulb and parolfactory area of one hemisphere to the uncus and olfactory bulb of the opposite hemisphere, and its commissural fibers between the two hippocampal gyri, comprising its greater part, it also carries fibers which arise in the cortex of the temporal lobe, the uncus chiefly, of one side and terminate in that of the opposite side. It crosses in the substance of the anterior boundary of the third ventricle, and through the inferior portions of the lenticular nuclei, and can be seen only in dissections (figs. 761, 769). It is a relatively small, round bundle, and its midportion between its terminal radiations presents a somewhat twisted appearance.

(3) The **hippocampal commissure** (*transverse fornix*) belongs wholly to the limbic lobe (rhinencephalon), and has been described there. It connects the hippocampal gyri of the two sides, and crosses the midline under and usually adhering to the inferior surface of the splenium of the corpus callosum. Crossing the body of the fornix, it thins anteriorly, its edge crossing in the posterior angle of the septum pellucidum.

With these three commissures of the telencephalon, the three other commissures of the prosencephalon should be called to mind. **The inferior cerebral commissure** (Gudden's

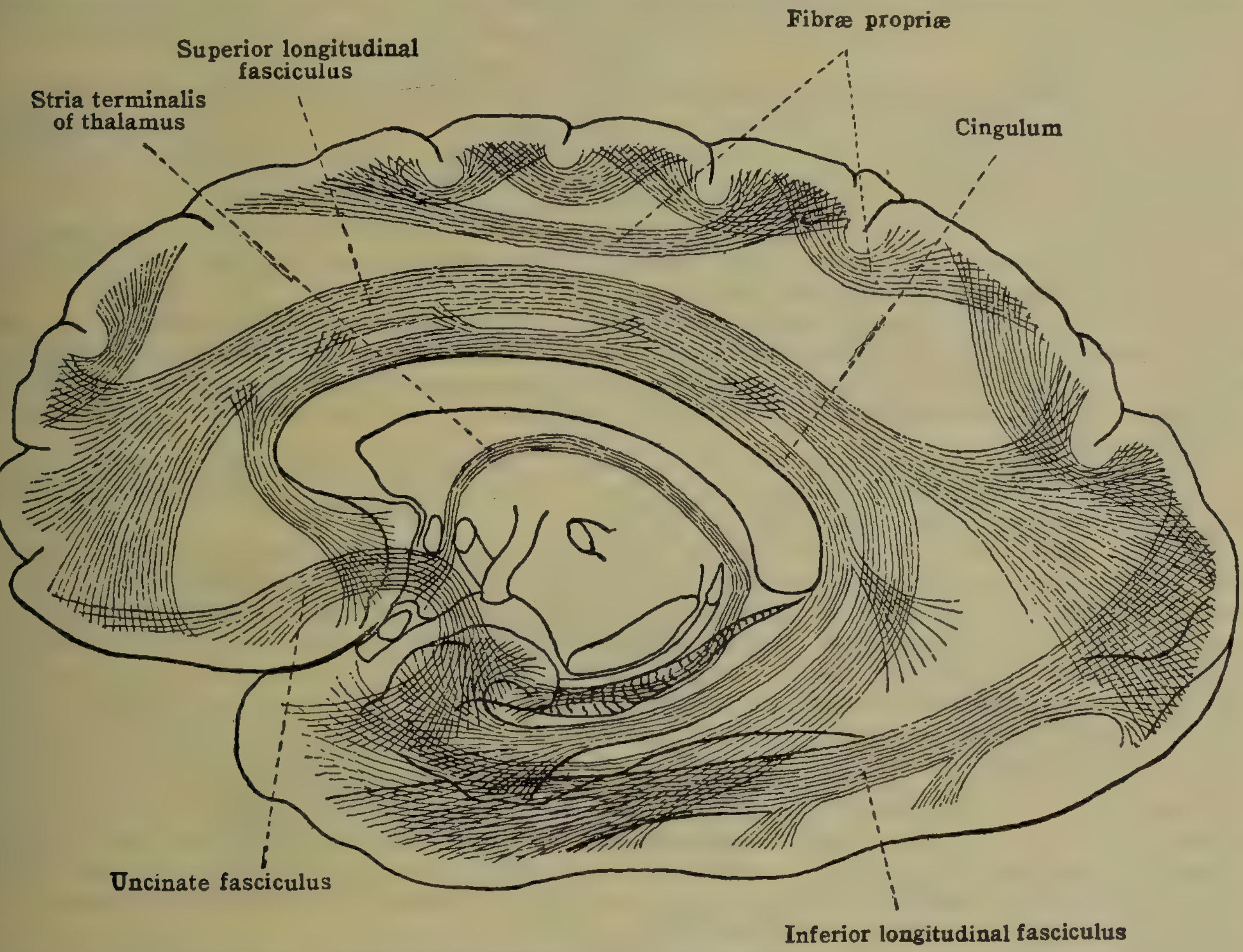


Fig. 777.—Schematic Representation of Certain of the Association-pathways of the Cerebral Hemisphere.

commissure), while occurring in the optic chiasma and allotted by position to the telencephalon, really belongs to the diencephalon since it connects with each other the medial geniculate bodies of the two sides. **The supramammillary commissure,** connecting the nuclei of the mammillary bodies of the two sides, is allotted to the diencephalon (hypothalamus). **The posterior cerebral commisure,** situated just below the stalk of the pineal body, belongs to both the diencephalon and mesencephalon. Its superior part, the *habenular commissure,* connecting the two nuclei of the habenulæ, belongs wholly to the diencephalon. In its inferior part, the fibers arising in the thalamus of one side and terminating in that of the other side belong likewise to the diencephalon, but those passing between the superior quadrigeminate bodies of the two sides and between the so-called nuclei of the medial longitudinal fasciculi belong to the mesencephalon.

The association system of the hemisphere.—The possibilities for association-bundles connecting the different parts of the same hemisphere with each other are innumerable, though only a few are designated by names. They serve for the distribution or diffusion of impulses brought in from the exterior by the ascending projection system, and it is by means of them that the different areas of the cortex may function in harmony and coördination. Most of the association-bundles are supposed to contain fibers coursing in both directions. Several of them have already been described in company with the gray masses with which they are concerned. They may be summarized as follows (see fig. 777):—

(1) Those of short course, the **fibræ propriæ,** which associate contiguous gyri with each other. These arise from the cells of a gyrus and loop around the floor of a sulcus, continu-

ally receiving and losing fibers in the cortex they associate. The stripes of Baillarger within the gray cortical layer might be included among the short association-bundles, these largely associating different regions of the same gyrus.

(2) The **cingulum** (girdle) lies in the gyrus cinguli and is shaped correspondingly. It extends from the anterior perforated substance and the subcallosal gyrus around the genu of the corpus callosum, then under cover of the gyrus cinguli and around the splenium, and thence downward and forward in the hippocampal gyrus to the uncus. It is chiefly an aggregation of fibers of short course—fibers which associate neighboring portions of the cortical substance beneath which they course, and which, by continually overlapping each other, form the bundle.

(3) The **uncinate fasciculus** is a hook-shaped bundle which associates the uncus and anterior portion of the temporal lobe with the olfactory bulb, parolfactory area and anterior perforated substance and perhaps the frontal pole with the orbital gyri. Its shape is due to its having to curve medialward around the stem of the lateral cerebral fissure.

(4) The **superior longitudinal fasciculus** is the longest of the association-paths, and associates the frontal, occipital, and temporal lobes. From the frontal lobe it passes laterally in the frontal and parietal operculum, transverse to the radiations of the corpus callosum and the lower part of the corona radiata, and above the insula to the region of the posterior end of the lateral fissure, and thence it curves downward and forward to the cortex of the temporal lobe. Some of its fibers extend to the cortex of the temporal pole. The occipital portion consists of a loose bundle given off from the region of the downward curve, which radiates thence to the occipital cortex.

(5) The **inferior longitudinal fasciculus** associates the temporal and occipital lobes and extends along the whole length of these lobes parallel with their tentorial surfaces. Posteriorly it courses lateral to the lower part of the occipitothalamic radiation, from which it differs by the fact that its fibers all arise within the hemisphere and are less compactly arranged. It associates the lingual and fusiform gyri and the cuneus with the temporal pole.

(6) A vertical or **transverse occipital fasciculus** (not included in fig. 777) associates the tentorial surface of the occipital lobe with the superomedial and lateral parts of this lobe and adjacent portions of the parietal lobe.

(7) The medial and lateral **longitudinal striæ** of the upper surface of the corpus callosum may be considered among the association pathways, since most of their fibers associate the gray substance of the hippocampal gyrus with the subcallosal gyrus and the anterior perforated substance of the same hemisphere. Their significance as parts of the rhinencephalon has already been given.

(8) Likewise the longitudinal fibers in the **stria terminalis of the thalamus** (tenia semicircularis) may be considered among the association pathways, since these connect the amygdaloid nucleus with the anterior perforated substance.

(9) The numerous fibers passing in both directions between the cerebral cortex and the nuclei of the corpus striatum belong to the association system. These do not form a definite bundle, though they contribute appreciably to the corona radiata. However, a pathway described as the **occipitofrontal fasciculus** probably consists largely of the more sagittally running fibers of this nature. The existence of this fasciculus has been noted in degenerations and in cases of arrested development of the corpus callosum. Its fibers are described as contributing greatly to the tapetum, and as coursing beneath the corpus callosum immediately next to the ependyma of the lateral ventricle. As a mass, they appear in intimate connection with the caudate nucleus, and are spread toward both the frontal and the occipital lobes (chiefly the latter), in the mesial part of the corona radiata of those lobes. It is described as also containing fibers in both directions associating the occipital with the temporal lobe. *Vertical association-fibers* pass through the caudate and lenticular nuclei between the cortex above and that of the temporal lobe below. Some of the association fibers of this striate group are included in the extrapyramidal system, discussed above.

(10) Since the olfactory bulb is a part of the hemisphere proper, the *olfactory tract* may be considered an association pathway connecting the olfactory bulb with the parolfactory area, the subcallosal gyrus, the anterior perforated substance, and the uncus. As already shown, a portion of the fibers of the tract belongs to the commissural system.

THE FUNCTIONAL AREAS OF THE CEREBRAL CORTEX

The definitely known areas of specific function of the human cerebral cortex are relatively small. They comprise but little more than a third of the area of the entire hemisphere. They are—(1) the general sensory-motor or somesthetic area, and (2) the more specific areas for the organs of special sense. They represent portions of the cortex in which terminate sensory or ascending projection-fibers bearing impulses from the given peripheral structures, and in which arise motor or descending projection-fibers bearing impulses in response.

Knowledge of the location of the areas has been obtained—(1) by the Flechsig method of investigation, and to a considerable extent by Flechsig himself; (2) from clinicopathological observations, largely studies of the phenomena resulting from brain-tumors, cerebral thrombi and traumatic lesions; (3) by experimental excitation of the cortex of monkeys and apes, the resulting phenomena being correlated with the anatomical findings and compared with the observations upon the human brain. The remaining larger and less known areas of the cortex are referred to as '*association-centers*' or *areas* of the 'higher psychic activities.'

In development, the sensory fibers to the specific areas acquire their medullary sheaths first, before birth, and then the respective motor fibers from each become medullated. It is not until a month after birth that the association-centers show medullation and therefore acquire active functional connection with the specific areas.

In defining an area it is not claimed that all the fibers bearing a given type of impulse terminate in that area, nor that all the motor fibers leading to the given reaction originate in the area. It can only be said that of the fibers concerned in a given group of reactions, more terminate and arise in the areas cited than in any other areas of the cortex. The corresponding

motor fibers arise both in the region of the termination of the sensory fibers (sensory area) and also in a zone (motor area) either partially surrounding or bordering upon a part of the region of the termination.

There is yet much lack of agreement among observers both as to the number of localized functional areas and as to the exact position of certain of the areas claimed. Some of the more recent and more trustworthy observations upon the human cortex are those made by Forester (1927). These were made upon chance cases in which the operation could be performed under local anesthesia, the patient fully conscious. The cortex was excited by electrical stimulus with the patient able to describe sensations experienced. Stimulation of an area resulting in a more instant and marked contraction of a muscle or group of muscles established the cortical area concerned with the muscles responding to it. Upon stimulation of a sensory area, the patient would report a sensory experience, 'an aura,' similar to that induced by a stimulation

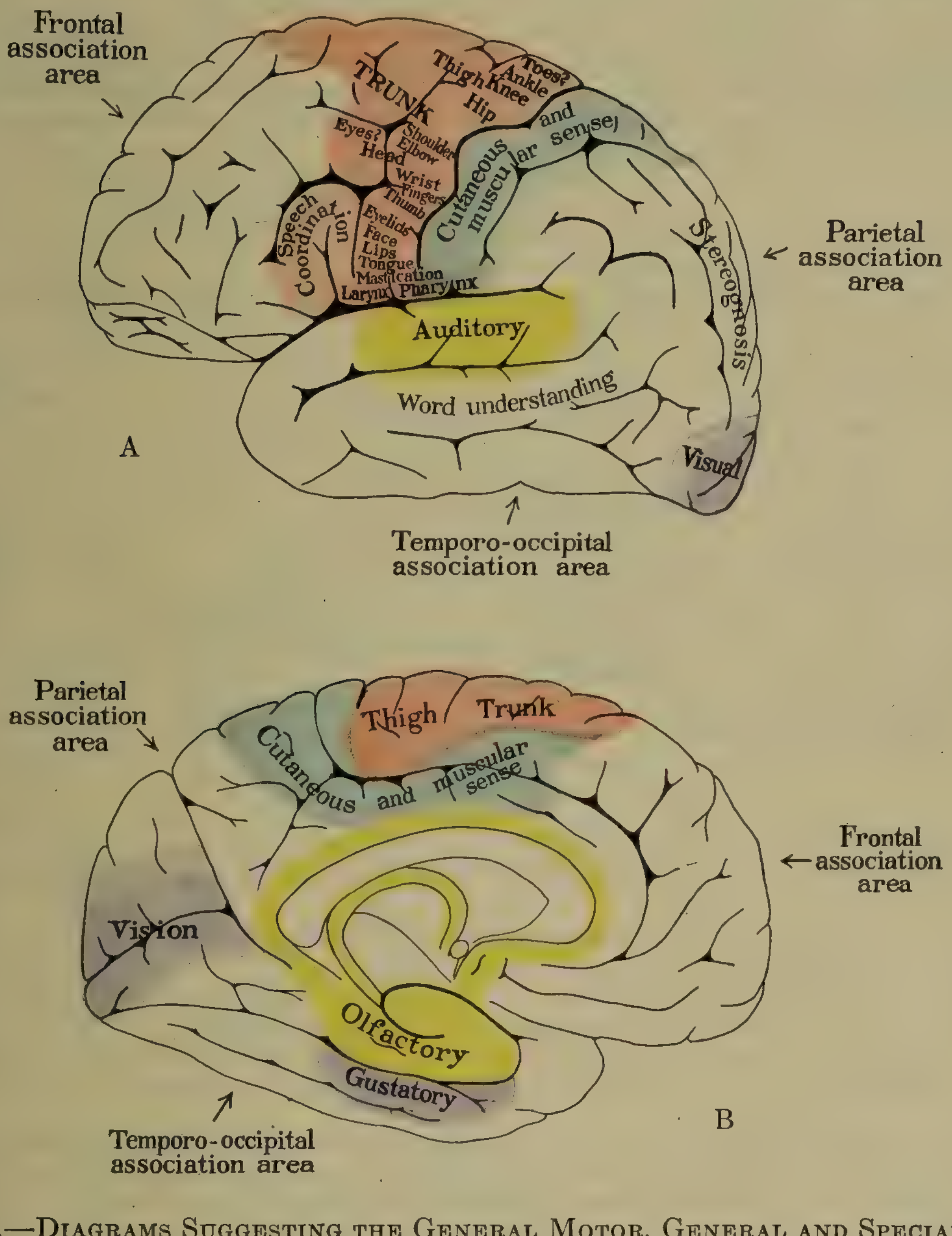


FIG. 778.—DIAGRAMS SUGGESTING THE GENERAL MOTOR, GENERAL AND SPECIAL SENSORY AND THE ASSOCIATION AREAS OF (A) THE CONVEX AND (B) THE MEDIAL SURFACE OF THE CEREBRAL HEMISPHERE. THE DIFFERENT SENSORY AREAS OF THE POSTERIOR CENTRAL GYRUS ARE LOCATED APPROXIMATELY OPPOSITE THEIR CORRESPONDING MOTOR AREAS AS NAMED.

of an organ or region of the general body normally related to that area of the cortex. Stimulation of a purely motor areas did not give an aura, while stimulation of a 'sensory' area was often followed first by an aura and then by a contraction of muscles normally occurring in response to sensations when aroused in the corresponding region of the body. The following are considered the more generally accepted of the areas:—

(1) The **somesthetic (sensory-motor) area,** the area of general sensibility, and the area in which arise the larger part of the cerebral motor or pyramidal fibers for the cortical control of the general muscular system. As is to be expected, it is the largest of the specific areas. It includes the anterior central gyrus, posterior central gyrus, the posterior ends of the superior, middle, and inferior frontal gyri, the paracentral lobules, and the immediately adjacent part of the gyrus cinguli. The ascending or sensory fibers are found to terminate most abundantly in the part posterior to the central sulcus (Rolandi), the posterior central gyrus being the special *area of cutaneous sensibility* of the human cortex, and the adjacent anterior ends of the horizontal parietal gyri have been designated as the area of '*muscular sense.*' Both these areas are carried over upon the medial surface to involve the lower part of the paracentral lobule and a part of the gyrus cinguli. The anterior central gyrus gives origin to relatively more motor fibers than

the other portions of the somesthetic area. In distribution, the muscles furthest away from the cortex are innervated from the most superior part of the area, the leg area being in the superomedial border of the hemisphere, while that for the head is in the anterior and inferior part of the area (fig. 778). The muscles of mastication and the laryngeal muscles are controlled from the frontoparietal operculum. Broca's convolution, the opercular portion and part of the triangular portion of the inferior frontal gyrus of the left hemisphere, constitutes the especial motor coördination-area of speech, and Mills extended this area to include the superoanterior portion of the insula below. The various authorities differ considerably as to the exact locations of many of the areas for the cortical control of given sets of muscles. Further observations must be skillfully made for localization of areas of the human cortex in detail and further correlations must be determined between the experiments upon the cortex of anthropoid apes and the functions of that of man. The accompanying diagrams (figs. 778, 779) are compiled from several of the diagrams more usually given and must be considered as only approximately correct.

(2) **The visual area.**—The especial sensory portion of this area is that immediately bordering upon either side of the posterior part of the calcarine fissure. The entire area, motor and sensory overlapping each other, includes the whole of the cuneus. The motor visual area proper is described as the more peripheral portion of the entire area. In addition, an area producing

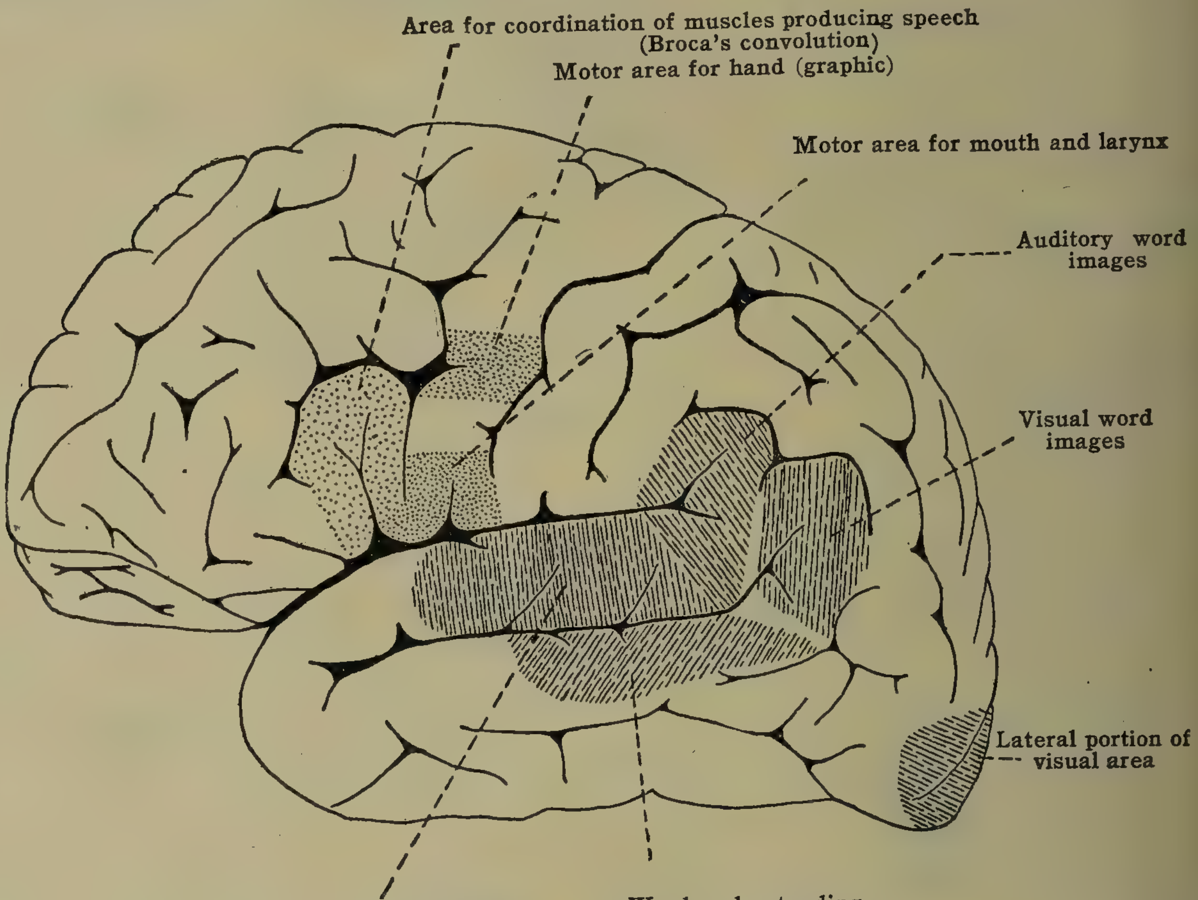


Fig. 779.—Convex Surface of Left Cerebral Hemisphere with Diagrammatic Presentation of the Areas Suggested as Concerned with Speech.

eye movements is described as comprising the posterior end of the middle frontal gyrus. Optic aura and optic hallucinations have been reported as being experienced with electrical stimulation of the region of the lateral occipital gyri just inferior to the lateral end of the parieto-occipital fissure.

(3) **The auditory (cochlear) area** comprises the middle third of the superior temporal gyrus and the transverse temporal gyri of the temporal operculum. This area has been determined not only by lesions and degenerations but also by auditory aura experienced upon its stimulation. The motor portion of this area lies in its inferior border. The fibers arising in the area course downward in the temporal pontile path to the motor nuclei of the medulla.

(4) **The olfactory area** consists of the olfactory trigone, the parolfactory area, the subcallosal gyrus, part of the anterior perforated substance, the hippocampal gyrus (especially the uncus), and the callosal half of the gyrus cinguli. Its motor or efferent area lies chiefly in the hippocampal gyrus, the fibers from which pass out from the telencephalon by way of the fornix and cingulum.

(5) **The gustatory area** is supposed to comprise the anterior portion of the fusiform gyrus and the zone (motor portion) about the anterior extremity of the inferior temporal sulcus. The area has been claimed to extend through the isthmus of the gyrus fornicatus to include a part of the callosal margin of the gyrus cinguli.

(6) **The association-areas.**—The relatively large areas allotted at present to the so-called higher psychic activities are indicated in fig. 778. The great relative extent of these is one of the characteristics of the human brain. They probably merely represent the portions of the cortex of which little is known, and may eventually be subdivided into more specific areas. They are considered to be connected with the structures below by fewer projection fibers than are the recognized areas named above, while, on the other hand, they are rich in association fibers. By means of the latter they are in intimate connection with the specific areas and have

abundant means of correlating and exercising a controlling influence upon the functions of these areas. According to Flechsig, they consist of—(1) a *parietal association-area*, comprising that part of the parietal cortex between the somesthetic area and the visual area; (2) an *occipito-temporal association-area*, including the unspecified portions of the temporal lobe and the adjoining portion of the occipital lobe not included in the visual area; (3) a *frontal association-area* including all the frontal lobe anterior to the somesthetic and olfactory area. A large frontal area is especially distinctive of man. In the folds of the inferior parietal lobule of the parietal association-area such intellectual activities as the optic discrimination of words, letters, numbers, and objects generally are supposed to take place, while the superior parietal lobule continued into the posterior part of the præcuneus is the general region for the perception of form and solidity of objects—the stereognostic center. No sensory aura are experienced in stimulation of the frontal association area.

The *insula* is suggested as the area in which auditory, olfactory and gustatory impulses are associated with the motor areas beginning in the operculum dorsolaterally adjacent to it.

Observations of symptoms and the position of lesions accompanying them have made it possible to arrive at some trustworthy conclusions regarding the **cortical areas controlling speech.** Broca announced in 1861 that the inferior frontal gyrus of the *left* hemisphere was peculiarly concerned with speech. This area was later confined to the posterior end or opercular portion of this gyrus and the name 'Broca's Convolution' was given it. It is now known that Broca's convolution and the adjacent portion of the triangular part of the inferior frontal gyrus as well comprise the *motor* or *emissive speech-area*—the area especially devoted to the control of that coördinated action of the muscles concerned which makes possible articulate speech. Patients in whom this area is impaired are unable to give utterance to words though they may understand them both written and spoken, and though they may give utterance to sound. This inability is known as *motor aphasia.* Results of observed lesions have further shown that the area in which the *auditory images* of words are retained (word memories) comprises the posterior end of the superior temporal gyrus and the adjoining portion of the supramarginal gyrus. Injury to this area is accompanied by inability to recognize spoken words although the patient hears them and may recognize and understand written words, a phenomenon known as 'word-deafness' or auditory *sensory aphasia.* This area may be considered as continuous with the superior portion of the posterior end of the middle temporal gyrus which has been suggested as the area of 'word-understanding,' or '*lalognosis.*' On the other hand, the area in which visual images of words are retained is located as the angular gyrus. Injury to this results in an inability to recognize printed or written words although the patient may hear, understand and speak them. This is called '*word-blindness*, (visual sensory aphasia). This area is nearest the special area of vision on the one hand and on the other hand, is continuous into the area to which word-understanding is attributed. For purposes of writing, it must be associated with the motor area for the muscles of the hand in the precentral gyrus.

While the motor area for speech is most functional in the left hemisphere of right-handed individuals, and *vice versa*, the remaining areas concerned are probably equally functional in the two hemispheres.

III. GENERAL SUMMARY OF SOME OF THE PRINCIPAL CONDUCTION-PATHS OF THE NERVOUS SYSTEM

In the following summary the arabic numerals indicate the nuclei or ganglia containing the cell-bodies of the neurones interposed in the chains; the letters in parentheses indicate the different names given to the different levels of the pathways through which their fibers run. For detailed descriptions of either nuclei or pathways see pages describing them. Only the more common neurone-chains are followed here.

I. The Spinocerebral and Cerebrospinal System

A. The ascending path of neurones (fig. 780).

1. Spinal ganglion—neurone of first order.
   (*a*) Terminal corpuscles and peripheral process of T-fiber.
   (*b*) Dorsal or afferent root of spinal nerve.
   (*c*) Ascending branch of bifurcation of dorsal root fiber in fasciculus gracilis or fasciculus cuneatus of spinal cord.
2. Nucleus of fasciculus gracilis or nucleus of fasciculus cuneatus in medulla oblongata —neurone of second order.
   (*a*) Internal arcuate fibers.
   (*b*) Decussation of medial lemniscus.
   (*c*) Interolivary stratum of opposite side.
   (*d*) Medial lemniscus.
3. Inferior and lateral nuclei of thalamus—neurone of third order.
   (*a*) Internal capsule, posterior segment of frontoparietal portion.
   (*b*) Corona radiata, frontoparietal part.
4. Posterior central gyrus of somesthetic area of cerebral cortex.
   (*a*) Association and commissural fibers of cortex.

1*x*. Spinal ganglion—neurone of first order.
   (*a*) Terminals, especially in skin, and peripheral process of T-fiber.
   (*b*) Dorsal or afferent root of spinal nerve.
   (*c*) Collaterals and terminal branches of bifurcation of dorsal root-fiber within spinal cord.

2*x*. Gray substance of spinal cord, dorsal horn especially—neurone of second order.
   (*a*) Decussation of fibers to opposite side within spinal cord.
   (*b*) Spinothalamic and spinotectal paths (*spinal lemniscus*).

3x. Inferolateral nuclei of thalamus—neurone of third order.
  (a) Internal capsule (medial side of frontoparietal portion).
  (b) Corona radiata.
4x. Posterior central gyrus of cerebral cortex—neurone of fourth order.
  (a) Association and commissural fibers of cortex.

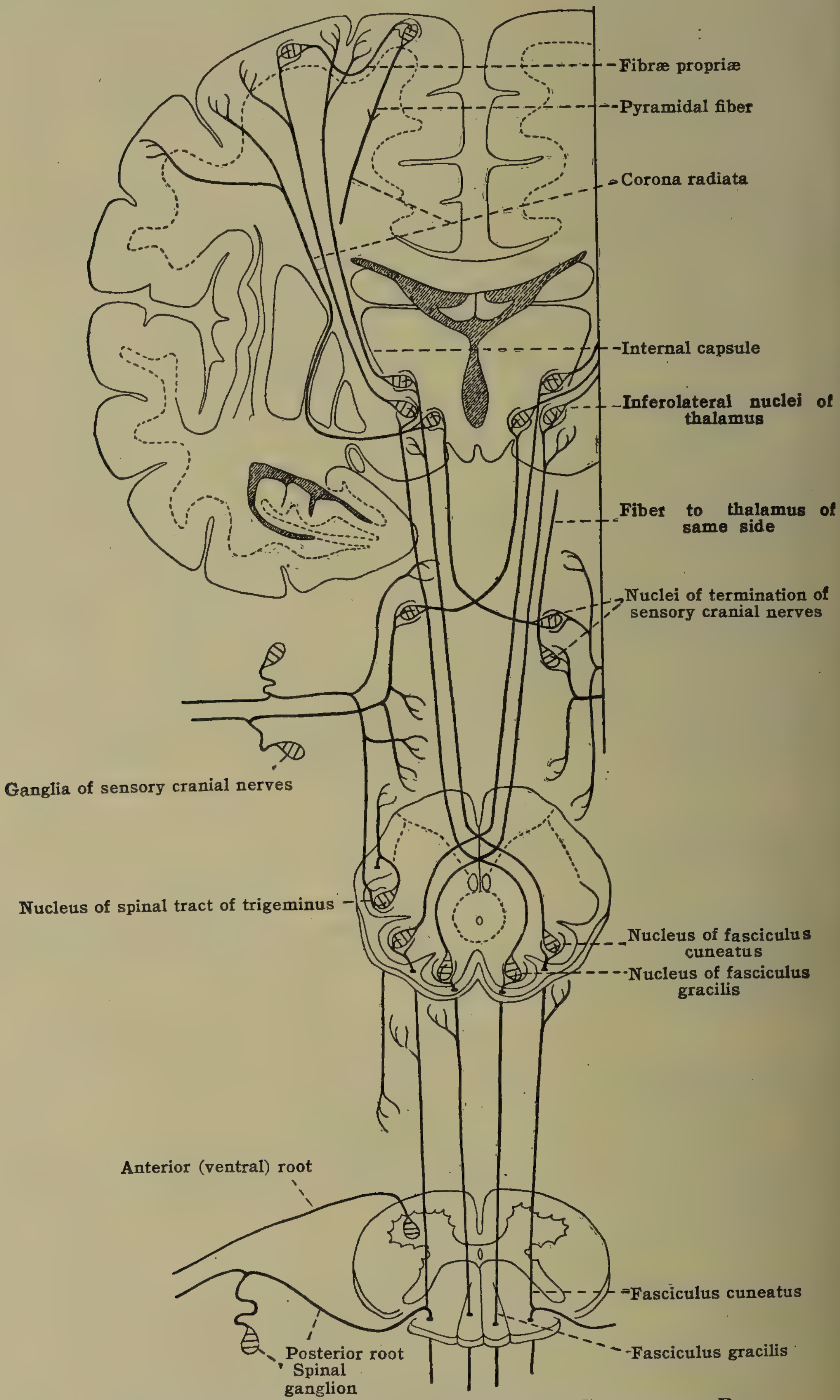


Fig. 780.—Scheme of Principal Spinocerebral Conduction-Path.

B. *Descending path of neurones* (fig. 781).
1. Giant pyramidal cells of precentral gyrus of somesthetic area.
  (a) Corona radiata, frontoparietal part.
  (b) Internal capsule, middle segments of frontoparietal portion.
  (c) Cerebral peduncle.
  (d) Pyramid of medulla oblongata.
  (e^1) Decussation of pyramids.

(f^1) Lateral cerebrospinal fasciculus (crossed pyramidal tract).
(e^2) Ventral cerebrospinal fasciculus (direct or uncrossed pyramidal tract).
(f^2) Gradual decussation of latter in cervical and upper thoracic regions of spinal cord.

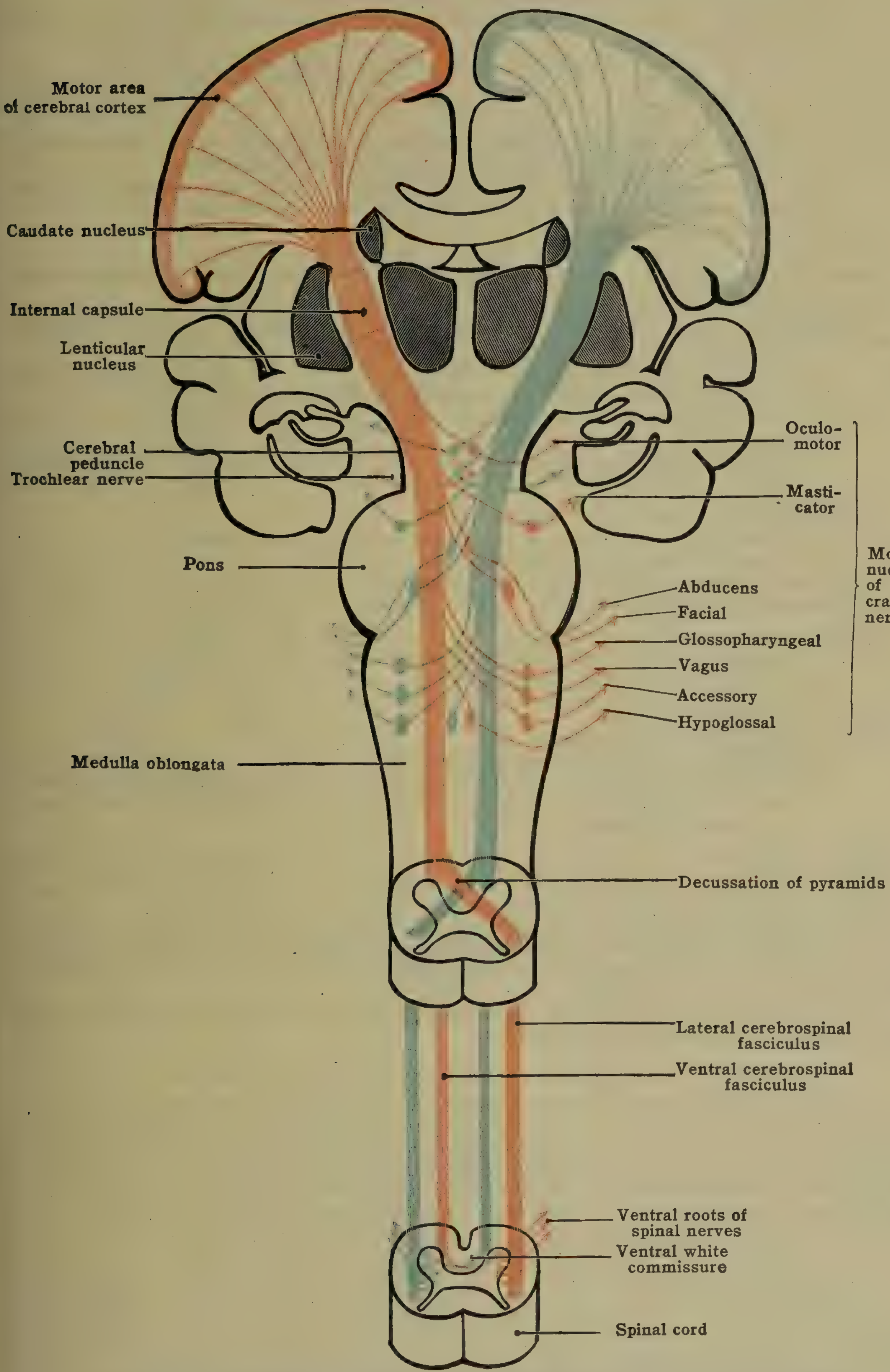


FIG. 781.—SCHEME OF DESCENDING CEREBROSPINAL CONDUCTION-PATH. (Extrapyramidal paths not included.)

1*x*. Extrapyramidal system, see p. 965.
2. Cells of ventral horn of spinal cord of opposite side.
   (*a*) Ventral or efferent roots of spinal nerves.
   (*b*) Peripheral nerve-trunks directly to skeletal muscles or indirectly to smooth muscle or glands by way of sympathetic neurones.

II. Short Reflex Paths of Spinal Cord

1. Spinal ganglia.
   - (a) Terminal corpuscles and peripheral process of T-fibers.
   - (b) Dorsal root of spinal nerve.
   - (c) Collaterals and terminal branches of bifurcation of dorsal root fibers within spinal cord
   - (d) Directly to ventral horn cells of same level of spinal cord.
   - (e) Or, more commonly, to same through intermediation of Golgi cell of type II.
   - (f) Or to neurones of fasciculi proprii to ventral horn cells of other levels of spinal cord.
2. Ventral horn cells of same (chiefly) and opposite side and thence by way of ventral roots and peripheral nerve trunks directly to skeletal muscles.
3. Dorsolateral group of ventral horn cells of same (chiefly) and opposite sides and thence by ventral root fibers to cell-bodies in sympathetic ganglia.
4. Sympathetic axones to smooth muscle or glands.

III. Cerebral Path for the Cranial Nerves, Exclusive of Those of Special Sense

A. Ascending system of neurones.

1. Ganglia of origin of sensory components of vagus, glossopharyngeus, glossopalatine and trigeminus.
   - (a) Peripheral arborizations and afferent peripheral branches of T-fibers of same.
   - (b) Central branches of T-fibers of same (sensory nerve roots).
2. Nuclei of termination of central branches (bifurcated and unbifurcated) in brain stem.
   - (a) Reticular formation, internal arcuate fibers and medial lemniscus of the opposite side. Trigeminal portion (trigeminal lemniscus) courses separated from medial lemniscus in mesencephalon.
3. Inferior and lateral nuclei of thalamus.
   - (a) Internal capsule, posterior segment of frontoparietal portion.
   - (b) Corona radiata, frontoparietal part.
4. Cerebral cortex—chiefly lower third of posterior central gyrus.
   - (a) Association and commissural fibers of cortex.

B. Descending system of neurones.

1. Pyramidal cells of opercular region of somesthetic area.
   - (a) Corona radiata, frontoparietal.
   - (b) Internal capsule, genu chiefly.
   - (c) Cerebral peduncle.
   - (d) Decussation in brain-stem.
   - (e) Aberrant pyramidal fibers and pyramid.
2. Nuclei of origin of motor cranial nerves and motor components of mixed cranial nerves, of opposite side chiefly, and thence by way of these nerves to the respective muscles supplied.

Notes: (1) Most of the descending cortical fibers to the nucleus of origin of the trochlear nerve and that portion of the nucleus of the oculomotor which supplies the internal rectus muscle apparently do not decussate but terminate in the nuclei of the same side.

(2) The efferent nucleus of the glossopalatine (salivatory nucleus) and the dorsal efferent nucleus of the vagus give rise to visceral efferent fibers, i.e., carry impulses destined for smooth muscle and glands by way of sympathetic neurones. The same is true for the superomedial part of the nucleus of the oculomotor.

(3) The nuclei of termination of the cranial nerves, especially those of the vestibular and trigeminus, send fibers also into the cerebellum.

IV. The Short Reflex Paths of the Cranial Nerves

These consist of the central branches of their afferent or sensory fibers, bearing impulses to the nuclei of origin of both their own motor components and to the nuclei of origin of other motor nerves. Fibers to the more distant nuclei pass to them by way of the medial longitudinal fasciculus. Instead of terminating in the motor nuclei directly, the sensory fibers are usually interrupted by a third or intermediate neurone interposed in the chain. The vagus and glossopharyngeal are connected by way of the solitary fasciculus and its nucleus with the structures below their level of entrance, the vagus with the ventral horn cells of the upper segments of the cervical cord, and through these with the muscles of respiration.

Depressor fibers of the vagus (or the *depressor nerve* of animals having one) collect 'inhibitory impulses' in the domain of the vagus. These impulses, to be inhibitory, either cause a blocking of the central synapses of vasomotor neurones, or they are transferred to certain neurones of the efferent nuclei of the vagus in the floor of the fourth ventricle whose axones carry efferent impulses inducing the secretion of some substance (acetylcholine?) which renders the cardiac and smooth muscle concerned incapable of contraction. Probably a sympathetic neurone is a link in such a chain as the latter, but the components of the inhibitory chain are not known with certainty.

V. Conduction-Paths Involving the Cerebellum

A. Ascending cerebellar pathways.

1. Spinal ganglia.
   - (a) Terminal corpuscles, trunks and dorsal roots of spinal nerves.

(*b*) Collaterals and terminal branches of bifurcation of dorsal root fibers in spinal cord, chiefly those conveying impulses of *muscle-sense.*

2*x*. Dorsal nucleus (Clarke's column).
(*a*) Dorsal spinocerebellar fasciculus (direct cerebellar tract).
(*b*) Restiform body (inferior cerebellar peduncle)—
(*c*) Joined in medulla by external arcuate fibers (crossed and uncrossed fibers arising in nuclei of funiculus gracilis and cuneatus);
(*d*) Joined in medulla by fibers arising in nuclei of termination of afferent vagus, glossopharyngeal, vestibular, and trigeminal nerves;

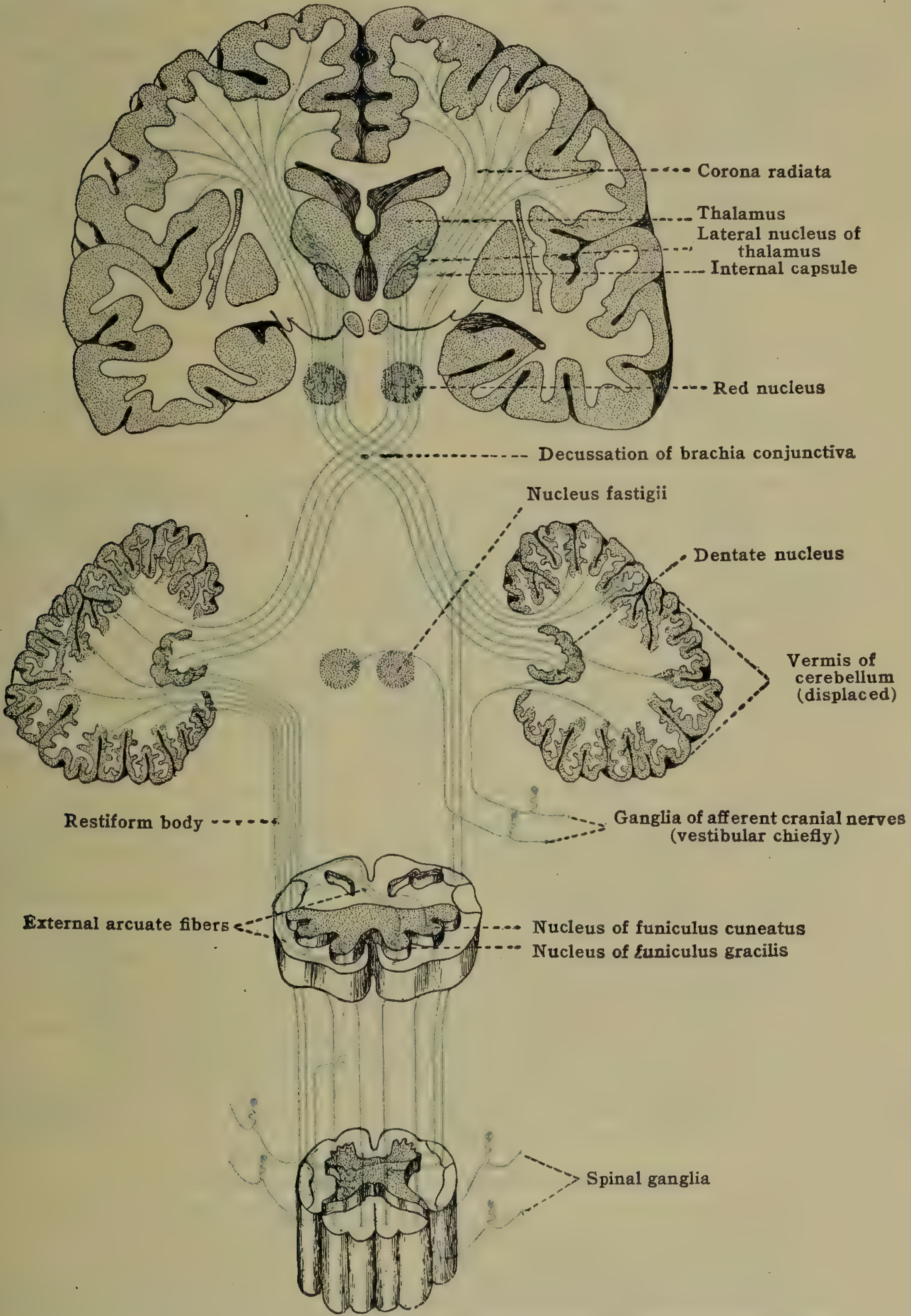


FIG. 782.—SCHEME OF PRINCIPAL ASCENDING CEREBELLAR CONDUCTION-PATHS.

(*e*) Joined by fibers both to and from (ascending and descending) the inferior olivary nucleus of the same and especially opposite sides (*olivo-cerebellar fibers*).

2*y*. Nerve-cells in base of ventral horn of same and opposite side (lumbosacral region).
(*a*) Superficial anterolateral spinocerebellar fasciculus (Gowers' tract), ascending through spinal cord and reticular formation of medulla and pons.
(*b*) Anterior medullary velum and brachium conjunctivum to cerebellar cortex (vermis chiefly).

3. Cerebellar cortex, dentate nucleus, nucleus fastigii, nucleus emboliformis, and nucleus globosus.

(a) White substance (corpus medullare) of cerebellum, associating various regions of its cortex and its nuclei with each other.
(b) Brachium conjunctivum (superior cerebellar peduncle) arising chiefly from dentate nucleus.
(c) Decussation of brachium conjunctivum.

4. Red nucleus and lateral nucleus of thalamus. Most fibers of the brachium conjunctivum terminate in the red nucleus; many merely give off collaterals to it in passing to their termination in the thalamus. Most of the ascending fibers arising in the red nucleus also terminate in the thalamus; some ascend to the cerebral cortex direct.
(a) Internal capsule, middle third, and frontoparietal part of corona radiata.
(b) Somesthetic area of cerebral cortex and cortex of frontal lobe anterior to it.
(c) Inferior peduncle of thalamus to cortex of temporal lobe.

B. *Descending cerebrocerebellar paths.*

1. Pyramidal cells of somesthetic area send fibers through corona radiata, internal capsule, and cerebral peduncle to nuclei of pons and arcuate nucleus of same and opposite side.
2. Cells of cortex of posterior part of frontal lobe give fibers to form frontal pontile path through frontal parts of corona radiata and internal capsule and through medial part of cerebral peduncle to nuclei of pons of opposite side.
3. Cells of cortex of temporal lobe (superior and middle gyri) give fibers to form temporal pontile path which passes under the lenticular nucleus into anterior segment of occipital portion of internal capsule and lateral part of cerebral peduncle to nuclei of pons of opposite side. This path is joined in the internal capsule by a small occipitopontile path.
4. Cells of nuclei of pons send fibers by way of brachium pontis (middle cerebellar peduncle) to cortex of cerebellar hemisphere of side opposite to that of the origin of the cerebral fibers making synapses with the cells of the pons.

C. *Descending cerebellospinal paths.*

1. Probably from cells of nucleus fastigius of same and opposite sides and probably from other nuclei of cerebellum arise fibers which terminate in the nuclei of termination of the vestibular nerve and reticular formation; these send fibers into the intermediate and anterior marginal fasciculi of spinal cord (fig. 698), and thence to the cells of the anterior horn.
2. The pathway arising in the red nucleus of the opposite side and descending in the rubrospinal tract of the lateral funiculus of the spinal cord (fig. 698). The rubrospinal tract decussates in the ventral portion of the tegmentum of the mesencephalon and is said to pass through the medulla oblongata in the medial longitudinal fasciculus. It must be noted here that in addition to the brachium conjunctivum some fibers arising in the cortex of the frontal lobe terminate in the red nucleus (corticorubral path). Compare with the extrapyramidal paths, p. 965.

VI. The Vestibular Conduction-Paths (Equilibration)

1. Vestibular ganglion gives origin to the peripheral utricular, saccular and three ampullar branches and to the combined and centrally directed vestibular nerve.
2. Lateral vestibular nucleus (Deiters'), medial nucleus, superior nucleus, and nucleus of descending or spinal root (nuclei of termination) give origin to fibers as follows:—
(a) From lateral and superior nuclei to nucleus fastigii of opposite side and to cortex of vermis and to dentate nucleus (cerebellar connection).
(b) From medial and superior nuclei to nuclei of origin of eye-muscle nerves of same and opposite sides, by way of medial longitudinal fasciculi.
(c) From lateral nucleus and nucleus of descending root through reticular formation into lateral and ventral vestibulospinal tracts of spinal cord.
(d) The nuclei receive fibers from the gray substance of the vermis. It is possible that all the nuclei of termination give off fibers bearing ascending impulses which ultimately reach the cerebral cortex, but the course pursued and neurones involved in such a chain are uncertain.

VII. The Auditory Conduction-Path (Cochlear Nerve)

1. Spiral ganglion of the cochlea gives origin to short peripheral fibers to organ of Corti, and to the centrally directed cochlear nerve.
2. Dorsal and ventral nuclei of the cochlear nerve (nuclei of termination).
(a) Some of the fibers of the striæ medullares arise from dorsal nucleus and pass around outer side of restiform body (acoustic tubercle), then medianward under ependyma of floor of fourth ventricle to midline, then ventralward into tegmentum, where they decussate and join trapezoid body and lateral lemniscus of opposite side.
(b) Fibers arising in ventral nucleus pass ventrally medianward and some terminate in the superior olivary nucleus of same side; others pass by way of trapezoid body and lateral lemniscus to terminate in superior olivary nucleus, nucleus of lateral lemniscus, medial geniculate body and nucleus of inferior quadrigeminate body of the opposite side.
3. Nuclei of superior olives of both sides and nucleus of lateral lemniscus send fibers to reticular formation and medial longitudinal fasciculus, associating auditory impulses with the nuclei of the motor cranial nerves.

4. Fibers from medial geniculate body and probably some from nucleus of inferior quadri geminate body pass into internal capsule and through temporal part of corona radiata to middle third of superior temporal gyrus and adjacent portions (auditory area).
5. It is probable that fibers from the auditory area of the cerebral cortex are also distributed to nuclei of the motor cranial nerves by way of the inferior quadrigeminate bodies.

VIII. Conduction-Paths of the Visual Apparatus

A. *Optic impulses.*

1. Synapses of central processes of rods and cones (neuroepithelium) with short (peripheral) processes of bipolar cells of retina and synapses of centrally directed processes of bipolar cells with dendrites of ganglion cells of retina (nucleus of termination).
2. Ganglion-cells of retina give origin to—
   (*a*) Optic (nerve-fiber) stratum of retina.
   (*b*) Optic nerve.
   (*c*) Optic chiasma; fibers from nasal side of retina cross in chiasma to opposite side; fibers from lateral side of retina continue on same side in—
   (*d*) Optic tract to —

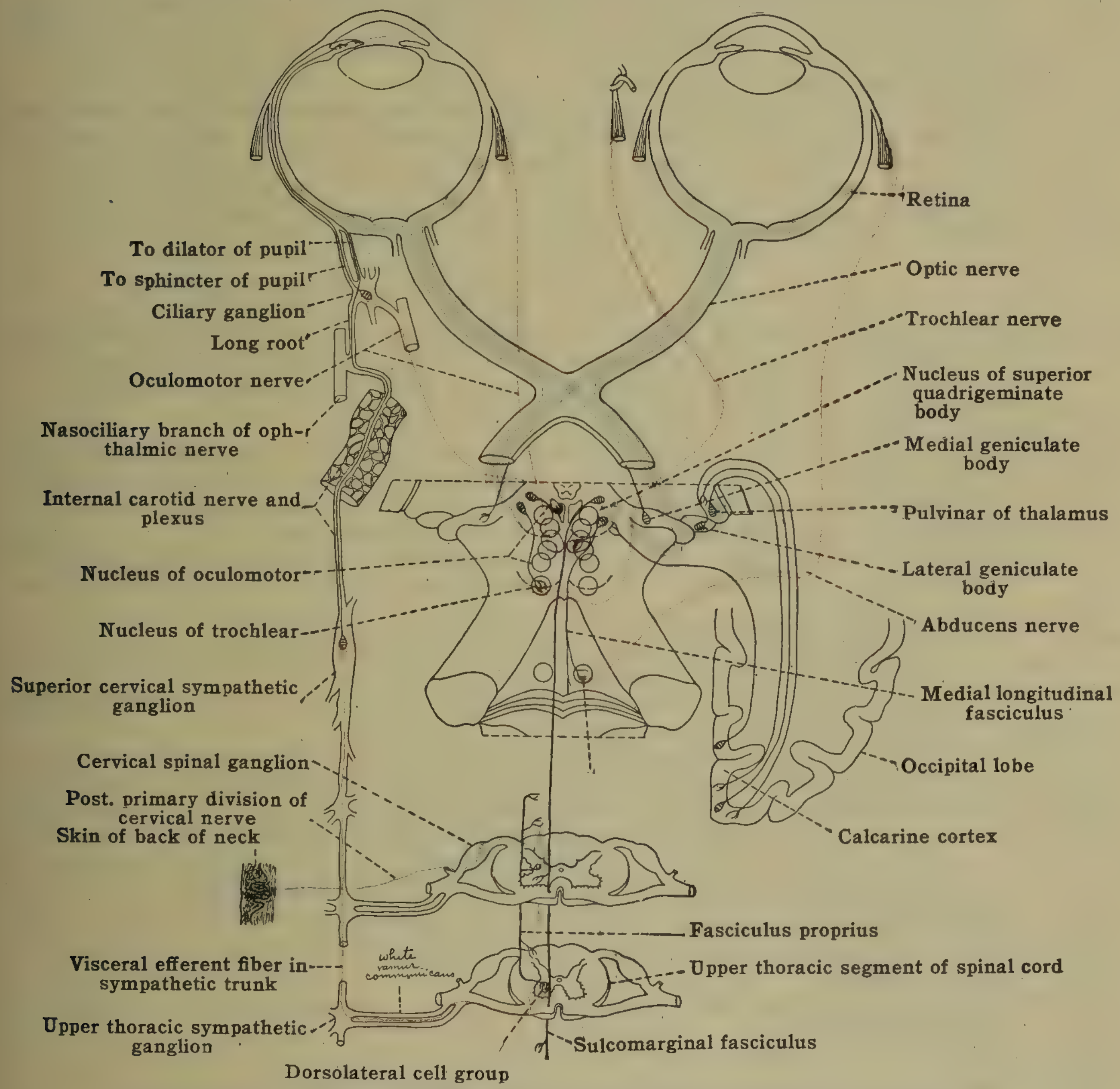


Fig. 783.—Diagram of Principal Pathways of Optic Apparatus.

3. Lateral geniculate body, pulvinar of thalamus, and nucleus of superior quadrigeminate body.
   (*a*) Fibers from nucleus of superior quadrigeminate body pass ventrally, to nuclei of origin of oculomotor and trochlear nerves and to medial longitudinal fasciculus of same and opposite sides, and from it are distributed to nuclei of origin of abducens and facial nerves.
   (*b*) Fibers from lateral geniculate body, chiefly, and pulvinar pass through occipital portion of internal capsule and occipitothalamic radiation (optic radiation) to cortex of occipital lobe (visual area).
4. Cells of visual area of cortex send fibers through occipitothalamic radiation and occipital portion of internal capsule to nucleus of superior quadrigeminate body (occipitomesencephilic fasciculus), and thence, probably interrupted by cells of this nucleus, the impulses are carried to nuclei of eye-muscle nerves.

5. Cells of nucleus of superior quadrigeminate body and pulvinar send fibers by way of medial longitudinal fasciculus into lateral and ventral funiculi of spinal cord (see fig. 698), chiefly of the opposite side. Fibers from the quadrigeminate body cross midline chiefly in decussation of 'optic-acoustic reflex path' (fig. 741) and in fountain decussation.
6. The smaller cells of the superomedial group of the nucleus of the oculomotor nerve (nucleus of Edinger and Westphal) send axones, by way of the trunk of the nerve and the short root of the ciliary ganglion, which terminate about cells in—
7. The ciliary ganglion, whose cells send axones to enter the ocular bulb and terminate upon the smooth muscle fibers of the ciliary body and sphincter of the iris.

B. *Spinopupillary ('ciliospinal') reflexes.*
1. Peripheral processes of spinal ganglion cells terminating in the skin and central processes of same entering by way of dorsal roots of spinal nerves to bifurcate in spinal cord and give terminal twigs about—
2. Cells of the dorsolateral group of the ventral horn of the same and opposite sides of cervical and upper thoracic regions of spinal cord. These cells send (visceral efferent) axones by way of white rami communicantes of upper thoracic nerves and sympathetic trunk to terminate about cells in—
3. The superior cervical sympathetic ganglion, which cells send axones chiefly by way of the carotid plexus and the sympathetic roots of the ciliary ganglion, through ciliary ganglion without synapses, into the ocular bulb to terminate in the ciliary body and radial (dilator) muscle fibers of the iris, producing dilation of the pupil.

C. *Auditory-eye reflexes.*
1. Cells of the nuclei of termination of the cochlear nerve and superior olive send fibers by way of the medial longitudinal fasciculus (some to this by way of the peduncle of the superior olive) to the nuclei of origin of the eye-moving nerves.
2. The same nuclei of the cochlear nerve send axones by way of the lateral lemniscus to terminate in the superior quadrigeminate body and thence may be sent impulses which are distributed to the nuclei of the eye-moving nerves.

IX. Principal Conduction-Paths of Olfactory Apparatus

1. Bipolar cells in olfactory region of nasal epithelium send short (peripheral) processes to surface of the epithelium and centrally directed processes, the olfactory nerve, through lamina cribrosa of ethmoid bone into olfactory bulb (glomerular layer).
2. 'Mitral cells' of olfactory bulb give fibers which form—
(a) The olfactory tract which divides into—
(b) Medial olfactory stria through which fibers pass—(1) into parolfactory area (Broca's area); (2) into subcallosal gyrus; and (3) by way of anterior cerebral commissure to olfactory bulb and uncus of hippocampal gyrus of opposite side.
(c) Intermediate olfactory stria to anterior perforated substance.
(d) Lateral olfactory stria, which terminates to some extent in anterior perforated substance, but chiefly in uncus, hippocampal gyrus, and gyrus cinguli (olfactory area) of same side.
3. Cells of uncus and hippocampal gyrus give fibers which form—
   (a) The cingulum (in part), by which they are associated with the cortex of the gyrus cinguli and other areas of the cerebral cortex.
   (b) The hippocampal commissure (in part), by which they are correlated with the gray substance of the opposite side.
   (c) The fornix, which, interrupted in part in the nuclei of the corpus mammillare, conveys impulses—(1) to the anterior nucleus of thalamus of the same (chiefly) and opposite sides (mammillothalamic fasciculus), and (2) into the mesencephalon and substantia nigra (mammillomesencephalic fasciculus), and by way of this tract probably to the nuclei of the mesencephalon and medulla oblongata.
4. The parolfactory area, anterior perforated substance, anterior nucleus of thalamus and fornix give fibers which form the medullary stria of the thalamus and which terminate in the habenular nucleus.
5. Habenular nucleus sends fibers in fasciculus retroflexus to terminate in interpeduncular nucleus.
6. Interpeduncular nucleus sends fibers to nuclei of mesencephalon and probably to structures below it.

The Relations of the Brain to the Walls of the Cranial Cavity

The precise methods by which the exact positions of the most important fissures, sulci, gyri, and areas can be ascertained and mapped out on the surface of the head in the living subject are usually described in the textbooks of surgery. Here, only a very general survey of the relations of the brain to the cranial bones is given and from a purely anatomical standpoint (fig. 784).

The parts of the brain which lie in closest relation with the walls of the cranial cavity are the olfactory bulb and tract, the basal and lateral surfaces of the cerebral hemispheres, the inferior surfaces of the lateral lobes of the cerebellum, the ventral surfaces of the medulla and pons, and the hypophysis.

Certain of these portions of the brain lie in relation with the basicranial axis, that is, with the basioccipital, the basisphenoid, and the ethmoid bones, while others are associated with the sides and vault of the cranial cavity. Considering the former portions first, the ventral surface of the medulla oblongata, which is formed by the pyramids, lies upon the upper surface of the basioccipital bone. More superiorly the ventral surface of the pons rests upon the basisphenoid, from which it is partly separated by the basilar artery and the pair of abducens

nerves. In front of the dorsum sellæ the hypophysis (pituitary body) is lodged in the hypophyseal fossa. Still further forward the olfactory tracts lie in grooves on the upper surface of the presphenoid section of the sphenoid bone; and in front of the sphenoid the olfactory bulbs rest upon the cribriform plates of the ethmoid.

Posterior and lateral to the posterior part of the foramen magnum the hemispheres of the cerebellum are in relation with the cranial wall, resting upon the lower parts of the supraoccipital and the posterior parts of the exoccipital portions of the occipital bone, while anteriorly each hemisphere is in relation with the inner surface of the mastoid process and the posterior surface of the petrous portion of the temporal bone. The area of the cranial wall which is in close relationship with the cerebellar hemispheres may be indicated, on the external surface of the skull, by a line which commences at the inferior part of the external occipital protuberance and thence runs upward and lateralward. It crosses the superior nuchal line a little beyond its center, and, continuing in the same direction, crosses the inferior part of the lambdoid suture and reaches a point directly above the asterion (the meeting point of the occipital, temporal, and parietal (bones); thence it descends, just in front of the occipitomastoid suture, to the tip of the mastoid process, and there turns medialward to its termination at the margin of the foramen magnum, immediately behind the posterior end of the occipital condyle.

The basal surface of each cerebral hemisphere may be said to consist of two parts, an anterior and a posterior, separated by the stem of the lateral cerebral (Sylvian) fissure. The anterior part, formed by the orbital surface of the frontal lobe, rests upon the upper surfaces of the orbital plate of the frontal bone and the lesser wing of the sphenoid. It is, therefore, in close relation with the upper wall of the orbital cavity. The posterior part, behind the stem of the lateral fissure, begins with the anterior portion of the temporal lobe, including its pole. The pole itself projects against the orbital plate of the great wing of the sphenoid bone, and it is in relationship with the posterior part of the lateral wall of the orbit. The basal surface of the hemisphere, behind the pole of the temporal lobe, is in contact with the upper surfaces of the great wing of the sphenoid and the petrous part of the temporal bone.

The convex surfaces of the cerebral hemispheres have the most extensive relationships with the cranial wall, and it is more especially to these surfaces that the surgeon turns his attention. The general area in which the convex surface of each cerebral hemisphere is in relation with the skull bones is readily indicated by a series of lines which correspond with the positions of its superciliary, inferolateral, and superomedial borders.

The line marking the superciliary margin of the hemisphere commences at the nasion (the midpoint of the frontonasal suture); it passes lateralward above the superciliary ridge, crosses the temporal ridge, then, turning posteriorly in the temporal fossa, it reaches the parietosphenoidal suture, and continues backward along it to its posterior extremity.

The line marking out the inferolateral border commences at the posterior end of the parietosphenoidal suture, whence it passes downward, in front of the sphenosquamous suture, to the infratemporal crest (pterygoid ridge); there it turns posteriorly and, running parallel with and medial to the zygomatic arch, it crosses the root of the zygoma, and ascending slightly, it passes above the external auditory meatus. Continuing backward with an inclination upward it reaches a point immediately above the asterion; thence it descends, and, crossing the inferior part of the lambdoid suture and the superior nuchal line, it passes medialward to the inferior part of the external occipital protuberance.

The superomedial border of the hemisphere is defined by a line which runs from the nasion to the inion. This line should be drawn about 5 mm. lateral to the sagittal suture, because the medial area is occupied by the superior sagittal sinus, and it should be further away from the middle line on the right than on the left side, because the sinus tends to lie more to the right side.

The area of the cranial wall enclosed by the three lines which mark the positions of the superciliary, inferolateral, and the superomedial borders of the cerebral hemisphere is formed by the vertical plate of the frontal bone, the parietal bone, the great wing of the sphenoid, the squamous part of the temporal, and the upper section of the supraoccipital segment of the occipital bone. It covers the convex surfaces of the frontal, parietal, temporal, and occipital lobes of the cerebrum and the fissures and sulci which bound and mark them.

In every consideration of the topographical relations of the cerebral gyri to the walls of the cranial cavity it must be borne in mind that the conditions are not constant, and that, therefore, the relations are variable. The three main factors upon which this variability depends are age, sex, and the shape of the skull. As examples of the variations which occur it may be mentioned that the lateral cerebral fissure is relatively higher in the child than in the adult (compare figs. 784 and 785). The superomedial end of the central sulcus is further away from the coronal suture in the female and in the child than in the adult male, and in dolichocephalic than in brachycephalic heads. The angle formed between the line of the central fissure and the midsagittal plane, which averages about 68° in the adult, is more acute in dolichocephalic heads, and the external part of the parietooccipital fissure is further forward in the child, and possibly in the female, than it is in the adult male.

The position of the posterior horizontal limb of the lateral fissure varies even in the adult. Its posterior part is always under cover of the parietal bone, and it terminates either in front of or inferior to the parietal eminence, but the anterior part may be above, parallel with, or inferior to the squamoparietal suture. In the adult the anterior part of the fissure runs upward and backward from the posterior end of the sphenoparietal suture along the anterior part of the squamoparietal suture to its highest point; thence it continues in the same direction beneath the parietal bone toward the lambda, terminating either in front of or below the parietal eminence. In the child, however, the fissure is considerably above the line of the squamoparietal suture (fig. 785), which it gradually approaches, attaining its adult position about the ninth year. This change of position, which occurs during the first nine years, is due partly to the ascent of the sutural line and partly to the descent of the fissure on the surface of the brain.

The frontal bone always covers the superior, middle, and inferior frontal gyri, except their posterior extremities, which are beneath the parietal bone (fig. 784). The ascending limb (ra-

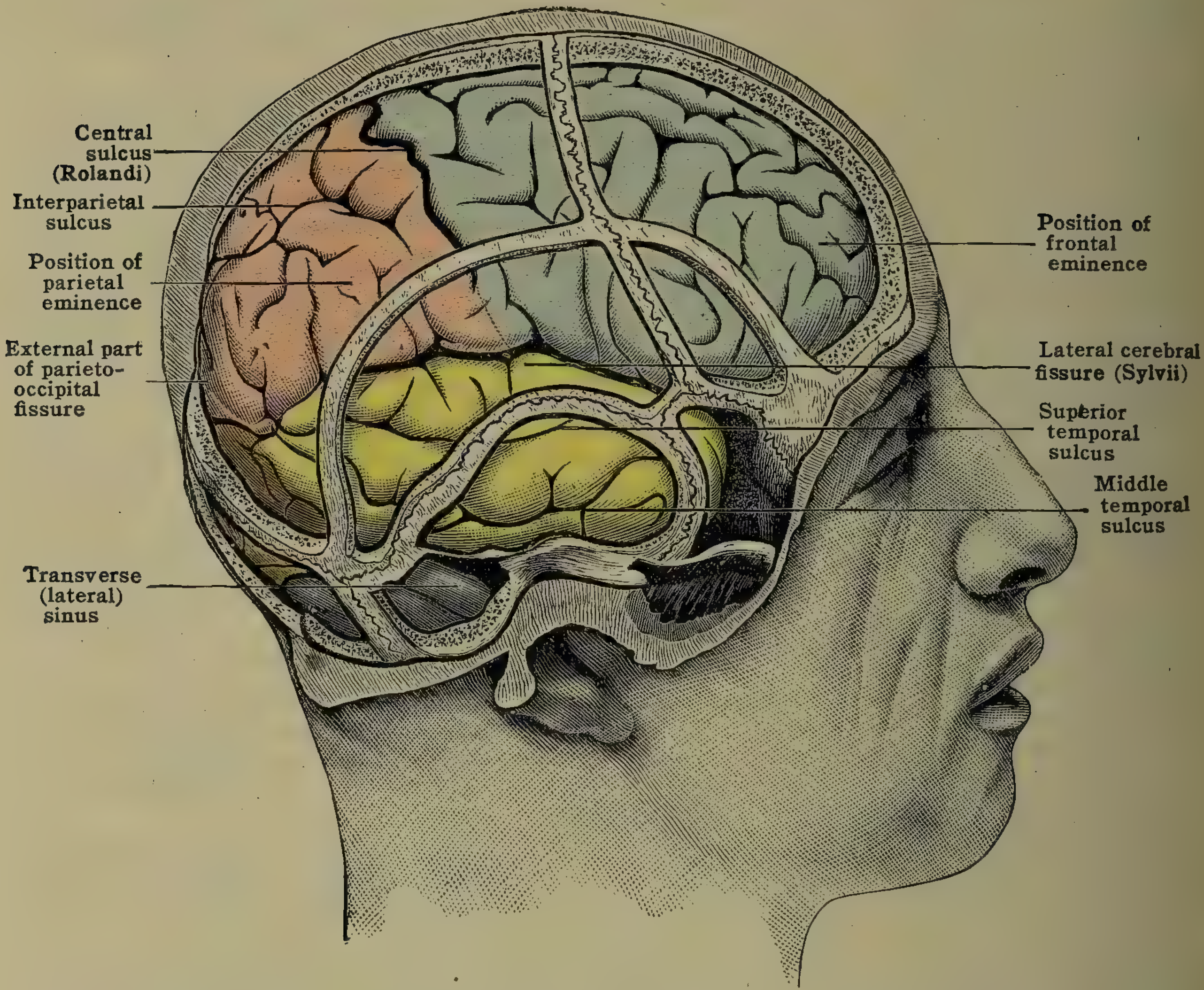


FIG. 784.—DRAWING OF A CAST OF THE HEAD OF AN ADULT MALE. (Prepared by Professor Cunningham to illustrate craniocerebral topography.)

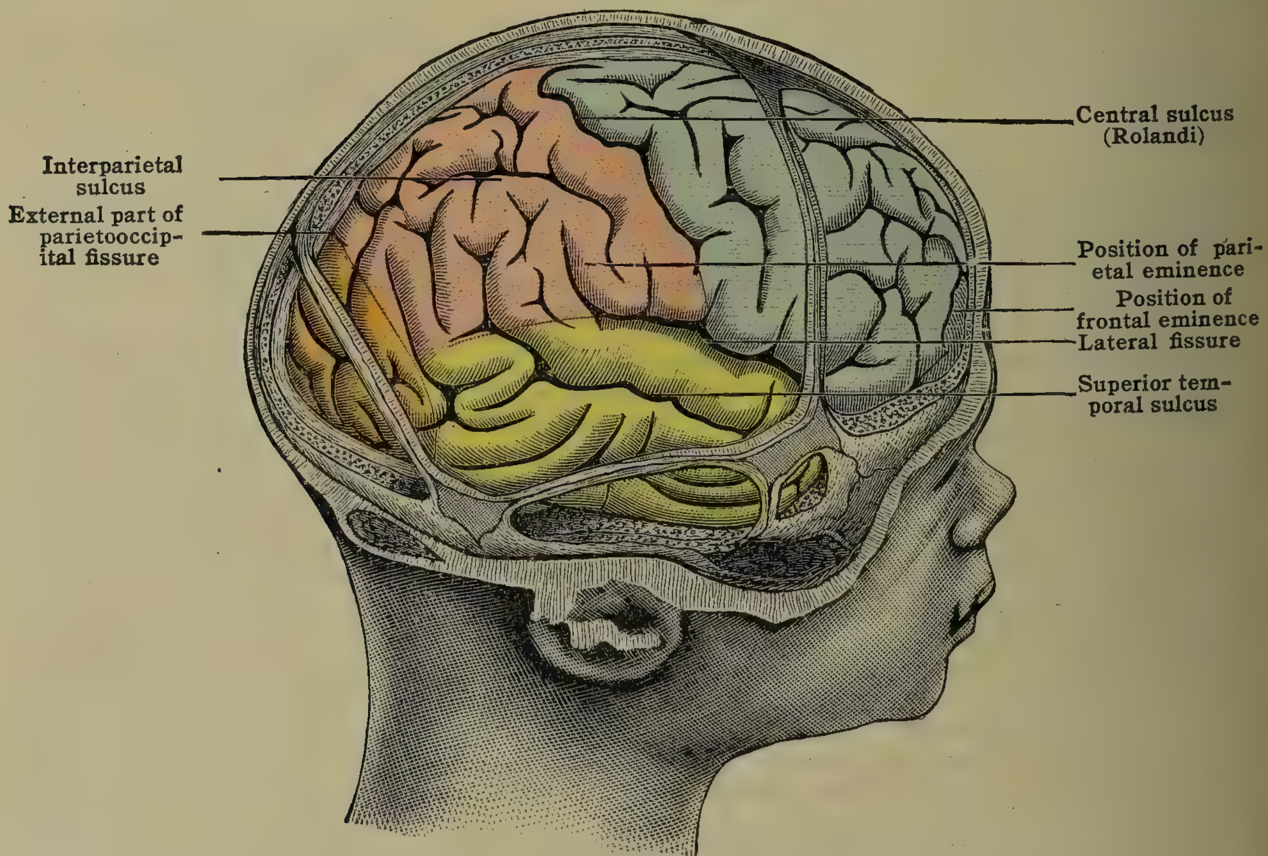


FIG. 785.—DRAWING OF A CAST OF THE HEAD OF A NEWLY BORN MALE INFANT. (Prepared by Professor Cunningham to illustrate craniocerebral topography.)

mus anterior ascendens) of the lateral fissure, which cuts into the posterior part of the inferior frontal gyrus, runs parallel with and under cover of the lower part of the coronal suture, or immediately in front of it, and the anterior horizontal limb is parallel with and beneath the upper margin of the great wing of the sphenoid.

The parietal bone is in relation with the convex surfaces of four lobes of the cerebrum. Speaking very generally, it may be said that the anterior third covers the posterior part of the frontal lobe, including the anterior central gyrus, the precentral sulcus and the posterior ends of the superior, middle and inferior frontal gyri. The posterior two-thirds of the bone are superficial to the parietal lobe, the posterior part of the temporal lobe, the anterior part of the occipital lobe, the posterior part of the horizontal limb of the lateral fissure, the superior and inferior parts of the postcentral sulcus, the interparietal sulcus, the posterior sections of the superior and middle temporal sulci, and the external part of the parieto-occipital fissure. The central sulcus is beneath the parietal bone at the junction of its middle and anterior thirds (fig. 784).

In the adult, the upper end of the central sulcus is situated at about 55 per cent. of the whole length of the nasoinionic line posterior to the nasion. It is about 4 or 5 cm. from the coronal suture. The inferior end of the sulcus, which extends to near the posterior horizontal limb of the lateral fissure, lies beneath the point of intersection of the auriculobregmatic line with a line drawn from the stephanion (the point where the temporal ridge cuts the coronal suture) to the asterion. This point is about 46 per cent. of the horizontal arc measured from the glabella to the inion.

The superior end of the parieto-occipital fissure usually lies about 5 mm. in front of the lambda, and the course of the fissure may be indicated by a line drawn from 5 mm. in front of the lambda to a point immediately above the asterion, and, as the latter point corresponds with the preoccipital notch on the inferolateral border of the hemisphere, the line in question will indicate the adjacent margins of the parietal, temporal, and occipital lobes.

The occipital bone is in close relation with the cerebellum, as already pointed out, but it also covers the posterior part of the lateral surface of the occipital lobe of the cerebral hemisphere. The great wing of the sphenoid covers the outer surface of the pole of the temporal lobe, and the squamous part of the temporal bone covers the anterior parts of the superior, middle, and inferior temporal gyri and the sulci which separate them.

The Blood-Supply of the Encephalon

The double origin of the continuous arterial system of the brain given by the confluence of the two vertebral arteries and the two internal carotid arteries, together with the description of the general distribution of the different cerebral, mesencephalic, and cerebellar arteries into which the system is divided, and the origin and course of the corresponding veins, are fully dealt with in Section VI. Here attention may be called briefly to the abundant and systematic internal distribution of the terminal branches of the system and their intimate arrangement for the nourishment of the actual nervous tissues within.

The general plan of the blood-supply for the entire encephalon may be summarized as follows:—(1) At their origin the different arteries are so connected, directly or indirectly, on the base of the encephalon, that the blood approaching the brain by way of the vertebral and internal carotid arteries is practically a common supply for all the arteries of the encephalon, and a given part of it may possibly pass into any one of them. (2) In the pia mater of each gross division of the encephalon, the different arteries again become connected with each other in a superficial, freely anastomosing plexus, continuous throughout. (3) From this plexus of the surface, naturally composed in part of the trunks of the different arteries themselves, arise central branches which enter directly into the nervous substance and which break up into twigs that are *terminal;* i.e., twigs that *do not* anastomose internally with the twigs of other central branches. (4) The arterial capillary system arising from the terminal twigs passes over into venous capillaries which converge to form corresponding venous twigs which in their turn pass to the surface and join in forming a peripheral, anastomosing venous plexus superimposed upon the similar arterial plexus. Thrombus or destruction of a central artery deprives of nourishment the domain it supplies, resulting in local necrosis (softening of the brain). (5) From this superficial venous plexus arise the different veins of the encephalon which may or may not accompany the arteries for a short distance, and which finally empty into the sinuses in the cranial dura mater. These, likewise confluent, empty into the internal jugular veins. The choroid plexuses of the ventricles of the brain are modifications of the general anastomosing peripheral plexuses. The choroid plexuses of the lateral and third ventricles are derived largely from the branches of the choroid arteries, which arise separately from the internal carotid arteries.

The **blood-supply of the cerebrum** may best be taken as an illustration of the general plan of the blood-vascular system of the encephalon. The terminal or internal branches of the surface plexus, derived from the posterior, middle, and anterior cerebral arteries, are arranged into two groups, a **ganglionic** (nuclear) and a **cortical group**. The ganglionic branches themselves form four groups in each hemisphere:—

(1) The *anteromedial group* consists of central branches from the plexus of the domain of the anterior cerebral artery, which pass through the medial part of the anterior perforated substance and supply the head of the caudate nucleus, the septum pellucidum, the columns of the fornix, and the lamina terminalis.

(2) The *anterolateral group* consists of central branches from the domain of the middle cerebral artery. These pierce the anterior perforated substance in two subgroups—(*a*) the internal and (*b*) the external striate arteries (fig. 786). The **internal striate arteries** pass through the segments of the globus pallidus of the lenticular nucleus and through the internal capsule, to both of which they give branches, and they terminate in the caudate nucleus and thalamus. The **external striate arteries** are larger and more numerous. They pass upward between the external capsule and the putamen, and then through or around the upper part of the putamen into the internal capsule, where they form two groups, the *lenticulothalamic*

and the *lenticulocaudate groups*. The former terminate in the thalamus and the latter in the caudate nucleus. On account of its larger size at its origin and its direct linear continuation with the internal carotid, emboli (*thrombi*) pass more frequently into the middle cerebral artery than into the anterior cerebral artery. One of the lenticulocaudate arteries which is larger and longer than the others and which is a direct branch from the middle cerebral artery has been called the **'artery of cerebral hemorrhage'** (Charcot), on account of the greater frequency with which it is blocked and ruptured.

(3) The *posteromedial* arteries are central branches of the posterior cerebral artery. They also enter the anterior perforated substance, but supply the floor of the third ventricle, the posterior part of the thalamus, and the hypothalamic region.

(4) The *posterolateral group* are also central branches of the posterior cerebral artery. They supply the posterior part of the internal capsule, the pulvinar of the thalamus, the geniculate bodies, the corpora quadrigemina and their brachia, the pineal body, and the cerebral peduncles.

The *cortical group* of the cerebral arteries arise from the anastomosing plexus in the pia mater of the cortical surfaces of the hemisphere. They pass into the cortical substance both from the summits of the gyri and from the walls of the sulci. They consist of short, medium, and long central branches, and pass at right angles into the gyri. The short branches terminate in the cortical substance; the medium branches supply the more adjacent white substance, and the longer branches pass more deeply into the general medullary center of the hemisphere.

All of both the ganglionic and the cortical arteries are terminal in the sense that they do not anastomose in the substance of the cerebrum. (Pfeifer, however, describes such anastomoses.)

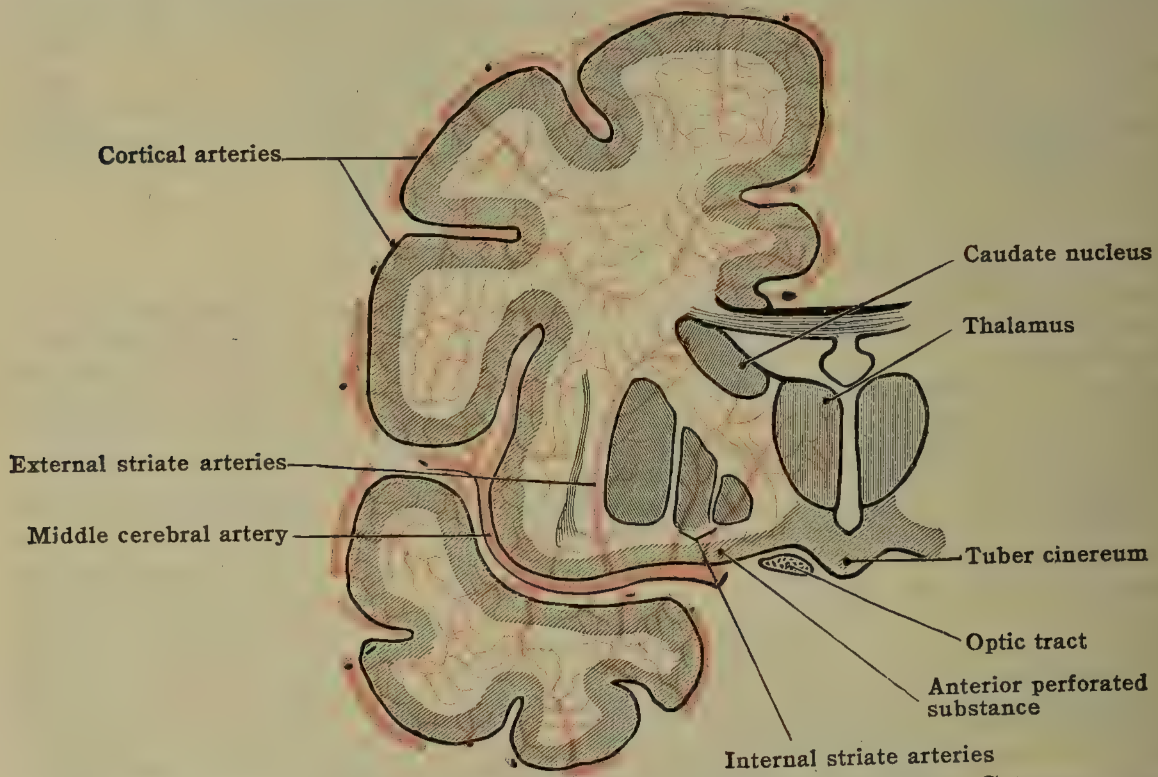


FIG. 786.—DIAGRAM SHOWING THE MANNER OF DISTRIBUTION OF THE CORTICAL AND CENTRAL BRANCHES OF THE CEREBRAL ARTERIES.

The blood-vascular system of the other divisions of the encephalon is in accordance with the same general plan of that of the cerebrum. Slight individual modifications of the general plan are to be expected.

The **blood-vessels of the mesencephalon**, in addition to the supply derived from the posterolateral group of ganglionic arteries, include the vessels of the quadrigeminate bodies and those of the cerebral peduncles. The **arteries of the quadrigeminate bodies** are usually six in number, three for each side—the **superior, middle,** and **inferior quadrigeminate arteries.** The superior and middle are branches of the posterior cerebral and the inferior are branches of the superior cerebellar arteries. The superior supply the superior quadrigeminate bodies and the pineal body; the middle supply both the superior and inferior quadrigeminate bodies, and the inferior the inferior quadrigeminate bodies. They all anastomose in the pia on the surface of the stratum zonale, forming a fine-meshed plexus, and from this superficial plexus the central branches pass into the substance of the bodies. The veins terminate in the vein of Galen (v. cerebri magna.)

The **arteries of the cerebral peduncles** form two groups, medial and lateral. The **medial peduncular arteries** are branches of the basilar and the posterior cerebral arteries. They pass to the medial sides of the peduncles and supply the superior and medial part of the tegmentum. The vessels of this group which accompany the fibers of the oculomotor nerves are known as the radicular arteries; they supply the root-filaments and the nuclei of the nerves, which receive no other branches. The **lateral peduncular arteries** are branches of the posterior cerebral and superior cellebellar arteries. They supply the lateral portions of the peduncles and the lateral part of the tegmentum. The veins of the midbrain terminate in the basilar veins and the vein of Galen.

The **blood-vessels of the cerebellum.**—Six arteries supply the cerebellum; two, the **posterior inferior cerebellar,** are derived from the vertebral arteries and the remaining four, two **anterior inferior** and two **superior cerebellar,** from the basilar artery. The course and

general distribution of the arteries are described in Section VI, but here it must be noted that the branches of these six vessels form a rich network in the pia mater on the surfaces of the cerebellar lobes, and that extensions of the plexus pass with the folds of the pia mater into the sulci and fissures. From the superficial plexus central branches pass into the interior of the cerebellum and their collaterals from capillary plexuses in the white and gray substance. These branches of the surface plexus are of three lengths:—(1) a longer set, which pass through the cortex of the cerebellum and supply the white substance of the corpus medullare; (2) a set of shorter arterioles which pass through the molecular layer of the cortex and break up in its granular layer; (3) the shortest set pass into the cortex and immediately break up in its molecular layer. The meshes of the capillary plexuses in the gray substance are ovoidal and their axes run radially. The meshes of the plexuses in the white substance are elongated parallel with the nerve-fibers. In addition to the vessels mentioned, a distinct central branch is distributed to each dentate nucleus. This springs either from the superior cerebellar or from the anterior inferior cerebellar artery of the corresponding side.

The **efferent veins** of the cerebellum do not accompany the arteries; they form a plexus in the pia mater which receives tributaries from the capillaries of the terminal branches of the central arteries in the interior, and they form two groups on each cerebellar surface, the vermian veins and the lateral veins. The **superior vermian vein** runs forward on the superior surface of the vermis and terminates in the vein of Galen. The **inferior vermian vein** runs posteriorly and ends in one of the transverse sinuses. The **superior lateral veins** open into the superior petrosal or transverse sinuses, and the **inferior lateral veins** into the inferior petrosal and transverse sinuses. The vein from the dentate nucleus usually joins the inferior lateral veins.

The blood-vessels of the pons.—The arteries to the pons are branches of the basilar artery, and of its anterior inferior and superior cerebellar branches. The plexus in the pia mater is comparatively unimportant, and the branches which enter the substance of the pons form two main groups, the central and the peripheral. The **central arteries** spring directly from the basilar. They pass backward along the raphe, giving branches to the adjacent parts, and they terminate in the nuclei of the pons and those in the floor of the fourth ventricle. The **peripheral arteries** are radicular and intermediate. The *radicular branches* spring from the peripheral plexus and from the anterior inferior cerebellar arteries; they accompany the roots of the trigeminus, abducens, facial, vestibular, and cochlear nerves, supply their fibers and the adjacent parts, and they end in the gray nuclei with which the nerve-fibers are connected. Of the radicular branches, the *internal auditory artery* is often quite large, arising directly from either the basilar artery (usually, figs. 536, 794) or from the anterior inferior cerebellar artery. For further details, see pp. 636, 1189. The *intermediate arteries* enter the surfaces of the pons irregularly and break up into capillaries in its substance, just as the central arteries. **The veins** form a plexus on the surface. The dorsal and lateral part of this plexus is drained into the basilar vein on each side, and the inferior part is connected by efferent channels with the inferior petrosal sinus and the cerebellar veins.

The blood-vessels of the medulla oblongata.—The **arteries of the medulla** are derived directly from the vertebral arteries, from their anterior and posterior spinal and posterior inferior cerebellar branches, and from the basilar artery. The branches of these vessels form a plexus in the pia mater from which, and from the arteries themselves, three main groups of vessels pass into the medulla—the choroidal, the central, and the peripheral. The **choroidal arteries** are derived chiefly from the posterior inferior cerebellar arteries. They supply the choroid plexus of the fourth ventricle. The **anterior central arteries** rise from the anterior spinal artery, from the basilar artery, and from the peripheral plexus; they pass caudalward along the raphe, supplying the adjacent parts of the ventral funiculi and the olivary bodies and they break up into fine terminals in the gray substance of the floor of the fourth ventricle around the nuclei of the cranial nerves. The **posterior central arteries** spring from the posterior spinal arteries; they pass down the median septum of the inferior part of the medulla and supply the adjacent nervous substance. The **peripheral arteries,** like those of the spinal cord, are separable into radicular and intermediate groups. The *radicular arteries* pass from the anterior and posterior spinal branches and from the trunks of the vertebral arteries and accompany the fibers of the last six cranial nerves into the substance of the medulla. They supply the nerve-roots and adjacent white substance and they terminate in capillaries in the gray substance of the lateral part of the floor of the ventricle. The *intermediate peripheral arteries* spring from the arteries previously named and from the peripheral plexus, and they pass directly into the funiculi of the medulla, where they terminate in a capillary plexus which supplies the white substance and the gray nuclei; some of these arteries, more especially those derived from the posterior inferior cerebellar and the posterior spinal arteries, extend inward to the lateral part of the floor of the fourth ventricle. Twigs of all peripheral arteries anastomose with the common superficial plexus in the pia mater with which all central arteries are connected.

The veins which issue from the medulla form a peripheral plexus in the pia mater in which there are two main longitudinal channels, and **anterior median** and a **posterior median vein.** The former communicates posteriorly with the anterior median vein of the cord, and anteriorly with the veins of the pons and with the veins which accompany the hypoglossal nerves. The latter veins empty into the internal jugular veins. The posterior median vein is continuous caudally with the corresponding vein of the cord, and anteriorly, in the region of the calamus scriptorius, it divides into branches which join the radicular veins. The blood is carried away from the peripheral plexus mainly by the **radicular veins,** which pass along the roots of the last six cranial nerves. Those which accompany the hypoglossal nerves have already been referred to. The others end in the terminal parts of the transverse sinuses, the inferior petrosal sinuses, or the inferior part of the occipital sinuses.

The **nerve supply of the blood-vessels** of the brain consists of a perivascular plexus of sympathetic nerve-fibers upon the walls of the vessels and medullated fibers which accompany the vessels and apparently terminate, for the most part, in the connective tissue about them. The former are thought to be vasomotor in function; the latter probably sensory fibers of the craniospinal type. Sensory nerve endings were first described only for the larger vessels by

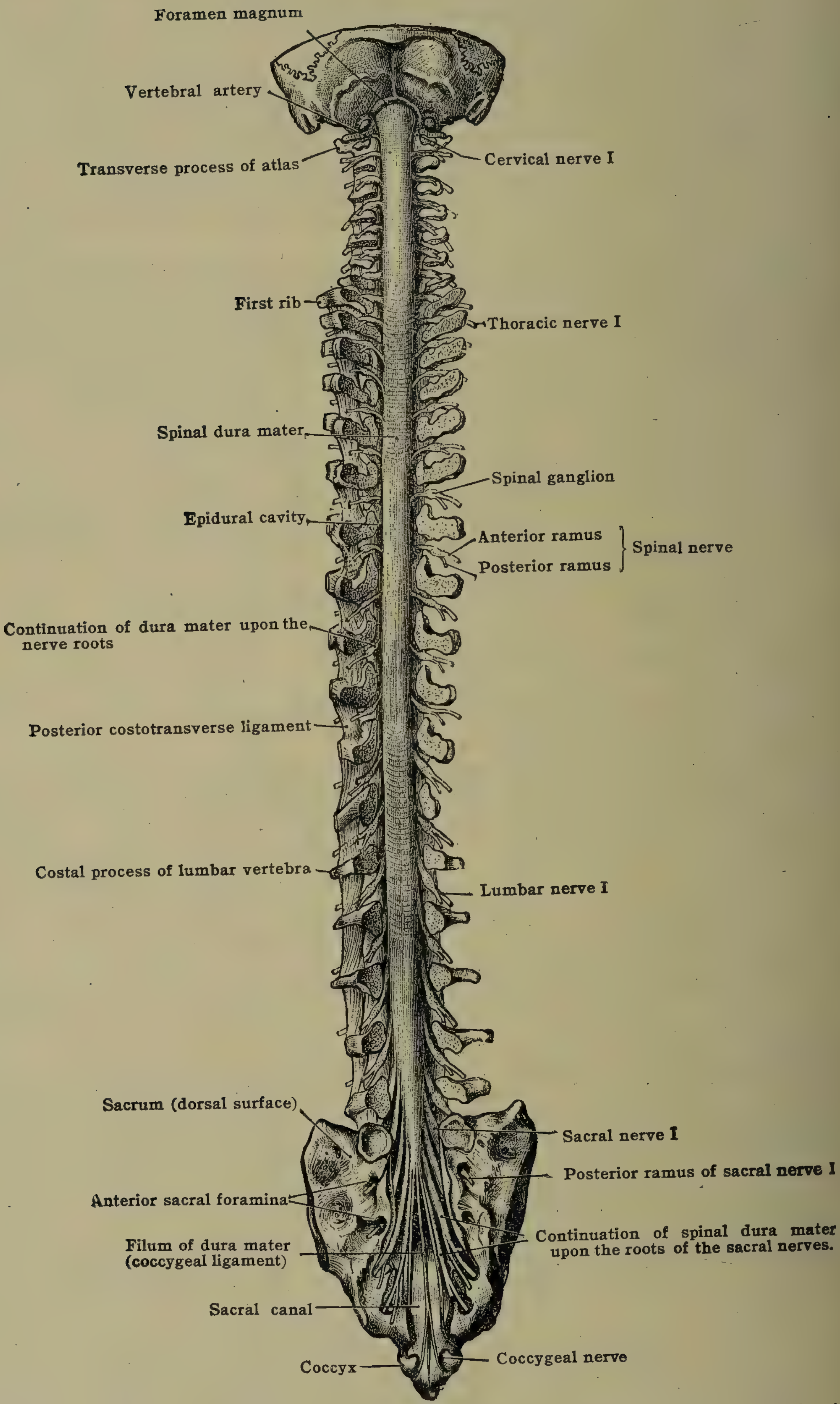


FIG. 787.—SHOWING THE SPINAL DURA MATER EXPOSED *in situ.* (Dorsal aspect.) (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

Huber. Certain headaches are explained by sensory nerve endings in the walls of the central vessels especially. The muscular coat of the arteries of the brain is peculiarly thin.

IV. THE MENINGES

Three membranes, collectively called the **meninges**, envelope the entire central nervous system, separate it from the walls of the bony cavities in which it lies, and aid in its protection and support. They consist of feltworks in which white fibrous connective tissue predominates, and through them pass the blood-vessels which supply the central nerve-axis and the nerves by which the axis is connected with the periphery. Though there are definite spaces or cavities between them, the membranes are not wholly separated from each other, and they are both continuous with and contribute to the walls of the blood-vessels and the sheaths (epineurium) of the nerves passing through them. Beginning with the outermost, they are—(1) the *dura mater*, the thickest, most dense and resistant of the membranes (pachymeninx); (2) the *arachnoid*, the much less dense, web-like middle membrane (leptomeninx); and (3) the *pia mater*, a thin, compact membrane, closely adapted to the surface of the central system, into which it sends numerous connective tissue processes. The pia is highly vascular, containing the rich superficial plexuses of blood-vessels from which the intrinsic blood-supply of the central system is derived. The space between the dura mater and the arachnoid is known as the *subdural cavity*, and that between the arachnoid and the pia mater is the *subarachnoid cavity*.

The Dura Mater

In the fresh condition the dura mater (or pachymeninx NK) appears as a bluish-white, exceedingly resistant membrane, forming the outermost envelope of the entire central nervous system. Its external surface or that next to the bony wall is rough, while its internal surface appears smooth, due to the fact that the subdural cavity partakes of the nature and has the lining of a lymph-space. The cranial dura mater consists of two distinct, closely associated layers, the outermost of which serves as the internal periosteum of the cranial bones. The spinal dura mater is described as consisting of but one layer. The internal periosteum of the spinal canal, though continuous at the foramen magnum with the outer layer of the cranial dura mater, is not considered a part of the spinal dura mater, from the fact that it is so widely separated from the layer actually investing the spinal cord by the epidural space. Thus, since the cranial and spinal portions of the dura mater differ, they are described separately.

The spinal dura mater is a fibrous tube with funnel-shaped caudal end which encloses and forms the outermost support of the spinal cord. It consists of but one layer and this corresponds to the inner layer of the cranial dura mater. It begins at the foramen magnum and terminates in the spinal canal at about the level of the second piece of the os sacrum. It is firmly attached to the internal periosteum of the surrounding bones of the vertebral canal only in certain localities:—

(1) The upper end of the tube blends intimately with the internal periosteum of the cranium at the margin of the foramen magnum, and thus in this locality it becomes continuous with the outer layer of the cranial dura mater. Also in this locality it is attached firmly, though less intimately, to the periosteum of the posterior surfaces of the second and third cervical vertebræ. This locality may be considered the upper fixation-point of the spinal dura mater. (2) It extends laterally and contributes to the connective tissue investments of each pair of spinal nerves, and as such it passes into the intervertebral foramina and becomes continuous with the periosteum lining each. (3) Along its ventral aspect the spinal dura mater is attached by numerous processes to the posterior longitudinal ligament of the vertebral canal. These latter attachments are more or less delicate, loose, and irregular, and are easily torn or cut in removing the specimen. They are stronger and more numerous in the cervical and lumbar regions than in the thoracic. (4) In the space between the dura and the walls of the vertebral canal (*epidural* or *extradural cavity*) lies the rich *internal vertebral venous plexus*, and along the lateral aspect the dura is occasionally connected with the periosteum through the tissue of the walls of the vessels of this plexus, especially in case of the vessels which penetrate the dura. Along its dorsal aspect the spinal dura mater is practically free from the wall of the vertebral canal. (5) At its lower and funnel-shaped extremity, opposite the second sacral vertebra, the dura suddenly contracts into a filament extending through the sacral canal and onto the coccyx and breaking up into a number of processes which become continuous with the periosteum of the dorsal surface of the coccyx. This filament is the **coccygeal ligament or filum of the dura mater**, and its attachment may be considered the lower fixation-point of the spinal dura mater. (See figs. 692 and 787.) The extent of the tube is maintained chiefly by means

of the two fixation-points, for all the other attachments are sufficiently loose to permit of the movements of the vertebral column.

The *inner surface* of the spinal dura mater appears smooth, but upon closer examination it is found to be connected with the arachnoid by a few delicate subdural trabeculæ—occasional fine stands of connective tissue bridging the subdural space (fig. 797). Along its lateral aspects the inner surface is at intervals quite firmly attached to the pia mater by the dentations of the ligamenta denticulata, which are prolonged from the pia through the arachnoid.

Further, it is continuous at intervals with both the pia mater and arachnoid by way of the connective-tissue sheaths of the nerve-roots which are prolonged from the pia and blend with the dura mater in the passage of the nerve-roots through it. The dura is also pierced by the spinal rami of the vertebral arteries, and the connective tissue of the outer walls of these vessels

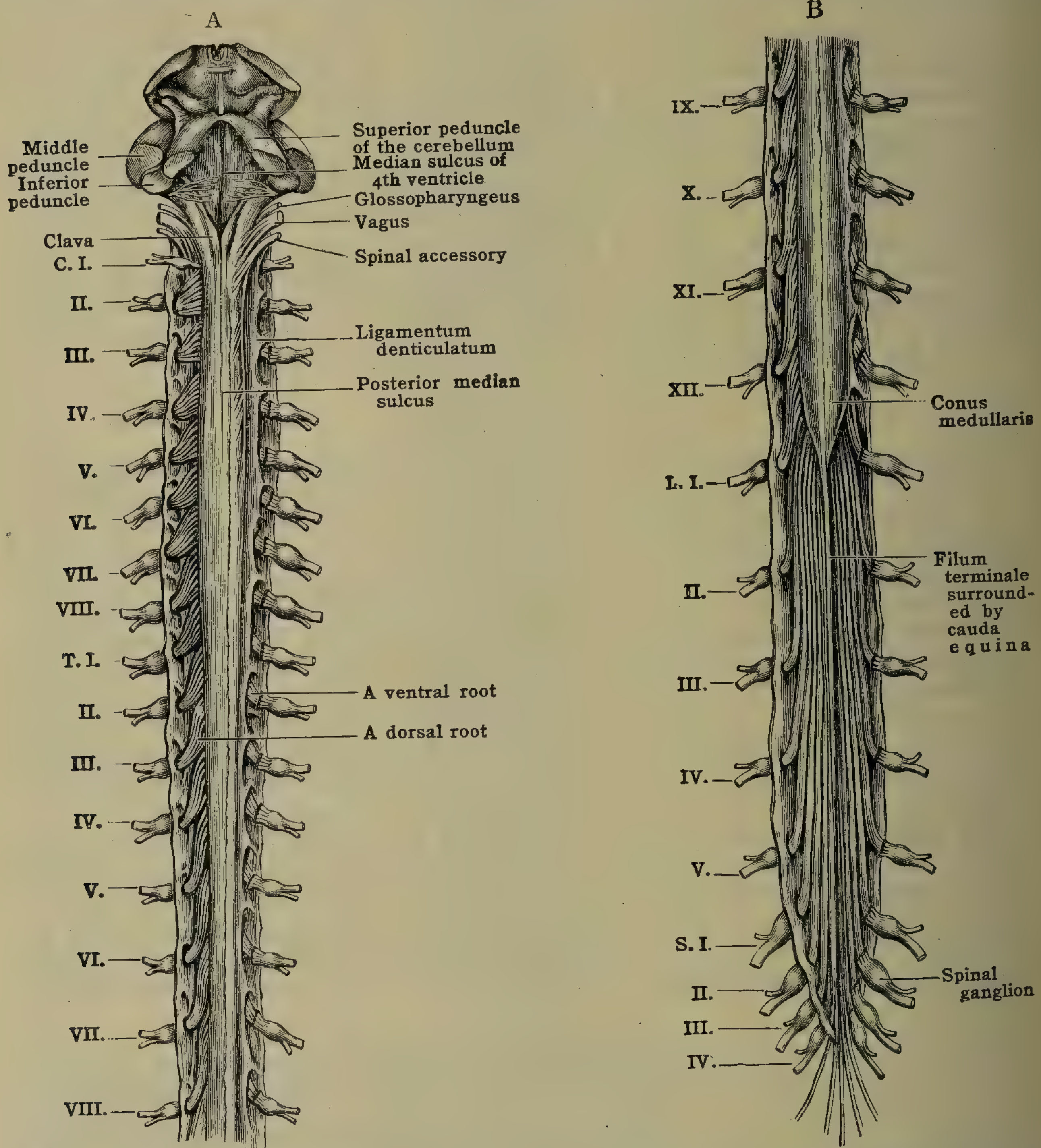


Fig. 788.—Dorsal Aspect of the Medulla Oblongata and Spinal Cord with the Dura Mater Partially Removed. (Hirschfeld and Leveillé.)

blends with all three of the meninges. The filum terminale of the pia mater extends below the termination of the spinal cord into the point of the funnel-shaped end of the dura mater, and there blends with it in line with the coccygeal ligament of the outer surface.

The tube of the spinal dura mater varies in caliber with the variations in the diameter of the spinal cord. However, the termination of its cavity occurs about seven segments below the termination of the spinal cord. This extension contains the long intradural nerve-roots forming the cauda equina, and the caliber of this part, before its sudden contraction, is about as great as that found in any other region. As each pair of the nerve-roots of the cauda equina pass outward, they lie free for a variable distance in this tubular cavity of the dura before the latter blends with and contributes to the thickness of their sheaths.

The **subdural cavity**, the space between the dura mater and the arachnoid, is the thinnest of the meningeal spaces. Along the ventral aspect especially, the spinal arachnoid is quite closely applied to the inner surface of the dura mater. It

contains a small amount of cerebrospinal fluid (lymph) which prevents friction between the opposing surfaces, and is continuous with the fluid in the like space of the cranial meninges.

The space is projected into the venous sinuses of the cranium in the region of the Pacchionian bodies (fig. 796), and its fluid is likewise in contact with the blood-vessels passing through it. It is probably continuous with the lymph-spaces of the nerve-roots passing through it, for colored fluids injected into it pass into the nerve-roots. The arachnoid is so thin and gauze-like that a ready interchange of fluids between the subdural and the subarachnoid spaces is possible by simple transfusion.

The cranial dura mater [dura mater encephali].—The dura mater investing the brain performs a double function—it serves as an internal periosteum for the cranial bones and gives support and protection to the brain. In conformity with its double function it consists of two layers, easily separable in the child, but closely adhering to each other in the adult, except in occasional localities, where there exist small clefts lined with mesothelium. The large blood-sinuses and venous lacunæ, corresponding to the internal vertebral venous plexus of the vertebral canal, are placed between the two layers and the semilunar ganglia of the trigemini also lie between them. The cranial dura begins with the adhesion of the spinal dura mater to the periosteum at the foramen magnum, and it forms a sac-

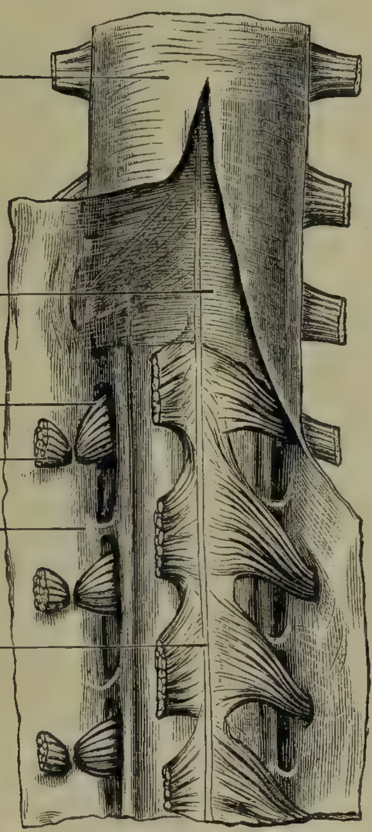


Fig. 789.—View of Membranes of Spinal Cord from Ventral Aspect. (Ellis.)

like envelope about the entire encephalon. Consisting of two layers, it is a much thicker membrane than that of the spinal cord.

The *outer surface* of the cranial dura mater when torn away from the cranial bones appears very uneven, and when placed in water presents a flocculent appearance due to its numerous filaments drawn from their small apertures in the bone.

This is due to the many fine bundles of connective tissue and the small blood-vessels which pass between the dura and the cranial bones and which are partially pulled out of their openings in the latter in the process of separation. The abundance of these connections, and, therefore, the degree of adhesion to the bones, varies in different localities. The separation is much less difficult from the inner table of the bones of the vault of the cranium than from the bones of the base of the cavity. The adhesions to the vault of the cranium are most firm along the lines of the sutures. This is due to the fact that during the period before the sutures are closed the outer layer of the dura mater (internal periosteum) is directly continuous with the external periosteum, and, in consequence of this condition during development, the connective tissue connection is more abundant along these lines and some is caught in the closure of the sutures. Along the vault there are occasionally noticed small lymph-spaces between the bone and the dura mater. The stronger adherence to the base of the cranial cavity is due to the numerous foramina in the floor, through which all the larger cranial blood-vessels and the cranial nerves pass, and the dura mater is continuous with the connective tissue investments of these as well as with the periosteum lining the foramina. Also the floor of the cavity is more uneven than the

vault, and the projections of the bones here tend to increase the firmness of attachment. The weight of the brain upon the floor may contribute to the greater adhesion.

The *inner surface* of the inner layer of the cranial dura mater forms the outer boundary of the subdural cavity. Except for the occasional delicate subdural trabeculæ and the passage of blood-vessels and nerve-roots, this surface appears smooth and glistening, being lined by a layer of mesothelium and containing a small amount of the cerebrospinal fluid.

The subdural cavity of the base of the brain is prolonged a short distance along the roots of the various cranial nerves before it is obliterated by the blending of the dura mater with the sheaths of the nerves. This outward extension of the space is most marked about the optic and auditory nerves. In the optic especially, the dura mater remains separate from the nerve throughout its length, only fusing with its sheath upon the posterior surface of the ocular bulb (fig. 790).

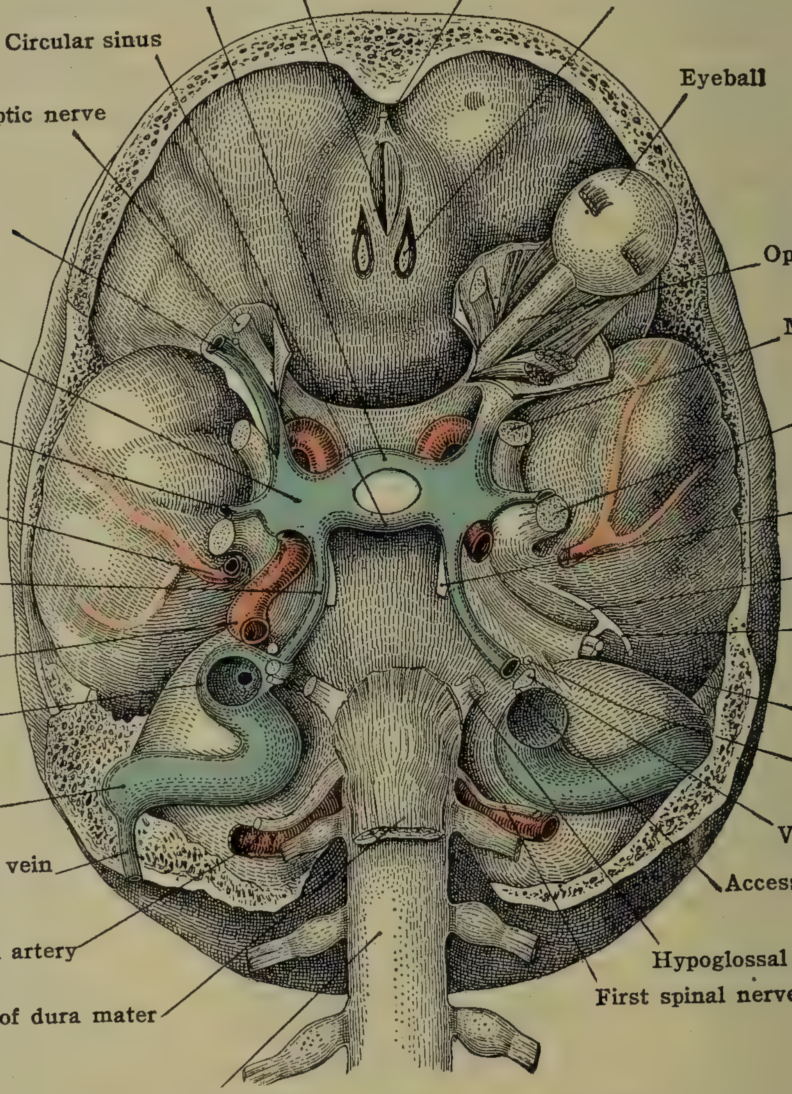


Fig. 790.—The Dura Mater Encephali of the Base of the Cranium. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

In addition to its two layers, one of the most striking differences between the cranial dura mater and that of the spinal cord is that the inner layer of the former undergoes striking septa-like duplications or folds, forming exceedingly strong partitions which project between the larger subdivisions of the encephalon. These are four in number, two large and two small—the falx cerebri and the tentorium cerebelli; the falx cerebelli and the diaphragma sellæ. The larger enclose within their folds the great venous sinuses, into which most of the blood of the encephalon collects to pass outward by way of the internal jugular veins (figs. 792, 793).

The **falx cerebri** is the most striking of these partitions. It is a sickle-shaped fold which projects vertically from the vault into the longitudinal fissure between the cerebral hemispheres. It begins attached to the crista galli in front, and arches to terminate by blending with the superior surface of the transversely placed tentorium cerebelli. Its convex, superior border joins the outer layer of the dura along the medial plane of the vault, and encloses the superior sagittal sinus. Its concave border is free and contains in its posterior two-thirds the smaller inferior sagittal sinus.

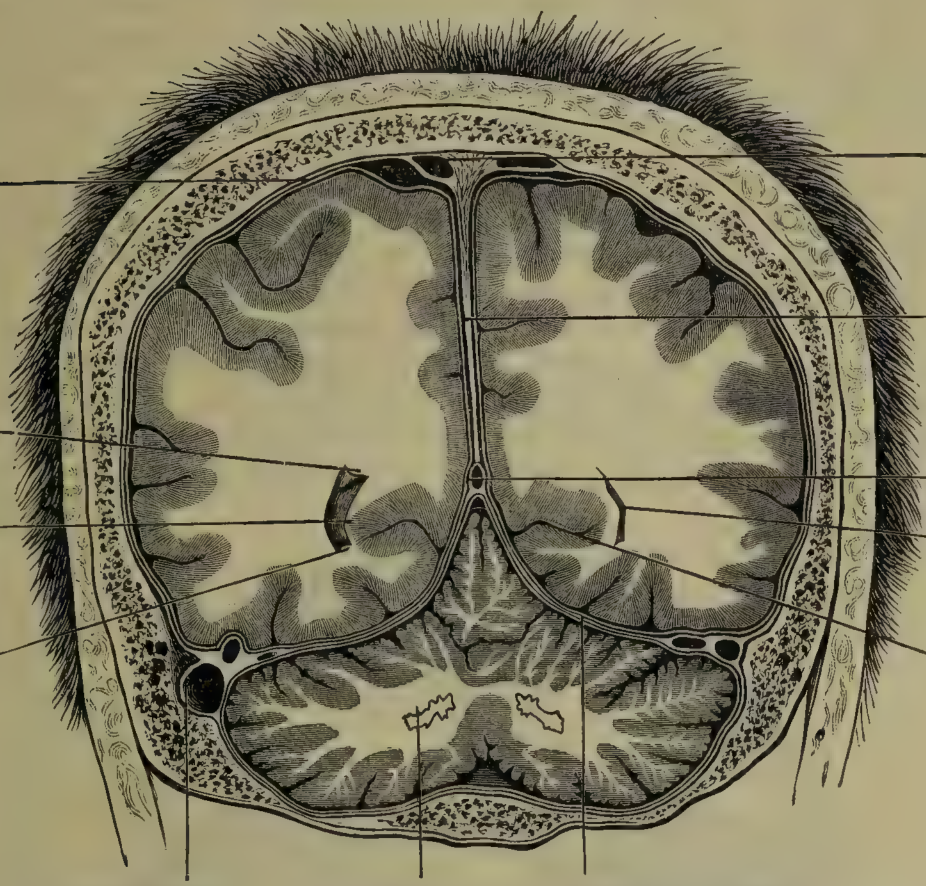


FIG. 791.—CORONAL SECTION OF THE HEAD, PASSING THROUGH THE POSTERIOR CORNUA OF THE LATERAL VENTRICLES.
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

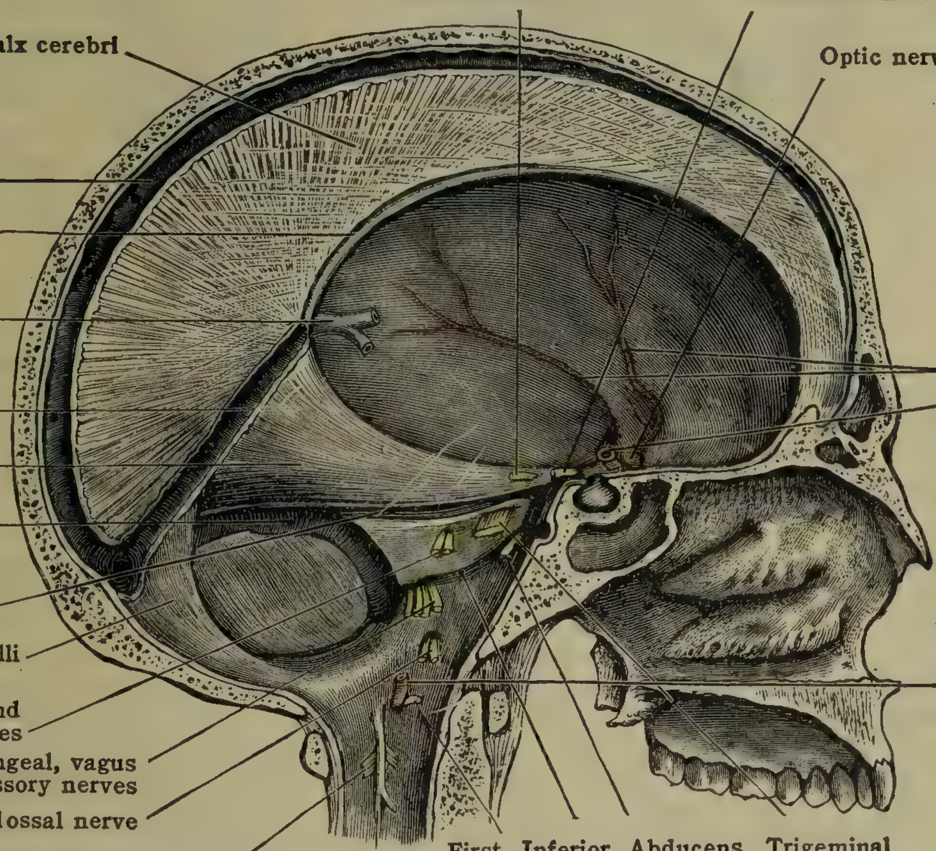


FIG. 792.—THE CRANIUM WITH ENCEPHALON REMOVED TO SHOW THE FALX CEREBRI, THE TENTORIUM CEREBELLI, AND THE PLACES WHERE THE CRANIAL NERVES PIERCE THE DURA MATER. (Sappey.)

The anterior and narrower end is often perforated and occasionally so much so as to appear as a coarse, fibrous reticulum. The posterior part of the concave border touches the upper surface of the corpus callosum, but the anterior part, which does not descend so low, is separated from the corpus callosum by a part of the subarachnoid space. The base of the fold which slopes downward and blends with the upper surface of the tentorium cerebelli, contains the straight sinus running along the line of the blending.

The **tentorium cerebelli** is a large transverse, semilunar fold, concave forward. It descends from its central part which is elevated, and consequently it forms a tent-shaped covering. Its superior surface is in relation with the tentorial surfaces of the cerebral hemispheres, and its inferior surface conforms accurately to the superior surface of the cerebellum. The outer or convex border of the fold is attached on each side to the posterior clinoid process, the superior border of the petrous portion of the temporal bone, the mastoid portion of the temporal bone, the posterior inferior angle of the parietal bone, and the transverse ridges of the occipital bone. The transverse sinus lies in this border, from the internal

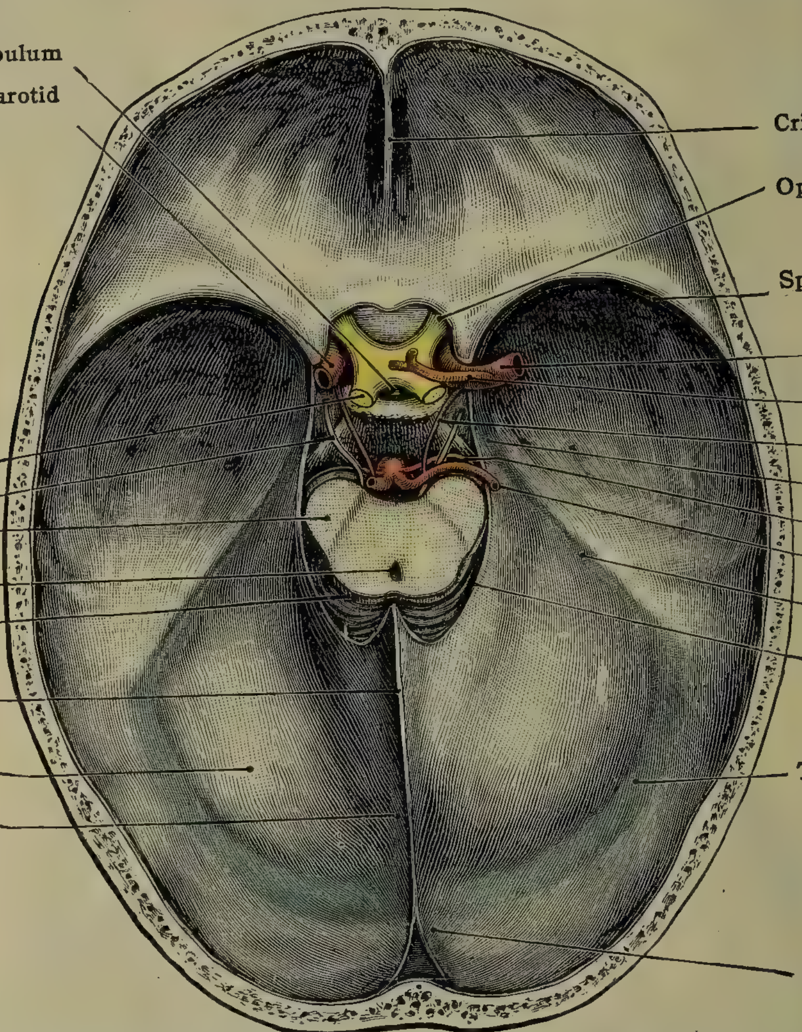


Fig. 793.—Showing the Upper Surface of the Tentorium Cerebelli and the Tentorial Notch Through which the Midbrain and Posterior Cerebral Arteries enter the Middle Fossa of the Cranium.

occipital protuberance to the mastoid portion of the temporal bone. Along the petrous part of the temporal bone it encloses the superior petrosal sinus.

The greater part of the inner or anterior border of the tentorium is free, and it forms the superior and lateral boundaries of an arched cavity, the **tentorial notch** or foramen ovale of Pacchioni, which encloses the mesencephalon, and through which ascend the cerebral peduncles and the posterior cerebral arteries. The anterior extremities of the inner border cross the outer border, where both are attached to the anterior clinoid processes. A depressed angle is formed between the inner and outer borders of the tentorium in the middle fossa of the skull at the lateral portion of the posterior clinoid process, and in this angle the root of the oculomotor nerve pierces the inner layer of the dura mater.

The **falx cerebelli** is a small, sickle-shaped, triangular fold which projects forward into the small groove (*posterior cerebellar notch*), between the hemispheres of the cerebellum. Its base is attached to the tentorium; its posteroinferior border, along which runs the occipital sinus, is attached to the internal occipital crest. Its anterior border is free, and its apex, which lies immediately above the foramen magnum, usually bifurcates as it disappears anteriorly, clasping the foramen magnum from behind. Bifurcation is always the case when the internal occipital crest splits below to enclose a vermiform fossa.

The **diaphragma sellæ** is a small circular fold, with a foramen in the center, which projects horizontally from the margins of the hypophyseal fossa or sella turcica. Its lateral border is

attached to the clinoid processes and the limbus of the sphenoid, and its medial border forms the boundary of the *foramen of the diaphragma sellæ* and surrounds the infundibulum. The superior surface of the diaphragm is in relation with the base of the brain, and its inferior surface is in relation with the hypophysis, which it binds down in the hypophyseal fossa.

The spaces which remain between the layers of the cranial dura mater are Meckel's caves, the spaces which lodge the endolymphatic sacs, the blood-sinuses and lacunæ. The diaphragma sellæ consists almost entirely of the inner layer of the dura, and thus the sella itself might be classed with these spaces.

Meckel's caves are two cleft-like spaces or niches which lie, one on each side, in the trigeminal impression on the apex of the petrous portion of the temporal bone. Each space lodges the semilunar (Gasserian) ganglion and the adjacent trigeminus and masticator nerves of the corresponding side, and it communicates with the subdural space in the posterior fossa of the cranium by an oval opening, which lies above the superior border of the petrous portion of the temporal bone and inferior to the superior petrosal sinus.

The space which contains the endolymphatic sac on each side lies behind the petrous portion of the temporal bone and communicates with the aqueductus vestibuli.

The venous sinuses and lucunæ.—The cranial blood-sinuses have already been fully described in the account of the vascular system, and it is sufficient to note here that they are continuous, on the one hand, with the meningeal veins, and, on the other, with the veins outside the cranial walls. The vessels which establish communication between the blood-sinuses and the extracranial veins are referred to collectively as **emissary veins.** They possibly help to maintain the regularity of the cranial circulation, and they have therefore a certain amount of practical importance.

The sinuses which are connected with the extracranial veins by emissary veins are the superior sagittal, the transverse (lateral), and the cavernous. Three or four emissary veins open into the superior sagittal sinus:—one passes through the foramen cecum and communicates with the veins of the roof of the nose, or, through the nasal bones, with the angular veins. Two pass through the parietal foramina and establish communications with the occipital veins, and a fourth, which is very inconstant, pierces the occipital protuberance and joins the tributaries of the occipital veins. Connecting each transverse sinus with the extracranial veins there are, as a rule, two emissary veins:—one, the mastoid emissary vein, which passes through the mastoid foramen to the occipital or posterior auricular vein; and the other, the postcondyloid vein, which traverses the condyloid (posterior condyloid) foramen and joins the suboccipital plexus. The cavernous sinus is in communication anteriorly with the superior ophthalmic vein, and through the latter with the angular vein; it is connected with the pterygoid plexus by emissary veins which pass either through the foramen ovale or the foramen Vesalii, and with the pharyngeal plexus by small venous channels which accompany the internal carotid artery through the carotid canal.

The **venous lacunæ** or spaces are small clefts lined by endothelium which communicate with the meningeal veins and with the blood-sinuses. They also have communications with the emissary veins and the diploic veins. They lie between the outer and inner layers of the dura mater, the majority of them at the sides of the superior sagittal sinus, but others are found in the tentorium associated with the transverse sinuses and the straight sinus.

Blood-vessels.—The blood-supply of the cranial dura mater is derived from the **meningeal arteries,** which ramify in its outer layer. The more important of these arteries have already been described in the account of the vascular system, and it is only necessary here to recall the fact that the greater part of the dura mater above the tentorium cerebelli is supplied by branches of the middle meningeal arteries. These are reinforced—(1) at the vertex by branches of the occipital arteries which enter through the parietal foramina; (2) in the middle fossa by the small meningeal arteries and by meningeal branches of the internal carotid, lacrimal, and ascending pharyngeal arteries; and (3) in the anterior fossa by meningeal branches of the anterior and posterior ethmoidal arteries.

The dura mater in the posterior fossa of the skull, below the tentorium cerebelli, also receives branches from the middle meningeal arteries, but its blood-supply is derived mainly—(1) from the meningeal branches of the vertebral arteries which enter the fossa through the foramen magnum, (2) from meningeal branches of the occipital arteries which enter through the mastoid and hypoglossal foramina, and (3) from meningeal branches of the occipital and ascending pharyngeal arteries which enter through the jugular and hypoglossal (anterior condyloid) foramina.

The **meningeal veins** accompany the arteries as *venæ comitantes,* usually one vein with each artery. The middle meningeal artery usually has two venæ comitantes. The meningeal veins communicate with the venous sinuses and with the diploic veins, and, unlike ordinary veins, they do not increase much in caliber as they approach their terminations.

The **nerves** of the dura mater are partly derived from the sympathetic filaments which accompany the arteries and partly from the cranial nerves. The nerves, other than sympathetic filaments, which supply the cranial dura mater are sensory fibers derived from the trigeminus (chiefly) and vagus nerves, and possibly from the first cervical nerves. The branches from the trigeminus are derived from the three divisions of that nerve on either side, and it has been stated that branches are given from the nasal branch of the ophthalmic division to the dura mater in the anterior fossa.

The meningeal branch of the opathalmic division of the trigeminus supplies the tentorium; that from the maxillary division accompanies the branches of the middle meningeal artery. The meningeal branch of the mandibular division (nervus spinosus) passes into the skull through the foramen spinosum and is distributed to the dura mater over the great wing of the sphenoid and to the mastoid cells. The '*recurrent branch of the hypoglossal nerve*' passes to the dura mater of the posterior fossa of the cranium. This recurrent or meningeal branch of the hypoglossal nerve really consists of fibers derived from the superior cervical ganglion of the sympathetic, and contains sensory fibers from the first and second cervical nerves. The meningeal branch of the vagus springs from the ganglion of the root of the nerve, and is distributed in

the posterior cranial fossa. The sympathetic filaments are distributed to the smooth muscle in the walls of the blood-vessels.

The cranial **subdural cavity** is not of uniform thickness throughout, being quite thin along the basal aspect of the encephalon. The lymph contained in it is usually but little more than is sufficient to keep moist its bounding surfaces. It is continuous with the lymph-spaces of the nerves and those of all the tissues bathed, and it is continuous with the similar cavity of the vertebral canal. Its lymph is in free contact with the blood-vessels passing through it, and it is replenished by filtration through their walls. Though extensive, the subdural space is thin at best, for the dura mater is quite closely applied to the second of the three meninges.

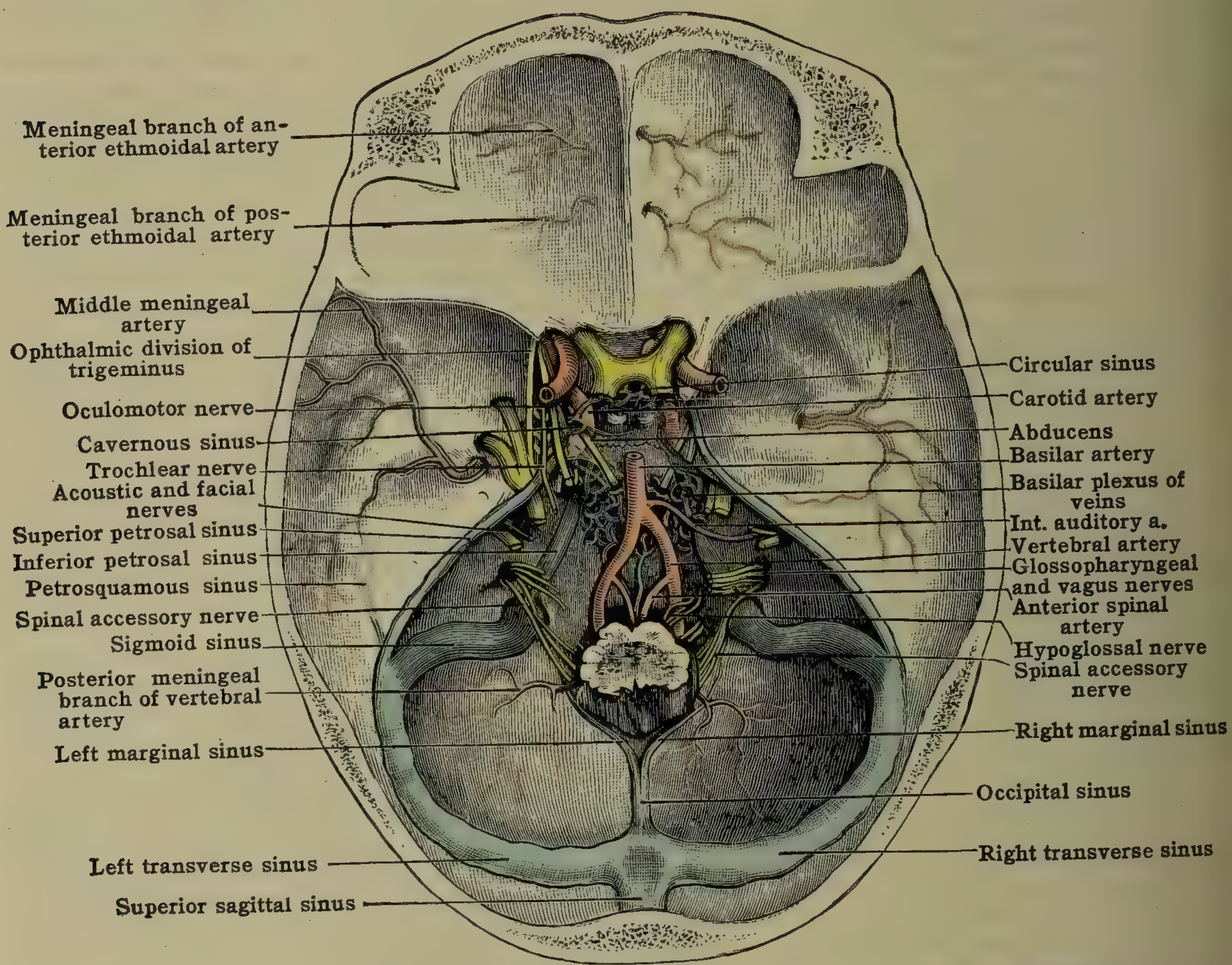


Fig. 794.—Showing Blood-vessels of Cranial Dura Mater and Cranial Nerves in the Base of the Skull.

(On the left side the dura mater has been removed from the middle fossa.)

The Arachnoid

The arachnoid or 'serous' membrane is the middle of the three meninges of the central nervous system. As in the case of the other two, an attempt is made to give this membrane a name descriptive of its texture. It is a gauzy reticulum of almost web-like delicacy, which in reality pervades the space it occupies. The term *leptomeninx* (NK) includes both the arachnoid and the pia mater.

Its *outer surface*, or that closely related to the dura mater and bounding the subdural cavity alone shows a sufficiently organized structure to merit the name of membrane. This surface is covered by a layer of mesothelium which is identical with that lining the inner surface of the dura mater and is continuous with the latter by way of the mesothelial covering the blood-vessels, the nerve-roots, the ligamenta denticulata of the spinal cord, and the occasional delicate trabecula passing between the dura mater and the arachnoid. Immediately under the mesothelium, the connective-tissue fibers of the arachnoid are woven into a very thin, more or less compact web. This, however, quickly grades into a loose, spongy reticulum which pervades the thick subarachnoid cavity throughout, and the strands of which are directly continuous into the more compact tissue of the pia mater. Thus an *inner surface* can hardly be claimed. This loose, sponge-like arachnoid tissue holds the cerebrospinal fluid of the subarachnoid cavity, the meshes of the sponge constituting a reticular web of intercommunicating spaces lined by mesothelial cells covering the strands of the web. In addition, the cavity is traversed by the spinal and cranial nerves, by the blood-vessels passing to and from the pia, and, in the vertebral canal distinctively, it is traversed by the ligamenta denticulata and the filum terminale.

Through these the arachnoid is further continuous with the pia mater. The cranial subarachnoid cavity is larger, and the strands of the web are relatively more abundant than in that of the vertebral canal.

The cranial arachnoid is directly continuous with that of the spinal cord, and in the two localities does not differ as much as does the dura mater. Within the cranium, the arachnoid does not closely follow the surface of the encephalon. It is folded in between the cerebellum and cerebral hemispheres, following the contour of the tentorium cerebelli, but it does not fold into the fissures and sulci except the anterior part of the longitudinal fissure and slightly into the lateral (Sylvian) fissure. Otherwise its spongy reticulum fills in the inequalities of surface of the encephalon, its outer surface forming a sheet enveloping the whole and bridging over the sulci and the deeper grooves between the gross divisions (fig. 703). Upon the summits of the gyri it is more closely applied to the pia mater, and there its reticulum becomes more dense. The sulci, occupied by its reticulum, form a continuous system of channels filled more abundantly by the cerebrospinal fluid.

The arachnoid folds in between the cerebellum and medulla oblongata, and at the base of the brain it enshrouds the olfactory bulbs and tracts, and its outer surface forms a continuous sheet stretching from one temporal lobe to the other

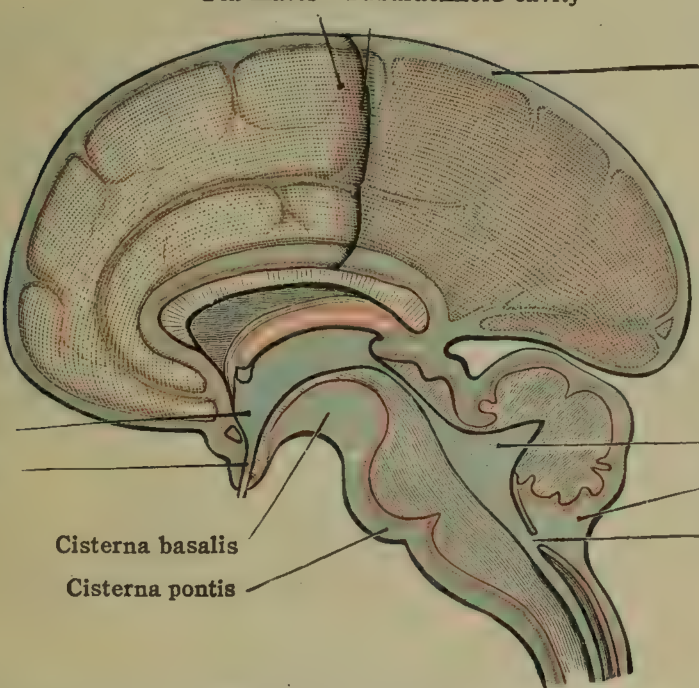


Fig. 795.—Diagram showing the Relations of the Pia Mater, the Arachnoid, and the Subarachnoid Cavity to the Brain.

and bridging over the interpeduncular fossa and the inequalities of surface in the region of the optic chiasma and the stems of the lateral fissures. Obviously, therefore, the subarachnoid cavity between its outer surface and the pia mater is of considerable depth in certain localities. These localities comprise the *subarachnoid cisternæ*. These occur where the cavity at the base of the brain is especially large, and make possible a web-invaded 'water-bed' which serves to protect the brain from injurious contiguity with the bones.

The following cisterns are distinguished (fig. 795):—

(1) **The cisterna basalis** lies at the base of the cerebrum and is divided by the optic chiasms into two parts —(*a*) the *cisterna chiasmatis* and (*b*) the *cisterna interpeduncularis.*

(2) **The cisterna pontis** is situated about the pons, especially in its basilar sulcus and the transverse fissures of either border, and is continuous anteriorly with the cisterna basalis and posteriorly with the subarachnoid cavity about the medulla. As a protective device, it is known as 'Hilton's waterbed.'

(3) **The cisterna superior** lies in the angle between the splenium of the corpus callosum and the superior surfaces of the cerebellum and the mesencephalon, and is connected ventrally, around the cerebral peduncles, with the cisterna basalis.

(4) **The cisterna cerebellomedullaris** (cisterna magna) is the cavity between the inferior surface of the cerebellum and the dorsal surface of the medulla oblongata. It is continuous below into the spinal subarachnoid space. The fluid in this cavity is directly continuous with that in the fourth ventricle by way of the foramen of Magendie (median aperture), and the lateral apertures of the fourth ventricle.

Pacchionian bodies [granulationes arachnoideales] (granula meningica NK) (figs. 703, 796).—In certain situations, especially along the margins of the longitudinal fissure, particularly in the frontal region of this, and to a much less extent upon the superior surface of the vermis of the cerebellum, the subarachnoid tissue elaborates numerous small, ovoid or villus-like projections, the Pacchionian bodies. Each arachnoid villus consists of a retiform network of subarachnoid connective tissue whose meshes are filled with cerebrospinal fluid. The Pacchionian bodies on the vertex of the brain project through the inner layer of the dura mater, both into the superior sagittal sinus and into the venous lacunæ or **parasinoidal sinuses** which lie at the sides of that sinus, and, as they become larger, they press against the outer layer of the dura and produce ovoid depressions in the inner plate of the cranium. Within the sinuses they are covered by the endothelium lining the sinuses.

They serve to increase the surface through which passes the lymph from the subarachnoid cavity into the blood-sinuses, and thus may aid in relieving pressure within. Similarly through

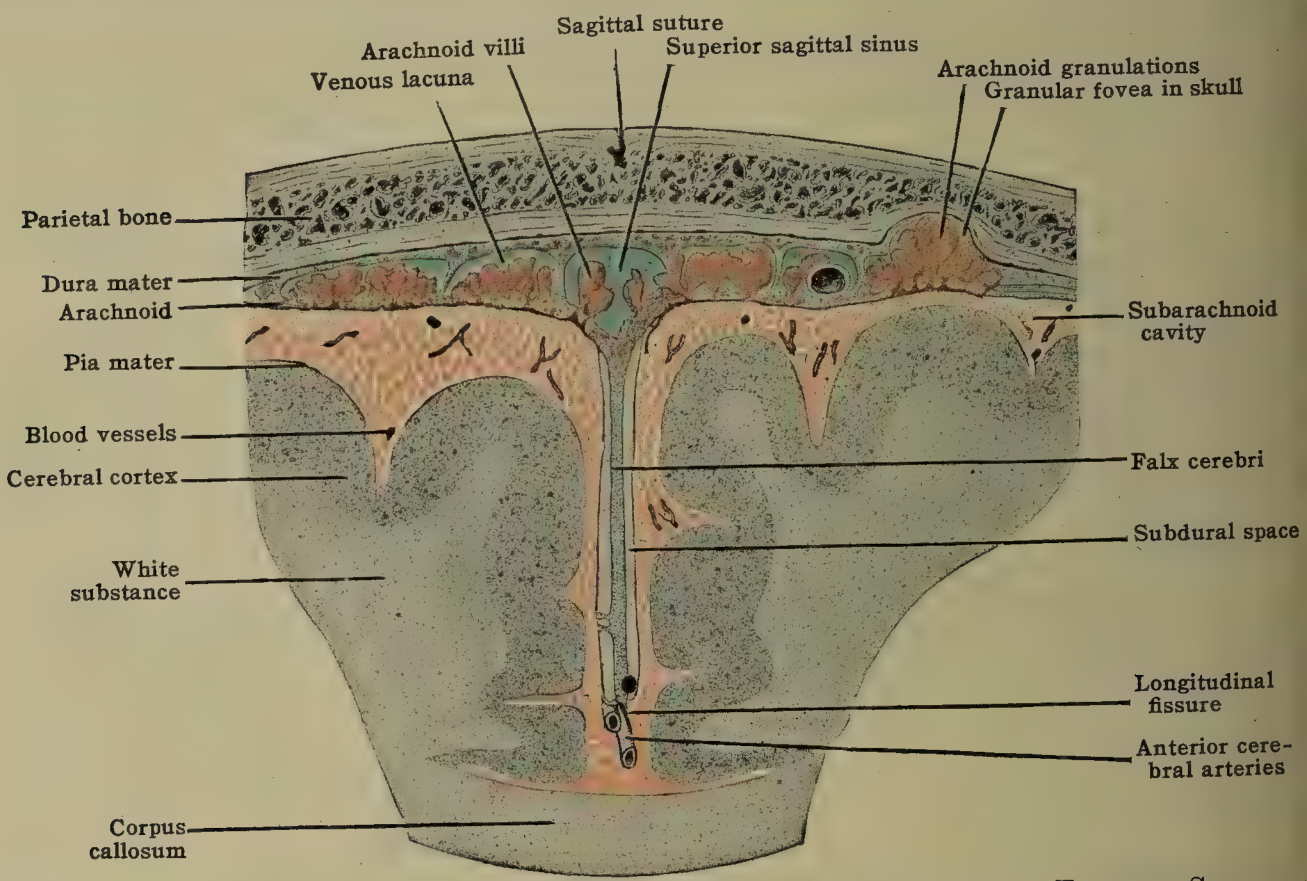


Fig. 796.—Coronal Section Transverse to the Great Longitudinal Fissure, Showing the Meninges. (Spalteholz.)

them the cerebrospinal fluid may be replenished at need from the blood plasma, though it is chiefly replenished by transfusion through the walls of the small arteries and capillaries of the choroid plexuses and those subjacent to the ependyma of the ventricles. These villi are not present at birth, but they appear at the tenth year and increase in number and size with advancing age. They are less marked in the female than in the male.

The spinal arachnoid (figs. 797, 798) is a loose, reticular sac which is most capacious about the lumbar enlargement of the spinal cord and about the cauda equina. Like that of the encephalon, the portion next to the dura mater alone resembles a membrane, being a loosely organized feltwork, covered on the side of the subdural cavity by a layer of mesothelium common to that cavity. Throughout its length the spinal subarachnoid cavity is relatively wide, and, as in the cranium, contains a fine, spongy, web-like reticulum, numerous threads of which are continuous with the pia mater. This spongy tissue is the inner modification of the arachnoid, and its meshes are occupied by the cerebrospinal fluid. It is not so abundant as in the cranial subarachnoid cavity.

In addition to the delicate threads, the arachnoid is more firmly attached to the pia mater by three imperfect partitions. The most continuous of these is arranged along the dorsal mid-line and is known as the **septum posticum** of Schwalbe (subarachnoid septum). This may be described as a linear condensation of the spongy tissue which pervades the subarachnoid space. It is most incomplete in the upper cervical region, where it becomes merely a line of threads connecting with the pia. It is most complete as a septum in the lower cervical and in

the thoracic region, but at best it maintains a spongy character. The other two partitions are formed by the **denticulate ligaments**, which extend laterally from either side of the spinal cord, connecting the pia and dura mater and involving the arachnoid in passing through it. Within the subarachnoid cavity these form more or less complete septa, though outside the arachnoid they are attached to the dura only at the intervals of their pointed dentations. They belong to the pia mater and will be described with it. The arachnoid is further continuous with the pia by way of the connective tissue sheaths of the roots of the spinal nerves and the blood-vessels passing through the subarachnoid cavity.

Vessels and nerves.—The arachnoid has no special blood-supply and probably no special nerves other than those supplying the walls of the blood-vessels passing through it.

The cerebrospinal fluid.—The subarachnoid cavity is the great lymph-space of the central nervous system. That of the spinal region is directly continuous into that of the cranium, and the fluid contained communicates freely with that in the ventricles of the brain and the central canal of the medulla and spinal cord by way of the foramen of Magendie or medial aperture into the fourth ventricle. In addition, there are the lateral apertures into the fourth ventricle and there is possibly an interchange of fluid between the lateral ventricle and the subarachnoid cavity of the base of the brain by diffusion through the thin floor of the choroid fissure. The arachnoid is not a membrane sufficiently compact to mechanically seriously oppose diffusion between the fluid contained in its cavity and that contained in the subdural cavity, though

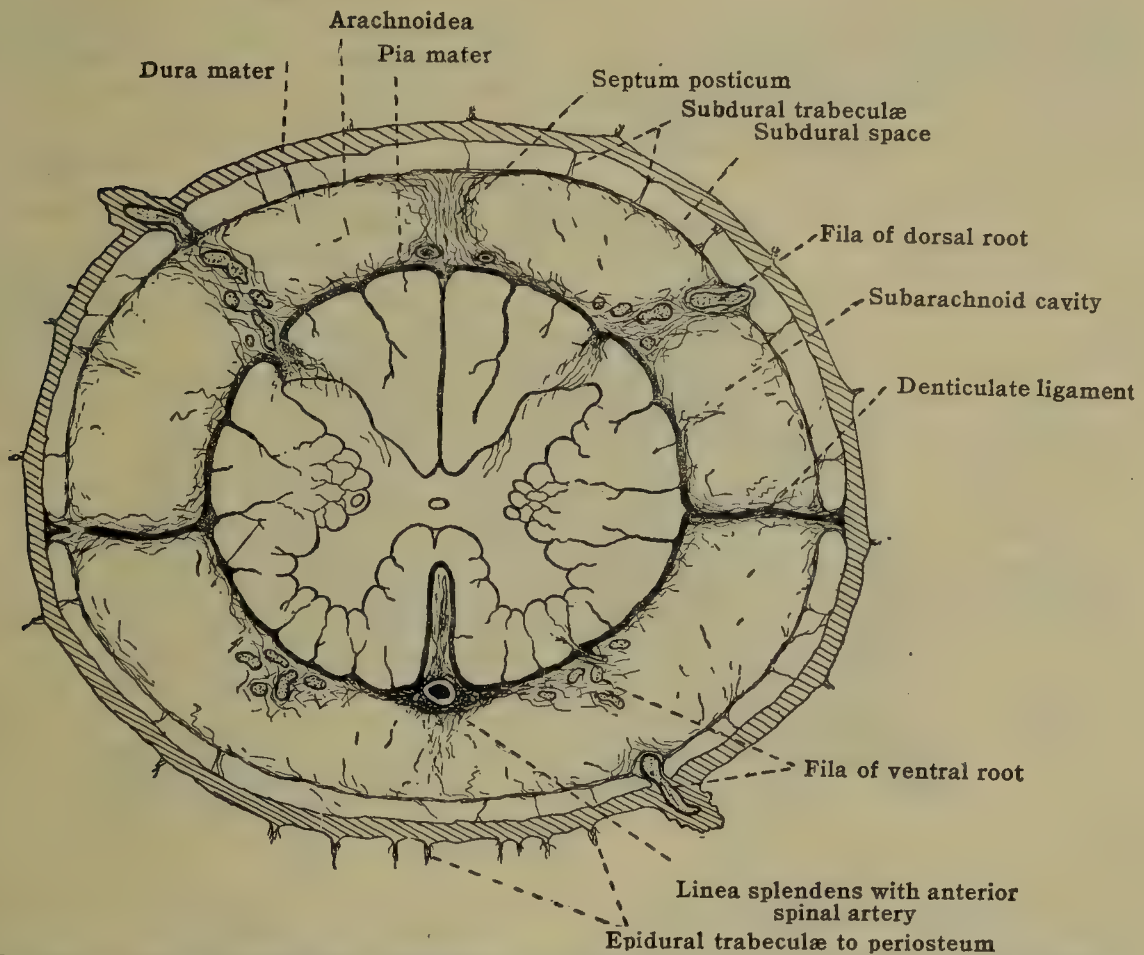


FIG. 797.—DIAGRAM OF TRANSVERSE SECTION OF UPPER THORACIC REGION OF THE SPINAL CORD SHOWING THE RELATIONS OF THE SPINAL MENINGES AND THEIR CAVITIES.

the mesothelium covering it probably controls such activities. The cerebrospinal fluid occupying the cavities is a transparent fluid of a slight yellow tinge, characteristic of the lymph in other lymph-spaces of the body. It is not very great in amount, probably never exceeding 200 c.c. in normal conditions. It is greatest in amount in old age, when the cavities are larger, due to atrophy and shrinkage of the nervous tissues. It collects by transfusion through the walls of the blood-vessels of the choroid plexuses, those in the walls of the ventricles and probably, but in less amount, through the walls of the sinuses, the ependyma lining the ventricles and the mesothelium on the meninges doubtless acting as semipermeable membranes in controlling its osmosis. Its amount may be temporarily increased by a period of increased blood-pressure in the cranial vessels. Pressure due to its abundance may be relieved by diffusion through the membranes containing it, and especially through the villi of the Pacchionian bodies into the venous sinuses and lacunæ, and thence into the veins.

The functions ascribed to the cerebrospinal fluid are the absorption of vibrations, the regulation of intracranial blood pressure and the drainage of waste products from the ever-active central system. Abnormal increase of the fluid in the cerebral ventricles is known as *internal hydrocephalus*. To relieve injurious pressure in the ventricles, surgeons usually employ one or the other of three locations for trephine and needle: (1) the inferior cornu by way of the middle temporal gyrus or sulcus; (2) the anterior cornu through the temporal lobe; and (3) by puncture of the corpus callosum. The approach to the corpus callosum is made through the anterior half, where it is thinner, usually at a point 2 cm. behind the bregma and to the side of the midline to avoid the superior sagittal sinus.

The Pia Mater

The **pia mater**, the third of the meninges, is a thin membrane which envelopes and closely adheres to the entire central nervous system and sends numerous processes into its substance. It likewise contributes the most proximal and compact portion of the sheaths of the nerve-roots in their passage through the meningeal spaces. It is very vascular in that the superficial plexuses of blood-vessels of the pia of both the brain and spinal cord ramify in it as they give off the central branches into the nervous substance. The structure and arrangement of the membrane vary somewhat in the cranial and spinal regions.

The spinal pia mater consists of two layers, an inner and an outer. It is thicker and more compact than that of the encephalon, due to the extra development of its outer layer, which is in the form of a strong, fibrous layer with the fibers arranged for the most part longitudinally.

Its inner layer is a thin feltwork of connective-tissue fibers which is closely adherent to the surface of the spinal cord throughout, sending numerous processes into it which contribute to the support of the nervous tissues. The larger of these processes carry with them the numerous intrinsic blood-vessels from the superficial plexus. The two layers are closely connected with each other, and are distinguished by the difference in the arrangement of their fibers. The spinal pia mater also appears less vascular than the cranial from the fact that the blood-vessels composing the plexuses lying in it are obviously much smaller than those of the encephalon.

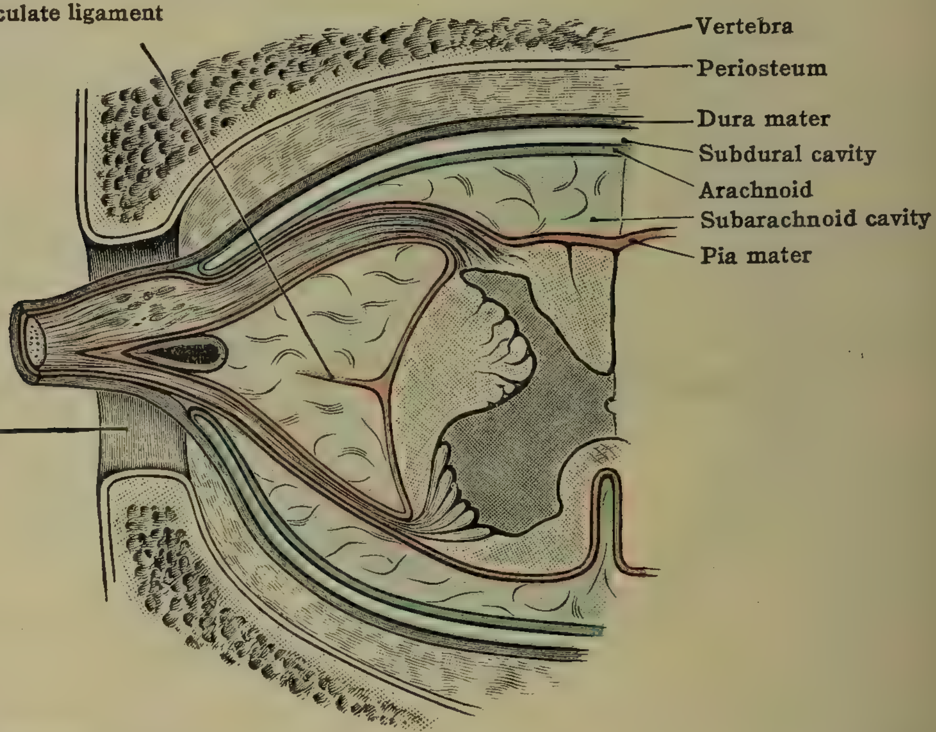


Fig. 798.—Diagram showing Relations of Meninges to Spinal Nerve-roots.

The membrane dips into the anterior median fissure and also bridges it over by forming an extra thickening along it. This thickening appears as a band along the midline of the ventral surface of the cord, the **linea splendens** (fig. 789). It carries, or ensheathes, the anterior spinal artery, the largest of the arterial trunks of the superficial plexus (figs. 702, 797).

The pia mater contributes the innermost and most compact portion of the epineurium of each of the nerve-roots, and thus, upon the roots, it is prolonged laterally into the intervertebral foramina, where the dura mater blends with it in producing the increased thickness of the epineurium.

Nerve fibers are distributed to the spinal pia from the dorsal nerve roots and from the ventral roots (mostly via meningeal rami when present), and some fibers are contributed from the white substance of the cord. These form plexuses in the pia composed of some medullated fibers but chiefly of nonmedullated. For the most part at least, they represent the vasomotor innervation of the blood-vessels in the pia and cord; but nerve endings of sensory type have been described in the pial tissue, as well as in the walls of the blood vessels of the cord and medulla of the cat (S. L. Clark). Presumably such is true for the cranial pia also.

From each side of the cord the pia mater gives off a shelf-like fold, the **denticulate ligament** (figs. 788, 789, 797), which spreads laterally toward the dura mater midway between the lines of attachment of the dorsal and ventral nerve-roots. The outer edge of this fold is dentate or scalloped into about twenty-one pointed processes, which extend through the arachnoid for their points to become continuous with the inner surface of the dura mater. The dentations are usually attached along the line between the roots of the spinal nerves, the uppermost

one a little cephalad to the first cervical nerve and the region where the vertebral artery perforates the dura mater; the most caudal one between the last thoracic and first lumbar nerves, or, between the last two thoracic nerves. The ligaments, aided slightly by the subarachnoid trabeculæ and the nerve roots, serve to hold the spinal cord more or less suspended in the subarachnoid cavity.

Below, at the sudden, conical termination of the spinal cord in the lumbar portion of the vertebral canal, the pia mater is spun out into a thin, tubular filament, the **filum terminale,** which continues caudalward into the sac formed by the dura mater about the cauda equina, and at the end fuses with the dura mater in line with the filum of the spinal dura mater (coccygeal ligament) of the outside (figs. 692, 787).

The cranial pia mater is closely applied to the external surface of the brain, dipping into all the fissures, furrows, and sulci. It is connected with the arachnoid by numerous filaments of the spongy subarachnoid tissue and by the blood-vessels traversing the subarachnoid cavity. It is also pierced by the cranial nerves, and furnishes them their sheaths, which become continuous with the arachnoid and dura mater.

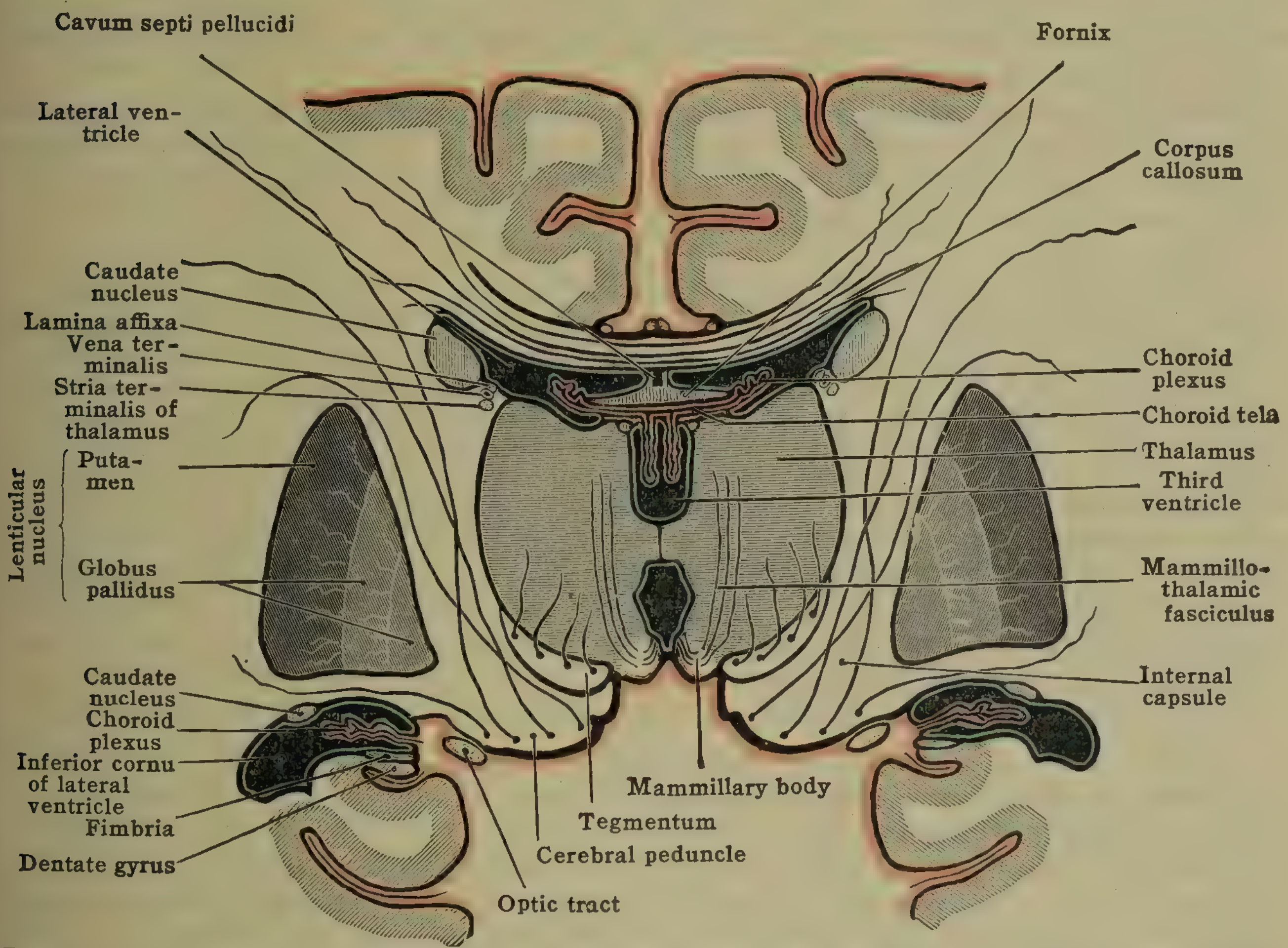


FIG. 799.—DIAGRAM OF CORONAL SECTION OF CEREBRUM THROUGH MIDDLE OF THALAMENCEPHALON SHOWING RELATIONS OF PIA MATER ENCEPHALI AND CHOROID PLEXUSES OF THIRD AND LATERAL VENTRICLES.

Its *outer surface* bounds the subarachnoid cavity. It is with difficulty separable into two layers of mixed white fibrous and elastic connective tissue, with slightly pigmented connective-tissue cells enmeshed between them. Its *inner surface* sends a large number of fibrous processes into the nervous substance, which blend with the neuroglia and aid in the support of the nervous elements. The larger of these processes accompany the central arterial and venous branches of the rich superficial plexuses of blood-vessels contained in the pia on the surface of the brain. Pieces of the pia when pulled off the brain and placed in water present a flocculent appearance, especially as to their inner surfaces, due to these processes having been pulled out.

The cranial pia mater sends strong, vascular duplications into two of the great transverse fissures of the encephalon; viz., the *transverse cerebellar fissure,* between the cerebellum and the medulla oblongata, and the *transverse cerebral fissure,* between the cerebellum, mesencephalon, and thalamencephalon below, and the overhanging cerebral hemispheres. These duplications are spread over the cavities of the fourth and third ventricles, and are known as the *choroid telæ* of these ventricles respectively.

The tela chorioidea of the fourth ventricle is that duplication which extends into the transverse cerebellar fissure, between the inferior surface of the cerebellum (vermis chiefly) and the dorsal surface of the medulla (fourth ventricle). The two layers of this fold of the pia remain separate and a portion of the cisterna cerebello-medullaris of the subarachnoid cavity lies between them.

The inferior of the layers is the tela chorioidea proper (fig. 718). It is triangular in shape, with its base cephalad at the nodule of the vermis and its apex below at the level of the tuber vermis. The superior layer of the fold is the pia mater of the inferior vermis. The tela chorioidea proper is strengthened by the epithelioid roof (ependyma) of the fourth ventricle and is continuous with the pia mater of the medulla oblongata and spinal cord. In roofing over the calamus scriptorius it constitutes the obex. A little above the calamus scriptorius it is pierced by the foramen of Magendie and the two lateral apertures into the fourth ventricle occur in its superolateral regions.

In front of the foramen of Magendie the vessels of the choroid tela, which are derived from the posterior inferior cerebellar arteries, form two longitudinal, lobulated strands occupying invaginations of the ependymal roof of the ventricle, projecting into its cavity, one on either side of the midline. These form the **choroid plexus of the fourth ventricle.** At the base of the triangular tela the two choroid plexuses join each other and then turn transversely lateralward into the lateral recesses of the ventricle, where they pass behind the restiform bodies and form the '*cornucopiæ.*'

The choroid tela of the third ventricle, or velum interpositum, is a triangular duplication of the pia mater which extends between the fornix above and the thalami and third ventricle below, and in front fuses with the brain substance at the interventricular foramina (figs. 765, 799).

In the transverse cerebral fissure the two layers of pia forming this tela are separate, the upper being the pia of the under surface of the corpus callosum and continuous with that of the tentorial surfaces of the occipital lobes; the lower being continuous into the pia enfolding the pineal body and covering the mesencephalon, anterior medullary velum, and cerebellum. The layers forming the portion of the duplication which roofs over the third ventricle are loosely adherent to each other and form the tela chorioidea proper of that ventricle. The upper surface of this portion is in relation with the fornix and its lower surface, covered by the ependymal lining of the ventricle, lies laterally over the superior surfaces of both thalami, and medially forms the roof of the third ventricle between them. The epithelioid ependyma is continuous with that covering the thalami and lining the ventricles. Between the two layers of this portion, and embedded in a small amount of the spongy subarachnoid tissue retained between them, are the two (internal cerebral) veins of Galen. Posteriorly these veins unite in the region of the pineal body to form the single great cerebral vein (*vena cerebri magna*) which empties into the straight sinus. Anteriorly the veins of Galen receive the veins of the septum pellucidum from each lamina of the septum pellucidum above, and also the terminal vein (vein of corpus striatum), lying in the stria terminalis of the thalamus, empties into them from each side.

The choroid tela of the third ventricle or velum interpositum extends laterally between the fornix and fimbria above and the stria terminalis of the thalamus below into each lateral ventricle. The blood-vessels of the border projecting into the lateral ventricle are amplified into a plexus which appears as a strip of reddish, lobulated, villus-like processes known as the **choroid plexus of the lateral ventricle.** The plexus, being in the border of the tela, begins at the interventricular foramen, extends through the body or central portion of the lateral ventricle, and downward into its inferior cornu. It is most developed at the junction of the body of the ventricle with the inferior cornu, and is there known as the **glomus chorioideum.**

From the inferior surface of the choroid tela of the third ventricle, hanging down on either side of the midline into the cavity of the ventricle, are two other longitudinal, lobulated invaginated strands of blood-vessels which are the **choroid plexuses of the third ventricle.** At the anterior end of the third ventricle these two plexuses join with each other and also with the plexus of the lateral ventricle of each side through the interventricular foramina.

The choroid plexuses of these ventricles are also covered by a layer of ependyma, *epithelial choroid lamina*, which is but a reflection of the ependyma lining the cavities throughout and represents the remains of the germinal layer of the embryonic brain-vesicles. The blood-vessels of the choroid plexus of the lateral ventricle receive blood by the choroid artery (a direct branch of the internal carotid), which enters the plexus through the choroid fissure immediately medial to the uncus, and also by the choroidal branches of the posterior cerebral artery, which supply the plexus of the body of the ventricle. The choroid plexuses of the third ventricle receive blood chiefly by branches from the superior cerebellar arteries. The greater part of the blood of both plexuses passes out by way ol the tortuous choroid veins, which, at the interventricular foramina, empty into the venæ terminales (veins of the corpus striatum), which, in their turn, go to form

the greater part of the veins of Galen. Thence the blood passes by way of the vena cerebri magna into the straight sinus. It is probable that the cerebrospinal fluid of the third and lateral ventricles is derived chiefly by diffusion through the walls of the vessels of the choroid plexuses.

Ventricular nerve plexuses.—There is a subependymal nerve plexus demonstrable in all the choroid plexuses and apparently more robust than is required for the smooth muscle of the blood-vessels there. Fibers from this plexus give nerve terminations of sensory type in the ependyma itself as well as in the connective tissue subjacent to it. The latter terminations are described as similar to sensory terminations found in the pia and they may indicate a continuous series of such, from the pia, through the tela choroidea of the ventricles, into the subependyma. Some of the endings in the ependyma may be secretory (efferent) in function. Exclusive of the vasomotor fibers for the blood vessels there, the subependymal nerve nets in the choroid plexuses of the lateral recesses of the fourth ventricle are described in the cat (S. L. Clark) as composed of fibers which arise directly from the dorsolateral margins of the medulla (Benedict's thirteenth cranial nerve), while the fibers of the nerve plexus for the medial portion of this choroid plexus arise from the substance of the medulla via the taenia of the fourth ventricle. Kolmer has described a subependymal nerve plexus in the wall of the brain ventricles of the monkey.

THE PERIPHERAL NERVOUS SYSTEM

The intimate connection and consequent control exercised by the central nervous system over all the tissues and organs of the body is attained through the peripheral part of the nervous system. This part or system, abundantly attached to the central system, consists of numerous bundles of nerve-fibers which divide and ramify throughout the body, anastomosing with each other and forming various plexuses, large and small. The terminal rami divide and subdivide until the divisions attain the individual nerve-fibers of which they are composed, and finally the nerve-fibers themselves divide and terminate in relations with their allotted peripheral elements. It is by means of these that stimuli arising in the peripheral tissues are conveyed to the central system, and that impulses in response are borne from the central system to the peripheral organs. For purposes of description, as well as upon the basis of certain differences in structure, arrangement, and distribution, the peripheral nervous system is separated into two main divisions: (1) **the craniospinal** and (2) **the sympathetic system.**

Both of these divisions include numerous ganglia or peripheral groups of nerve-cells from which arise a considerable proportion of the fibers forming their nerve-trunks, but neither of the divisions may be considered wholly apart from the central system nor are they independent or separate from each other. The sensory or afferent fibers of the craniospinal nerves pass by way of the afferent nerve-roots into the central system and contribute appreciably to its bulk, and the motor or efferent fibers of these nerves have their cells of origin (nuclei) situated within the confines of the central system. The sympathetic system is intimately associated with the craniospinal, and consequently with the central system—(1) by means of fibers which enter and terminate in the craniospinal ganglia and the spinal cord and brain to supply the blood-vessels there; (2) by efferent fibers of central origin which course in the nerve-trunks and terminate in the ganglia of the sympathetic system; (3) also, the sympathetic trunks usually contain numerous afferent and efferent craniospinal fibers which thus pass to their peripheral termination, usually in the so-called 'splanchnic area,' or domain of the sympathetic, in company with the sympathetic fibers. Likewise the peripheral branches of the craniospinal nerves usually carry for varying distances numerous sympathetic fibers which are on their way to terminate upon their allotted peripheral tissue-elements.

The following **differences** between the craniospinal and sympathetic systems of nerves may be cited: (1) The craniospinal nerves are anatomically continuous with the brain and spinal cord; probably no fibers arising in the sympathetic ganglia actually enter the central system other than for the innervation of its blood-vessels. (2) The ganglia of the craniospinal nerves all lie near the central axis, in line on either side of it, and at more or less regular intervals; the sympathetic ganglia are scattered throughout the body, are far more numerous and more variable in size, and many of these ganglia are not symmetrical for the two sides of the body. (3) The craniospinal nerves are paired throughout, and the nerves of each pair are symmetrical as to their origin and also, with certain exceptions (notably the vagus), in their course and distribution; some of the larger and more proximal of the sympathetic nerve-trunks and plexuses are symmetrical for the two sides of the body; many of them are not, and many of the smaller and most of the more peripheral nerves and ganglia, large and small, are not paired at all. (4) Even in their finer twigs, the craniospinal nerves of the two sides probably do not join with each other across the midline of the body; the sympathetic nerves do so abundantly, especially within the body-cavity. (5) The craniospinal nerves are distributed to the ordinary

sensory surfaces of the body and the organs of special sense and to the skeletal, (striated or 'voluntary') muscles of the body; the sympathetic fibers are devoted chiefly to the supply of the so-called involuntary muscles of the body, including the smooth muscle in the walls of the viscera and in the walls of the blood and lymph vascular-systems, and also to (striated) cardiac muscle, while others serve as secretory fibers to the glands. (6) Craniospinal nerve-fibers are characterized in general by well-developed medullary sheaths, making the nerves appear as white strands; most of the sympathetic fibers are non-medullated, some are completely and some partially medullated, but none possess as thick medullary sheaths as those of the craniospinal nerves. Thus sympathetic nerves appear as gray strands in the periphery. However, many unmedullated craniospinal fibers are to be found.

The craniospinal nerves.—There are forty-six pairs of craniospinal nerves, of which thirty-one pairs are attached to the spinal cord (spinal nerves) and fifteen pairs to the encephalon (cranial nerves). The spinal nerves are the more primitive and retain the typical character, i. e., each is attached to the spinal cord by two roots, a dorsal or sensory ganglionated root, and a ventral, which is motor and not ganglionated. Most of the cranial nerves have only one root, which in some cases corresponds to a dorsal root and therefore has a ganglion, and in other cases corresponds, physiologically at least, to a ventral root of a spinal nerve. Among other individual differences, the fibers of the first cranial nerve, for example, do not collect to form a distinct nerve-trunk and its fibers are not medullated.

I. THE CRANIAL NERVES

Customarily, the cranial nerves [nervi cerebrales] are described as comprising twelve pairs and each is referred to by number. However, present knowledge of their origin, central connections and peripheral distribution suggests that those enumerated as the fifth, seventh, and eighth pairs under the old nomenclature are better each separated into its two component nerves, each of which merits a separate description and a separate name. None of the cranial nerves corresponds closely to a typical spinal nerve with its motor and sensory root. The so-called motor portion of the fifth is no more its motor root than is the seventh nerve. The sensory portion of the seventh is not wholly sensory and rather resembles the ninth pair in distribution, and it has long been commonly referred to as a separate nerve. The two parts of the eighth nerve, both sensory, are known to be wholly different in functional character and are so named. Further, the names of the nerves, descriptive of their function, are pedagogically much more efficient than the use of numbers in referring to them.

Separating the three pairs mentioned, each into its two nerves, gives fifteen pairs instead of twelve. Their names and functional nature are given in the following table. The Roman numerals given in parentheses correspond to the serial numbers given when twelve pairs only are considered. It is also customary to enumerate the cranial nerves from in front backward and caudalward, and this custom is followed here, but again it would be pedagogically better to take them in the reverse order. Then each in its turn could be directly considered as in continuous series with the spinal nerves below and the similarities to and progressive modifications from the spinal type could be better realized. It will be remembered that *somatic efferent* or *motor* fibers are those which terminate directly upon the fibers of skeletal muscle while *visceral efferent* or motor fibers transfer their impulses to sympathetic neurones, and the axones of the latter terminate upon gland cells and upon the fibers of cardiac and smooth muscle.

Name	Nature	General Distribution
Olfactory (I)	Sensory	Olfactory region, nasal epithelium.
Optic (II)	Sensory	Retina.
Oculomotor (III)	Motor { Somatic	Eye-moving muscles.
	Motor { Visceral	Ciliary body, iris.
Trochlear (IV)	Motor-somatic	Eye-moving muscles.
Abducens (VI)	Motor-somatic	Eye-moving muscles.
Trigeminus (V)	Sensory	Face, mouth, and scalp.
Masticator (*minor part or motor root of trigeminus*)	Motor-somatic	Muscles of mastication.
Facial (VII)	Motor { Somatic	Facial muscles.
	Motor { Visceral (?)	Salivary glands, vessels (?).
Glossopalatine. (*Intermediate part of facial.*)	Sensory { Somatic, visceral }	Tongue, palate.
	Motor-visceral	Salivary glands.

Name	Nature	General Distribution
Cochlear (*auditory*) (VIII)	Sensory	Internal ear (cochlea)
Vestibular (*equilibrator*) (VIII)	Sensory	Semicircular canals, utriculus, sacculus.
Glossopharyngeal (IX)	Sensory: Somatic, Visceral	Tongue, palate, pharynx.
	Motor: Somatic	Pharynx.
	Motor: Visceral	Glands and vessels.
Vagus (X)	Sensory: Visceral, Somatic	Alimentary canal, lung, heart, ear.
	Motor: Somatic	Larynx, pharynx.
	Motor: Visceral	Alimentary canal, heart, larynx, trachea, lung.
Hypoglossal (XII)	Motor-somatic	Tongue-moving muscles.
Spinal accessory (XI)	Motor: Somatic	Neck and shoulder-muscles.
	Motor: Visceral	Pharynx, larynx, heart.

The cranial nerves, like the spinal nerves, are developed from cells of the primitive neural tube and, beginning with the trigeminus downward, all the sensory nerves are developed from the cells corresponding to those of the ganglion crest which give origin to the spinal ganglia and the sensory components or dorsal roots of the spinal nerves. Otherwise between the cranial nerves and the spinal nerves there are many important differences. Each spinal nerve has a dorsal or sensory root, which springs from the cells of a spinal ganglion; a ventral or motor root, whose fibers are processes of the nerve-cells which are situated in the walls of the central system, and at their attachment to the surface of the cord the two roots are some distance apart. Only one of the (usually recognized) twelve pairs of cranial nerves corresponds at all closely with typical spinal nerves. This one is the trigeminus which possesses a sensory ganglionated root and near its attachment is accompanied by a small motor nerve, the masticator, which serves in very small part as a corresponding motor root of the trigeminus. But even in this case where the similarity between the cranial and spinal nerves is greatest, there are still points of anatomical difference, which if not essential are very obvious, for the so-called motor root joins not the whole but only with one branch of the sensory portion. The two are only slightly separated from each other at their attachment to the surface of the brain. All the other cranial nerves differ in a still more marked manner from typical spinal nerves. The olfactory nerve is an afferent nerve whose cells of origin (olfactory ganglion) are scattered in the mucous membrane of the nose, an organ of special sense, and its fibers are not collected together into a nerve-trunk, but pass, as a number of small bundles, through the lamina cribrosa of the ethmoid bone directly into the olfactory bulb. The optic nerve is also a nerve of special sense. Its fibers form a very distinct bundle, similar in appearance to an ordinary nerve, from which, however, it differs essentially, both with regard to structure and development; for, unlike an ordinary nerve, its connective tissue consists to a large extent of neuroglia instead of ordinary connective tissue, and its component nerve-fibers are of much smaller caliber than those of an ordinary nerve. It represents the location of the original optic stalk, a diverticulum from the neural tube, and it associates the retina (optic cup), a bit of modified cortex, with the encephalon. The optic nerve, therefore, corresponds more closely with an association tract of the central system than with an ordinary nerve. Its ganglion of origin is a layer of the retina.

The oculomotor, trochlear, abducens and hypoglossal nerves are practically purely motor nerves, and thus correspond only with the ventral roots of spinal nerves. The spinal accessory is purely motor. Its fibers arise from the cells of the anterior horn of the spinal cord and from a nucleus of the medulla which represents an upward extension of that horn, but they do not leave the surface of the spinal cord and brain in the usual situation of ventral roots. On the contrary, they emerge as a series of rootlets from the lateral funiculus of the cord on the dorsal side of the ligamentum denticulatum, and from the upward prolongation of this funiculus.

The cochlear and vestibular are nerves of special sense, and in some respects both correspond closely with the dorsal root of a typical spinal nerve, and the ganglia of both represent spinal ganglia, but their peripheral distribution is limited to the membranous labyrinth.

The vagus and glossopharyngeal nerves contain both motor and sensory fibers, but they differ from typical spinal nerves in that the motor fibers, in company

with the sensory, issue from the posterolateral sulcus of the medulla, and they are intimately intermingled, from their origin, with the sensory fibers, which latter arise from ganglia interposed in the trunks of the nerves and otherwise correspond with the fibers of the dorsal root of a typical spinal nerve.

Superficial attachments and origins.—It is customary to speak of the area where the nerve-fibers leave or enter the brain substance as the superficial attachments of the cranial nerves, and the groups of cells from which their fibers spring, and about which they terminate, as their nuclei of origin and of termination, respectively.

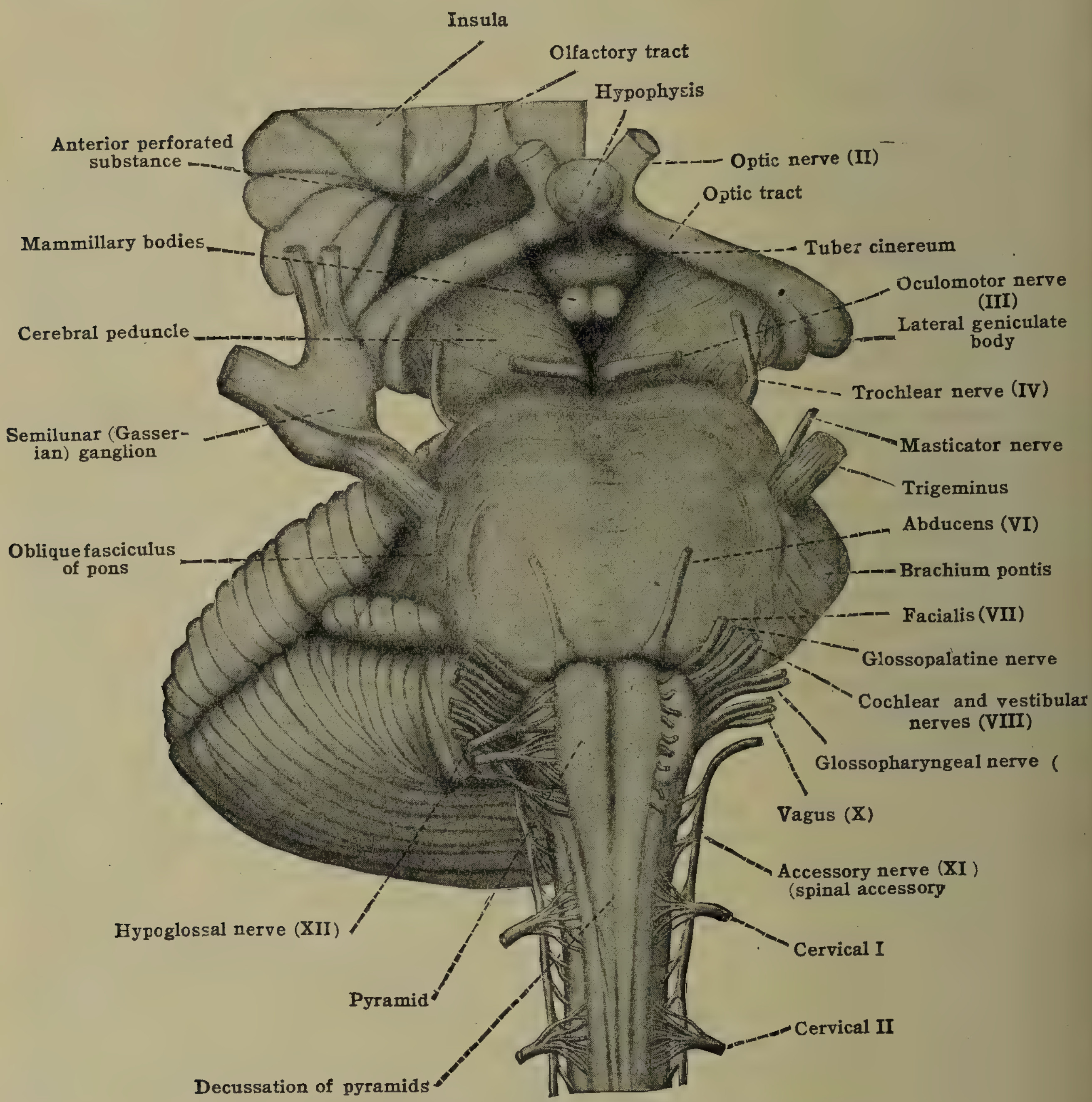


Fig. 800.—Surface Attachment of the Cranial Nerves. (After Allen Thomson modified.)

THE OLFACTORY NERVES

The **olfactory nerve-fibers** (fila olfactoria NK) (fig. 801) are the central processes of the bipolar olfactory nerve cell-bodies situated in the olfactory region of the nasal mucous membrane. In man, the olfactory region comprises the epithelium upon the superior third of the nasal septum and that upon practically the whole of the superior nasal concha. The area is relatively small as compared with that of other mammals and, as in other mammals, is characterized by an increased thickness of the epithelium and a yellowish brown color when fresh. The peripheral processes of the olfactory cell-bodies (the olfactory ganglion) are short and extend only to the surface of the olfactory epithelium. As the central processes pass upward from their cells of origin they form subepithelial plexuses in the mucous membrane, and from the upper parts of these plexuses, immediately below the lamina cribrosa of the ethmoid, about twenty filaments

issue on each side. These filaments comprise the **olfactory nerve.** They are non-medullated. They pass upward, through the foramina in the lamina cribrosa, into the anterior fossa of the cranium in two rows, and after piercing the dura mater, the arachnoid, and the pia mater, they enter the inferior surface of the olfactory bulb.

They contribute to the superficial stratum of nerve-fibers on the inferior surface of the olfactory bulb, ending in the *glomeruli* formed by the terminal ramifications of the olfactory nerve-fibers in synapsis with the similar ramifications of the main dendrites of the large mitral cells which lie in the deeper part of the gray substance of the olfactory bulb.

The olfactory nerve-fibers are gray fibers, since they do not possess medullary sheaths, and they are bound together into bundles by connective-tissue sheaths derived from the pia mater, from the subarachnoid tissue, and from the dura mater.

Central connections—The olfactory impulses are transmitted by way of the peripheral processes of the olfactory neurones through the cell-bodies and the olfactory nerve-fibers and by way of the glomeruli to the mitral cells. Thence they are carried by the central processes (axones) of the mitral cells, which pass backward along each olfactory tract and its three olfactory striæ. (See Rhinencephalon, p. 940.)

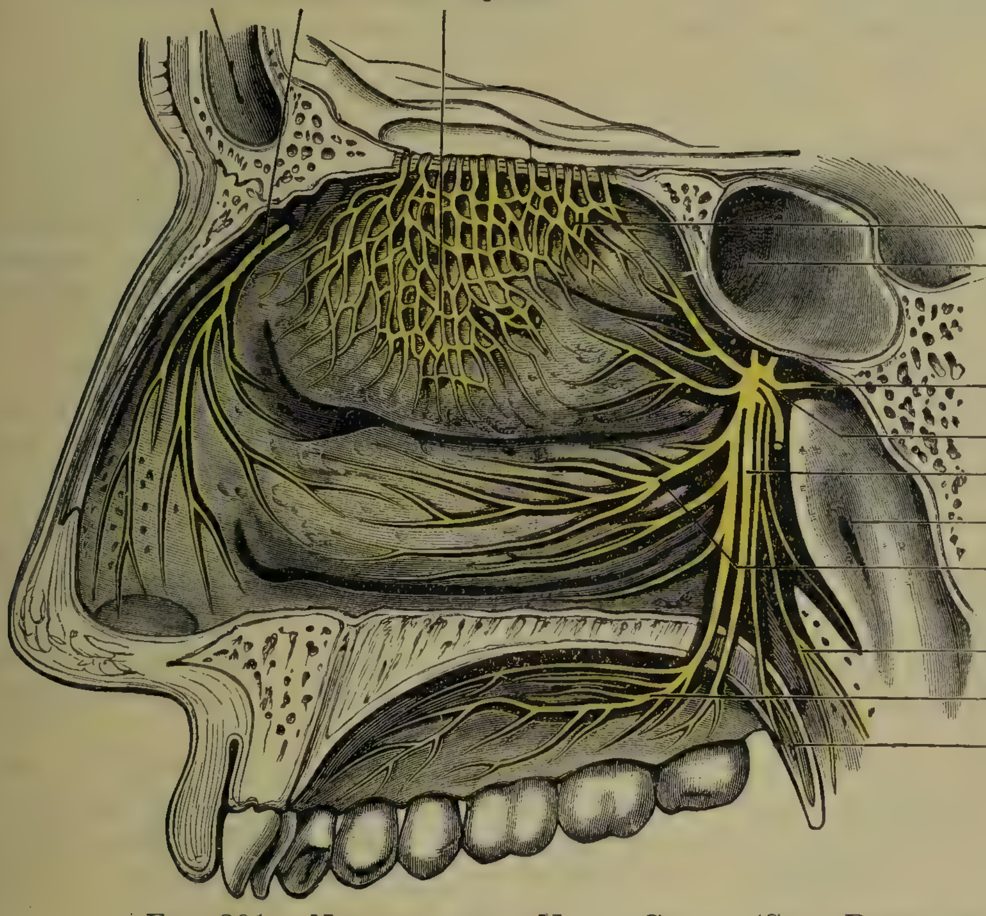


FIG. 801.—NERVES OF THE NASAL CAVITY (SEMI-DIAGRAMMATIC.)

THE TERMINAL NERVE (*Nervus Terminalis*)

In lower vertebrates and recently in those mammals whose sense of smell is relatively much more developed than in man, three nerves have been found in relation with the olfactory apparatus:—(1) The olfactory nerve proper whose fibers, as noted above, are the central processes of the nerve cell-bodies situated in the epithelium of the olfactory region of the nasal mucosa, and which terminate in the olfactory bulb; (2) the vomeronasal nerve, whose fibers are the central processes of nerve cell-bodies situated in the epithelium of the vomeronasal (Jacobson's) organ and which pass caudalward in the submucosa and upward to join the filaments of the olfactory nerve proper and which, in the dog, cat, rabbit, rat, etc., terminate in the accessory olfactory bulb—a small protuberance possessed by these animals on the posteromedial aspect of the olfactory bulb proper; (3) the terminal nerve, a small plexiform nerve, which unlike the other two is ganglionated.

In man, the vomeronasal (Jacobson's) organ is rudimentary after birth and, therefore, the vomeronasal nerve is not present, the only fibers for the vomeronasal region being those of general sensibility from the trigeminus and sympathetic fibers common to the epithelium of the entire nasal fossa.

The terminal nerve has been recently described as present in the human fetus and in the adult of other animals. It is mentioned here because of the expressed belief that it is an added cranial nerve and that it is present in the human adult. From the observations recorded for human and rabbit fetuses and the adult dog, ox, horse, squirrel and cat, the following description may be given: It is variably plexiform throughout its course. Peripheral twigs have been described for it as distributed to the mucosa of the nasal septum, some to the mucosa joining the olfactory

region while other and larger twigs extend further forward and are distributed to the mucosa of the vomeronasal organ, accompanying and sharing in the distribution of the vomeronasal nerve when this is present. It is not certain that many of the fibers of these twigs are not fibers of the trigeminus and vomeronasal nerves. Its central connections are in the form of two or three small roots which pass through the cribriform plate of the ethmoid bone in company with and medial to the vomeronasal nerve and then, still plexiform, extend caudalward over the inferomedial aspect of the olfactory bulb and upon the olfactory peduncle or stalk (olfactory tract) beyond, a root often extending to near the lamina terminalis and optic chiasma. The roots disappear in the medial and inferomedial aspect of the frontal portion of the brain at different localities caudal to the olfactory bulb and usually near the olfactory peduncle, but often one may disappear in the region corresponding to the anterior perforated substance of the adult human brain.

Numerous small groups of ganglion-cells are found interposed along both the peripheral and intracranial course of the terminal nerve. A group, larger in size than the others and situated in the intracranial course of the nerve, is called the *ganglion terminale*. The fibers of the nerve are non-medullated. Both the ganglion-cells and the fibers of the nerve are described as having more the appearances characteristic of sympathetic neurones than of craniospinal. On the other hand, our conceptions of sympathetic neurones do not permit of their terminating within the central system except for the innervation of its blood-vessels. It may result that, instead of being an independent nerve as has been claimed, the nervus terminalis is a part of the forward extension of the cephalic sympathetic, the larger ganglia and plexuses of which latter are well known, and that its neurones receive and convey impulses to the gland-cells of the nasal mucosa and to the muscle of the blood-vessels of the mucosa and those supplying blood to the infero-medial part of the frontal end of the cerebrum (Brookover, Larsell).

THE OPTIC NERVES

The **fibers of the optic nerve** (tractus opticus NK) are the central processes of the ganglion-cells of the retina. Within the ocular bulb they converge to the optic papilla, where they are accumulated into bundles which pierce the choroid and the sclerotic coats, and, at the back of the bulb, assemble into a rounded, compact cord, the optic nerve, which traverses the orbital fat to pass backward and medialward to the optic foramen. It is the largest of the cranial nerves. After traversing the foramen it enters the middle fossa of the cranium, and joins with its fellow from the opposite side, forming the optic chiasma. It may, therefore, for descriptive purposes, be divided into four portions—the intraocular, the intraorbital, the intraosseous, and the intracranial (fig. 867). The total length of the nerve varies from forty-five to fifty millimeters.

The **intraocular part** is rather less than one millimeter in length. It passes backward from the optic papilla through the choroid and through the sclerotic coats of the bulb. As it passes through the latter coat of the bulb in many separate bundles, the area of the sclera it traverses has a cribriform appearance when the nerve is removed, and consequently is known as the *lamina cribrosa scleræ*.

The **intraorbital part** (pars orbitalis of tractus opticus NK) of the nerve emerges from the sclerotic about three millimeters below and to the medial side of the posterior pole of the bulbus, and it is about thirty millimeters long. It passes backward and medialward, surrounded by the posterior part of the fascia bulbi (Tenon's capsule) and by the orbital fat, to the optic foramen.

As it runs backward in the orbit it is in relation above with the nasociliary (nasal) nerve and the ophthalmic artery which pass obliquely from behind and laterally, forward and medialward across the junction of its posterior and middle thirds, and also it is in relation with the superior ophthalmic vein, the superior rectus muscle, and the upper branch of the oculomotor nerve. Below it are the inferior rectus muscle, and the inferior division of the oculomotor nerve. To its lateral side, near the posterior part of the orbit, are the ophthalmic artery, the ciliary ganglion, the abducens nerve, and the external rectus muscle. The anterior two-thirds of this portion of the optic nerve are surrounded by the ciliary arteries and the ciliary nerves and it is penetrated on its medial and lower aspect by the central artery of the retina. As it enters the optic foramen as the intraosseous part, it is in close relation with the ligaments of Lockwood and Zinn (annulus tendineus communis) and with the four recti muscles which arise from them.

The **intraosseous portion** is from six to seven millimeters long. It lies between the roots of the small wing of the sphenoid and the body of that bone, and it is in relation below and laterally with the ophthalmic artery.

The **intracranial portion** (pars cerebralis NK) (fig. 800), which is from ten to twelve millimeters long, runs backward and medialward, beneath the posterior end of the olfactory tract, and above the ophthalmic artery, the medial border of the internal carotid artery and the diaphragma sellæ, to the chiasma. From the chiasma to the central connections of the nerve, the path is known as the optic tract.

Central connections.—The central connections of the fibers of the optic nerve have been considered with the optic chiasma and the optic tract (see pp. 924, 977).

The sheaths of the optic nerve.—The optic nerve receives a sheath from each of the membranes of the brain, and thus prolongations of the subdural and subarachnoid cavities pass outward along it to the posterior part of the sclera. The sclera may be considered as a modified dura mater.

THE OCULOMOTOR NERVES

The oculomotor or third cranial nerve is a motor nerve. Each supplies seven muscles connected with the eye, two of which, the sphincter of the iris and ciliary muscle, are smooth muscle and within the eyeball. The remaining five (skeletal muscle) are in the orbital cavity, and four of them—the superior, inferior, and medial recti and the inferior oblique—are inserted into the eyeball, while the fifth, the levator palpebræ superioris, is inserted into the upper eyelid.

The fibers of the oculomotor nerve spring from their nucleus of origin situated in the gray substance of the floor of the cerebral aqueduct in the region of the superior quadrigeminate body (fig. 741). The cells of this nucleus are divided into two main groups, a superior and an inferior (fig. 742). The **superior group** gives rise to visceral motor (autonomic) fibers and it includes two nuclei, a medial and a lateral. The latter, besides being lateral, is also somewhat dorsal to the former. The **inferior group** (somatic motor) has been divided into five secondary nuclei, according to the eye-muscles the cells of each group innervate. Three of the five lie lateral to the others and somewhat dorsally, and of the remaining two, which are placed more medially, one encroaches upon the midline (*nucleus medialis*) and is continuous with the corresponding group of the opposite side and is common to the oculomotor nerves of both sides.

It has been found, by the study of diseased conditions and by experiments with animals, that the sources of innervation of the eye-muscles supplied by the nerve correspond to the above divisions of both the superior and inferior group of cells into a medial and lateral series. The relative position of the divisions of each group on the two sides and the muscles they are thought to innervate are shown in the following diagram devised by Starr:

Median Plane.

SUPERIOR GROUP.	Sphincter of Iris.	Ciliary Muscle.	Ciliary Muscle.	Sphincter of Iris.
INFERIOR GROUP.	Levator Palpebræ Superioris.	Medial Rectus.	Medial Rectus.	Levator Palpebræ Superioris.
	Superior Rectus.	Inferior Rectus.	Inferior Rectus.	Superior Rectus.
	Inferior Oblique.			Inferior Oblique.

As they leave their nucleus of origin in the midbrain, the fibers of the oculomotor nerve form a series of fasciculi, which curve ventrally around and through the red nucleus and the medial part of the substantia nigra, to the oculomotor sulcus on the medial surface of the cerebral peduncle (fig. 800), where they emerge in from six to fifteen root-filaments which pierce the pia mater and collect into the trunk of the nerve. Immediately after its formation along the oculomotor sulcus, the trunk of the nerve passes between the posterior cerebral and the superior cerebellar arteries, and, running downward, forward, and laterally in the posterior part of the cisterna basalis, it crosses the anterior part of the attached border of the tentorium cerebelli at the side of the dorsum sellæ, and, piercing the arachnoid and the inner layer of the dura mater, it courses through the outer wall of the cavernous sinus about midway between the anterior and posterior clinoid processes. Immediately after its entry into the wall of the sinus it lies at a higher level than the trochlear nerve, but the latter soon crosses on its lateral

side and gets above it, and directly afterward the oculomotor nerve divides into a smaller superior and a larger inferior branch (fig. 803). Before its division **communications** join it from the cavernous plexus of the sympathetic about the internal carotid artery, and from the ophthalmic division of the trigeminus. Both branches proceed forward, and the nasal branch of the trigeminus, which has passed upward on the lateral side of the inferior branch of the oculomotor, lies between them. At the anterior end of the cavernous sinus the two branches pass through the superior orbital (sphenoidal) fissure, between the heads of the lateral rectus muscle, and enter the orbital cavity. In the orbit, the **superior branch** (ramus brevis NK) lies between the superior rectus and the optic nerve; it supplies the superior rectus and then turns round the medial border of that muscle and terminates in the levator palpebræ superioris. The **inferior branch** (ramus longus NK) runs forward, beneath the optic nerve, and divides into three branches which supply the inferior and medial recti and the inferior oblique.

The branch to the inferior oblique muscle is connected with the ciliary ganglion by a short thick visceral efferent offset, the **short root of the ciliary ganglion.** Fibers of this offset make synapses with the sympathetic neurones of this ganglion whose axones carry the oculomotor impulses to the ciliary muscle and the sphincter muscle of the iris.

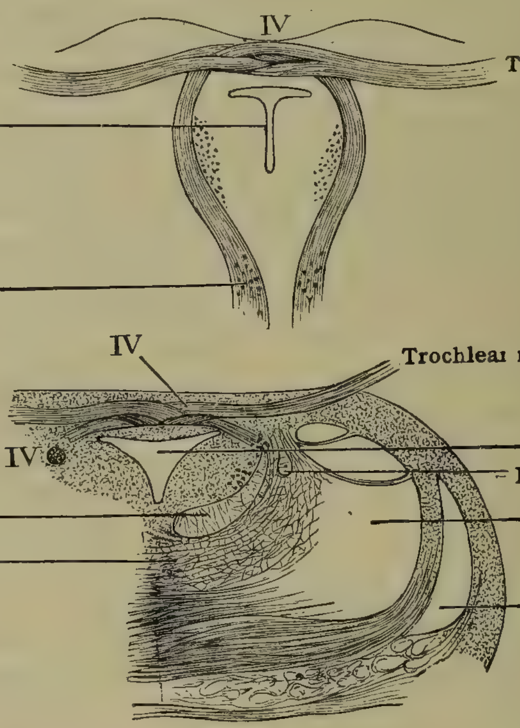


Fig. 802.—Diagrams of Sections through the Origin of the Trochlear Nerve. (Stilling.) (The upper figure is an oblique section, the lower is a coronal section.)

The inferior branch also gives some small twigs to the inferior rectus. The branches of the oculomotor nerve which supply the recti muscles enter the muscles on their ocular surfaces, but the branch to the inferior oblique muscle enters the posterior border of that muscle.

Some of the fibers which spring from the medial portion of the oculomotor nucleus do not pass into the nerve of the same side, but into that of the opposite side, and it is believed that they are distributed to the opposite medial rectus muscle. Other fibers which arise from the nucleus descend in the medial longitudinal fasciculus and either terminate about the cells of the nucleus of the facial or join the facial nerve, in which they pass to the upper part of the orbicularis palpebrarum. The opening of the eye is controlled by the oculomotor and the closing of the eye by the facial nerve.

Against the common contention that the oculomotor is a purely motor nerve is the claim that it contains some somatic afferent (sensory) fibers carrying impulses of muscular sense from the muscles the nerve supplies. A few branched nerve cell-bodies have been found (Kopsch) scattered among its fibers in serial sections of its root. All the eye-moving nerves receive sensory fibers from the ophthalmic branch of the trigeminus.

Central connections.—The nucleus of the oculomotor is associated with the middle portion of the anterior central gyrus, the posterior end of the middle frontal gyrus and with the cortex about the visual area of the occipital lobe of the same and opposite sides by the pyramidal fibers. It is associated with the superior colliculus, and probably the cerebellum by the fibers in the superior cerebellar peduncles, and with the sensory nuclei of the other cranial nerves by the medial longitudinal fasciculus. To produce the coördinated activities of the eye-moving muscles, it must be associated with the nuclei of the trochlear and abducens.

THE TROCHLEAR NERVES

The fibers of each trochlear or fourth nerve (or patheticus) spring from the cells of a nucleus which lies in the gray substance of the floor of the cerebral aqueduct in line with the oculomotor nucleus, but in the level of the inferior quadrigeminate bodies. As the fibers pass from their origins they run ventrally and laterally in the substance of the tegmentum for a short distance, then they curve medianward and dorsalward, and, in passing through the anterior end of the superior medullary velum, they decussate totally with the fibers of the trochlear nerve of the opposite side (figs. 738, 800, 802). After the decussation the fibers emerge from the surface of the superior medullary velum, at the side of the frenulum veli, usually in two small bundles, which pierce the pia mater and join together to form the slender trunk of the nerve. This trunk curves forward and ventralward to the base of the brain around the sides of the superior peduncle of the cerebellum and the cerebral peduncle of the side opposite to that in which the nerve originates, running parallel with and between the superior cerebellar and posterior cerebral arteries. As it reaches the base of the brain behind the optic tract the nerve enters the cisterna basalis, in which it runs forward, immediately beneath or piercing the free border of the tentorium cerebelli, to the superior border of the petrous portion of the temporal bone, where it pierces the arachnoid and the dura mater and enters the posterior end of the lateral (outer) wall of the cavernous sinus. In the wall of the cavernous sinus it receives **communications** from the cavernous plexus of the sympathetic and, by a small filament, from the ophthalmic division of the trigeminus. It gradually ascends, as it passes forward in the lateral wall of the sinus, and, beyond the middle of the sinus, it crosses the lateral side of the trunk of the oculomotor nerve and gains a higher position (fig. 803). At the anterior end of the sinus the nerve enters the orbit above the lateral rectus and immediately turns medialward between the periosteum of the roof of the orbit and the levator palpebræ superioris. At the medial border of the roof it turns forward to its termination, and enters the orbital or superior surface of the superior oblique muscle to which its fibers are distributed.

The central connections of the nucleus of the trochlear nerve are similar to those of the oculomotor save that its cells probably do not send fibers which connect with the facial nerve. The trochlear is peculiar in that—(1) it is the smallest of the cranial nerves; (2) it is the only nerve having its superficial attachment upon the dorsal aspect of the encephalon; (3) it is the only cranial nerve whose fibers undergo a total decussation, and (4) in that it terminates in a muscle of the side of the body opposite that in which it has its origin. Gaskell has suggested that this latter condition has probably been brought about, phylogenetically, by the transference of the muscles which have carried their nerves with them. It should be remembered that most of the fibers arising from the medial group of the cells of the nucleus of the oculomotor cross to the opposite side. This is thought to be especially true for those supplying the medial rectus muscle. It is claimed that the trochlear and the abducens carry also some somatic sensory fibers, but the proof of this is not so well established as for the oculomotor.

THE ABDUCENS

The abducens (or sixth) nerve on each side arises from the cells of a nucleus which lies in the gray substance of the floor of the fourth ventricle in the region of the inferior part of the pons (fig. 731). The nucleus is situated close to the middle line, ventral to the acoustic medullary striæ and beneath the colliculus facialis and it is in direct linear series with the nuclei of the oculomotor, trochlear and hypoglossal nerves. It is the third of the eye-moving nerves. The fibers which pass from the nucleus into the nerve run inferiorly and ventralward through the reticular formation, the trapezium, and the pyramidal fasciculi, and they emerge from the ventral surface of the medulla in the sulcus at the inferior border of the pons and the upper end of the pyramid of the medulla (fig. 800). From this superficial attachment the nerve runs upward and forward in the subarachnoid space between the pons and the basisphenoid and at the side of the basilar artery. A little below the level of the upper border of the petrous portion of the temporal bone it pierces the dura mater, passes beneath the petrosphenoidal ligament, at the side of the dorsum sellæ, and enters the dura of the medial wall of the cavernous sinus, in which it runs forward along the lateral side of the internal carotid artery. At the anterior end of the sinus it passes through the superior orbital (sphenoidal) fissure between the heads of the rectus lateralis, below the inferior

branch of the oculomotor nerve, and above the ophthalmic vein. In the orbit it runs forward on the inner or ocular surface of the rectus lateralis, and finally it pierces this muscle and terminates upon its fibers.

While it is in the cavernous sinus it receives communications from the carotid plexus of the sympathetic and from the ophthalmic nerve.

All the fibers arising in the nucleus of the abducens do not pass into the nerve. Some of them ascend in the medial longitudinal fasciculus of the same and opposite sides, and terminate about cells of the medial group of the nucleus of the oculomotor nerve, from which the impulses are conveyed to the opposite medial rectus muscle. Thus impulses reaching the abducens nucleus can throw into simultaneous action the lateral rectus of the same side and the medial rectus of the opposite side, and thus turn both eyes in the same direction.

Central connections.—The nucleus of the abducens receives impulses from the anterior central gyrus of the opposite side by the pyramidal fibers, and it is associated with the sensory nuclei of other nerves by way of the medial longitudinal fasciculus, and that of the trigeminus especially through the reticular formation.

THE TRIGEMINUS

The trigeminus is the largest of the cranial nerves with the exception of the optic. It is usually described as the fifth cranial nerve and as possessing both a sensory [portio major] and a motor root [portio minor]. For reasons already given, the 'motor root' is here described separately and given the separate name, *masticator nerve.* The fibers of the trigeminus proper, which are all sensory, spring from cells of the semilunar (Gasserian) ganglion, which corresponds with the ganglion of the dorsal root of a spinal nerve, and they enter the brain-stem through the side of the anterior half of the pons (fig. 800).

The **semilunar (Gasserian) ganglion** (fig. 803) is a semilunar mass which lies in Meckel's cave, a cleft between the layers of the dura mater above a depression in the medial part of the anterior surface of the petrous portion of the temporal bone. The concavity of the ganglion is turned forward, and from it three large nerves, the *ophthalmic*, the *maxillary* and the *mandibular*, are given off. From the convexity, which is directed backward, springs the root of the nerve. The medial end of the ganglion is in close relation with the cavernous sinus and the internal carotid artery at the foramen lacerum, and the lateral end lies to the medial side of the foramen ovale. The surfaces of the ganglion are striated, due to bundles of fibers traversing them. The upper surface is separated by the inner layer of the dura mater from the temporal lobe of the brain, and the lower rests upon the masticator nerve and the outer layer of dura mater upon the petrous portion of the temporal bone.

The fibers of the trigeminus root as they leave the semilunar (Gasserian) ganglion, form from thirty to forty fasciculi which are bound together into a flat band, from 6 to 7 mm. broad, which passes backward over the upper border of the petrous portion of the temporal bone and below the superior petrosal sinus into the posterior fossa of the cranium. In the posterior fossa the root runs backward, medialward, and downward, entering the pons through its continuation into the middle peduncle of the cerebellum. In the tegmentum of the pons region, the fibers bifurcate into ascending and descending branches which terminate about the cells of the nucleus of termination of the trigeminus. This nucleus, large at the level of the entrance of the root, has tapering superior and inferior extremities. The inferior extremity of the nucleus, which is much the longer, descends as low as the upper portion of the spinal cord and the fibers of the root terminating about the cells of this extremity are known as the spinal tract of the trigeminus. (See description of the nuclei under Rhombencephalon.)

Central connections.—The nuclei of termination of the trigeminus send impulses to the somesthetic area of the cortex of the opposite side by the fibers of the medial leminscus (trigeminal lemniscus) and, for reflex actions, to the motor nuclei of other cranial nerves and to ventral horn cells of the cervical spinal cord by the medial longitudinal fasciculus and by fasciculi proprii in the reticular formation of the same, and opposite sides. Of especial interest are the rapid palpebral reflexes mediated through its supratrochlear, infratrochlear, lacrimal and inferior palpebral terminal branches.

Clinical aspects.—The semilunar (Gasserian) ganglion lies at a depth of 5.5–6 cm. (2¼ in.) under the eminentia articularis. In exposing it for the purpose of excision for intractable neuralgia the following structures are encountered: (1) Skin and superficial fascia with branches of the superficial temporal artery; (2) temporal fascia and muscle with deep temporal vessels; (3) squamous bone and great wing of sphenoid, which are trephined, the floor of the middle fossa being gouged away; (4) middle meningeal vessels and dura mater. By elevating the dura mater and superimposed temporal lobe, and securing the middle meningeal artery, the ganglion is exposed, lying in a separate compartment [cavum Meckelii] of the dura, which contains cerebrospinal fluid. The motor nerve for the muscles of mastication lies on the lower and medial aspect of the ganglion, and should not be divided. Division of the sensory root of the ganglion is a simpler operation than removal of the ganglion and the results are more satisfactory.

THE BRANCHES OF THE TRIGEMINUS

The main branches of the trigeminus, given off by the front side of the semilunar ganglion, are three in number (ophthalmic, maxillary, and mandibular), each of which is referred to as a nerve and each of which is purely sensory, though the third branch, or mandibular nerve, is joined by the fibers of the masticator nerve which is motor. For the cutaneous distribution of the trigeminus, see also p. 1098.

(1) The Ophthalmic Nerve or First Division

The ophthalmic nerve, the first division of the trigeminus, is the smallest of the three branches which arise from the semilunar (Gasserian) ganglion. It springs from the medial part of the front of the ganglion and passes forward, in the lateral wall of the cavernous sinus, where it lies below the trochlear nerve and lateral to the abducens nerve and the internal carotid artery (fig. 803). A short distance behind the superior orbital (sphenoidal) fissure the nerve divides into three terminal branches—the frontal, lacrimal, and nasociliary (nasal) nerves. They pierce the dura mater, which closes the fissure, and pass forward into the orbit. Before its division the ophthalmic nerve receives filaments from the cavernous plexus of the sympathetic and it gives off, soon after its origin, a **tentorial (recurrent meningeal) branch** which runs backward, in close association with the trochlear nerve, and ramifies between the layers of the tentorium cerebelli. Further forward three branches spring from the ophthalmic nerve which contribute sensory fibers to the oculomotor, trochlear, and abducens nerves.

The terminal branches.—(*a*) The **frontal nerve** (n. supraorbitalis NK) is the largest terminal branch. It pierces the dura mater and passes into the orbit through the superior orbital (sphenoidal) fissure, above the rectus lateralis and a little below and to the lateral side of the trochlear nerve. In the orbit it runs forward, between the levator palpebræ superioris and the periosteum, and breaks up into three branches, the supraorbital, frontal proper, and supratrochlear.

The **supraorbital nerve** (ramus lateralis n. supraorbitalis NK), the largest of the three branches, leaves the orbit at the supraorbital notch (fig. 803). As it passes through the notch it gives off a small branch which enters the bone and supplies the diploë and the mucous membrane of the frontal sinus. Its terminal branches give twigs to the pericranium and to the skin of the scalp, the upper eyelid, the frontal region, and the parietal region almost as far as the lambdoid suture (fig. 809). One branch running at the upper margin of the orbital cavity unites with a branch of the facial nerve.

The **frontal branch** (ramus medialis n. supraorb. NK), given off at a variable point, lies medial to the supraorbital, passes through the frontal foramen, and is distributed to the skin of the forehead and upper eyelid (fig. 803).

The **supratrochlear branch** runs forward and medialward toward the upper and medial angle of the orbit, where it passes above the pulley of the superior oblique muscle, pierces the palpebral fascia, and ascends to the lower and middle part of the forehead, accompanied by the frontal artery (fig. 803). Before it leaves the orbit it sends a branch downward behind or in front of the pulley of the obliquus superior which joins with the infratrochlear nerve, and as it leaves the orbit it gives off filaments to supply the skin and conjunctiva of the medial third of the upper eyelid. Its terminal branches pierce the orbicularis and frontalis muscles, and, as they pass to the skin of the forehead, they communicate with branches of the facial nerve.

For the **cutaneous nerves of the scalp**, see p. 1098.

(*b*) The **lacrimal nerve** [n. lacrimalis] is the smallest of the three branches of the ophthalmic division. It passes through the superior orbital (sphenoidal) fissure lateral to and slightly below the frontal nerve, and is directed forward and lateralward, along the upper border of the rectus lateralis to the lacrimal gland (fig. 803). On the lateral wall of the orbit it receives a small branch from the zygomatic nerve (the orbital branch of the maxillary nerve). This branch brings to the lacrimal nerve secretory fibers for the lacrimal gland. A small twig passes beyond the gland, pierces the palpebral fascia, supplies filaments to the conjunctiva, and is then distributed to the integument at the lateral angle of the eye and to the skin over the zygomatic process of the frontal bone.

(*c*) The **nasociliary (nasal) nerve** enters the orbit between the two heads of the rectus lateralis and between the superior and inferior branches of the oculomotor nerve. In the orbit it lies at first lateral to the optic nerve, but, as it runs obliquely forward and medialward to the medial wall of the orbital cavity, it crosses above the optic nerve and between it and the rectus superior and, near the border

of the rectus medialis, it divides into its terminal branches, the chief of which are the *infratrochlear* and *anterior ethmoidal* nerves (fig. 803). In addition to those received from the cavernous plexus before the division of the ophthalmic nerve, the nasociliary nerve itself receives numerous sympathetic (secretory and vaso-motor) fibers.

Its several **branches** are: (i) The **long root of the ciliary ganglion** which is given off at the superior orbital (sphenoidal) fissure. It is a slender filament which runs forward on the lateral side of the optic nerve to the superior and posterior part of the ciliary ganglion (fig. 803).

(ii) The **long ciliary nerves,** usually two in number, which arise from the nasociliary nerve as the latter is crossing above the optic nerve. They run forward, on the medial side of the optic nerve, pierce the sclerotic, and are distributed with the lower set of short ciliary nerves (fig. 803). The long root of the ciliary ganglion and the long ciliary nerves carry sensory fibers which belong to the nasociliary nerve proper. The long root also carries sympathetic fibers, most of which merely pass through the ganglion. The ciliary branches of the nasociliary and other terminal twigs of the frontal nerve are offered as chiefly explaining the neuralgia in acute iritis, glaucoma and herpes frontalis.

(iii) The **posterior ethmoidal** (n. ethmoidalis minor NK) springs from the posterior border of the nasociliary nerve near the upper border of the rectus medialis. It passes through the

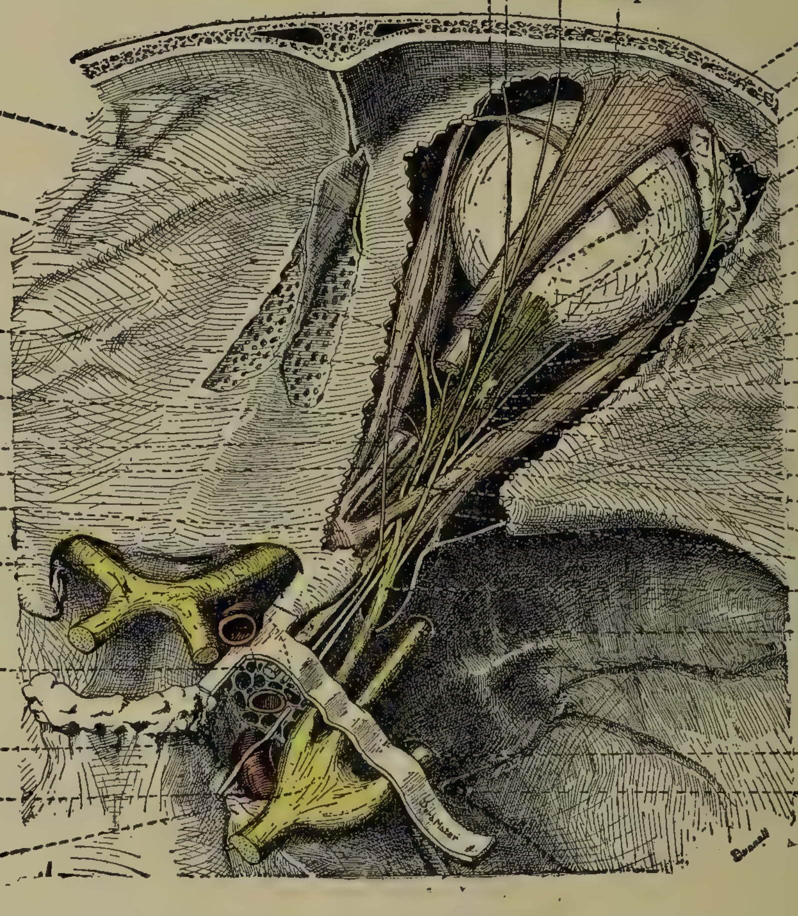


FIG. 803.—NERVES OF THE ORBIT FROM ABOVE AND BEHIND. (Schematic.)

posterior ethmoidal canal and is distributed to the mucous membrane of the posterior ethmoidal cells and the sphenoidal sinus.

(iv) The **infratrochlear nerve** passes forward between the obliquus superior and the rectus medialis, and under the pulley of the former muscle divides into two branches: The **superior palpebral branch** helps to supply the eyelids with sensory fibers and usually anastomoses with the supratrochlear nerve. The **inferior palpebral branch** is distributed to the lacrimal sac, the conjunctiva and skin of the medial part of both eyelids, the caruncle, and the skin of the upper part of the side of the nose.

(v) The **anterior ethmoidal** (n. ethmoidalis major NK) **nerve,** passing forward and medialward between the obliquus superior and the rectus medialis, leaves the orbit through the anterior ethmoidal foramen, accompanied by the anterior ethmoidal vessels, and enters into the anterior fossa of the cranium (fig. 803). It then crosses the lamina cribrosa of the ethmoid, lying outside the dura mater, which separates it from the olfactory bulb, and descends into the nasal fossa through the ethmoidal fissure, a slit-like aperture at the side of the crista galli. In the submucosa of the nasal fossa it terminates by dividing into two sets of *anterior nasal branches:* the internal nasal branches and the external nasal branch (fig. 801).

The **internal nasal branches** divide into the **medial nasal branches** (the septal branches of the nasal nerve), which run downward and forward on the upper and front part of the septum, and the **lateral nasal branches** (the external terminal branch of the nasal nerve), which give

twigs to the anterior extremities of the superior and middle nasal conchæ (turbinated bones), and to the mucous membrane of the lateral wall of the nose (fig. 801).

The **external nasal branch** (the anterior terminal branch of the nasal nerve) runs downward in a groove on the inner surface of the nasal bone. It pierces the wall of the nose between the nasal bone and the upper lateral cartilage, and supplies the integument of the lower part of the dorsum of the nose as far as the tip.

(2) The Maxillary Nerve or Second Division of the Trigeminus

The maxillary nerve is entirely sensory in function and it is intermediate in size between the ophthalmic and mandibular nerves. It springs from the middle of the anterior border of the semilunar (Gasserian) ganglion and runs forward in the lower and outer part of the lateral wall of the cavernous sinus (fig. 804). Leaving the middle fossa of the cranium, by passing through the foramen rotundum, it enters the pterygopalatine (sphenomaxillary) fossa (figs. 801, 803), where it is joined by twigs with the sphenopalatine ganglion; then, changing its name, it passes forward, as the **infraorbital nerve,** through the inferior orbital (sphenomaxillary) fissure into the infraorbital sulcus in the floor of the orbit; continuing forward it traverses the infraorbital canal accompanied by the infraorbital artery, and appears in the face, beneath the levator labii superioris (quadratus) and above the levator anguli oris (caninus) muscles where it divides into four sets of terminal branches which anastomose more or less freely with branches of the facial nerve to form the **infraorbital plexus.**

In cases of intractible neuralgia, the maxillary nerve may be injected with alcohol by passing a needle along the floor of the orbit from its inferolateral angle in a direction backward and slightly medially to the foramen rotundum which lies 4.5 cm. from the surface.

Branches.—The branches of the maxillary nerve are—(*a*) branches given off in the middle fossa of the cranium; (*b*) branches given off in the pterygopalatine (sphenomaxillary) fossa; (*c*) branches given off in the infraorbital sulcus and canal; and (*d*) terminal branches.

(*a*) The **middle (recurrent) meningeal branch** (ramus meningeus NK), given off in the middle fossa of the cranium, breaks up into numerous branches which supply the dura mater with sensory fibers, reinforce the sympathetic plexus on the middle meningeal artery, and anastomose with the spinous nerve (the recurrent branch of the mandibular nerve).

(*b*) The branches given off in the pterygopalatine (sphenomaxillary) fossa are the sphenopalatine nerves, the zygomatic branch of the maxillary nerve, and the posterior superior alveolar nerves.

The **sphenopalatine nerve** has two or three branches which descend in the pterygopalatine fossa and give a small part of their fibers to the sphenopalatine (Meckel's) ganglion (figs. 801, 804), the larger part of their fibers passing through the ganglion into its orbital, nasal, and palatine branches. (See Sphenopalatine Ganglion, p. 1037.)

The **zygomatic (orbital or temporomalar) nerve,** given off from the upper surface of the maxillary nerve, passes forward and lateralward, and, at the end of the inferior orbital (sphenomaxillary) fissure, passes through it into the orbit and divides into two branches, facial and temporal.

The **zygomaticofacial branch** runs forward, passes through a zygomatico-orbital foramen, then through the zygomaticofacial (malar) foramen, pierces the orbicularis palpebrarum, communicates with the zygomatic (malar) branch of the facial nerve, and supplies the skin of the prominence of the cheek. The **zygomaticotemporal branch** runs upward in a groove in the lateral wall of the orbit, passes through a zygomatico-orbital foramen, then through the zygomaticotemporal (sphenomalar) foramen, and enters the temporal fossa. It turns around the anterior border of the temporal muscle, pierces the deep layer of the temporal fascia, and runs backward for a short distance in the fat between the superficial and deep lamellæ, then, turning lateralward, it pierces the superficial lamellæ about an inch above the zygoma, anastomoses with the temporal branch of the facial nerve, and supplies the skin of the anterior part of the temporal region.

The **infraorbital nerve,** that large part of the maxillary nerve lying distal to the sphenopalatine ganglion, enters the orbit through the inferior orbital (sphenomaxillary) fissure, accompanied by the infraorbital artery, and with it passes through the infraorbital canal (fig. 804)) to the face, where it divides into four sets of terminal branches, some of which, by anastomoses with the branches of the facial nerve, form the **infraorbital plexus.**

Three sets of **superior alveolar nerves** arise from the maxillary and the infraorbital nerves, namely, the posterior superior alveolar branches, the middle superior alveolar branch, and the anterior superior alveolar branches.

The **posterior superior alveolar (dental) nerves** (rr. alveolares maxillares aborales NK) are usually two in number, but sometimes arise by a single trunk. They pass downward and lateralward through the pterygomaxillary fissure into the zygomatic fossa, where they give branches to the mucous membrane of the gums and the posterior part of the mouth; then they enter the posterior alveolar (dental) canals and unite with the other alveolar branches to form

the **superior dental plexus**, through which they give branches to the roots and pulp cavities of the molar teeth and to the mucous membrane of the maxillary sinus (fig. 804).

(*c*) The branches given off in the infraorbital sulcus and canal are the middle and anterior superior alveolar (dental) nerves.

(i) The **middle superior alveolar (dental) nerve** (r. alv. maxillaris medius NK) leaves the infraorbital nerve in the posterior part of the infraorbital sulcus, and, passing downward and forward in a canal in the maxilla, it divides into terminal branches that anastomose with the other alveolar branches to form the *superior dental plexus*. Through the plexus it supplies the bicuspid teeth and gives branches to the mucous membrane of the maxillary sinus and also to the gums (fig. 804).

(ii) The **anterior superior alveolar (dental) nerve** (rr. alv. maxillares orales NK) is the largest of the superior alveolar nerves. It is given off by the infraorbital nerve in the anterior part of the infraorbital canal, and passes downward in a bony canal in the anterior wall of the maxilla. After uniting with the other alveolar nerves to form the superior dental plexus, it supplies the canines and the incisors and gives branches to the mucous membrane of the maxillary sinus and the gums (fig. 804). It also gives off a **nasal branch** which enters the nasal fossa through a small foramen, and supplies the mucous membrane of the anterior part of the inferior meatus and the adjacent part of the floor of the nasal cavity.

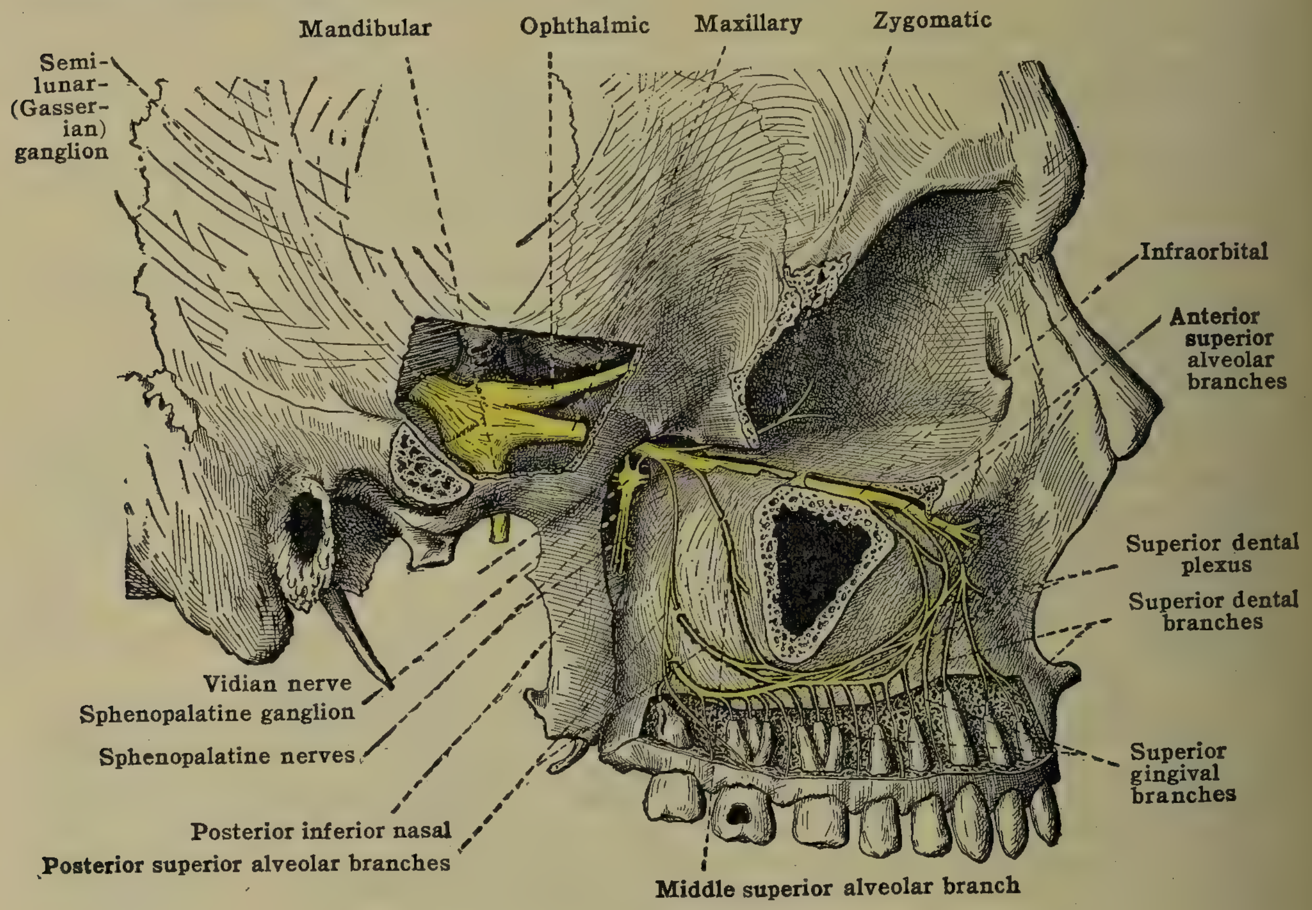


FIG. 804.—LATERAL VIEW OF THE MAXILLARY NERVE.

The **superior dental plexus** (plexus dentalis maxillaris NK) is formed in the bony alveolar canals by the three superior alveolar nerves. It is convex downward and anastomoses across the midline with the corresponding plexus of the other side (fig. 804). From it arise the **superior dental branches** supplying the superior canines and incisors, **superior gingival branches** supplying the gums, and also branches to the mucous membrane of the maxillary sinus and to the bone. On the plexus are two gangliform enlargements, one, called the *ganglion of Valentine*, situated at the junction of the middle and the posterior branches, and the other, called the *ganglion of Bochdalek* at the junction of the middle and anterior branches.

(*d*) The terminal branches of the maxillary nerve are the inferior palpebral, the external and internal nasal (nasal), and the superior labial.

The **inferior palpebral branches** (rr. palpebrales malares NK) usually two, pass upward and supply sensory fibers to all the skin and conjunctiva of the lower eyelid (fig. 809).

The **external nasal branches** pass medialward under cover of the levator labii superioris (quadratus), and supply the skin of the posterior part of the lateral aspect of the nose.

The **internal nasal branches** pass downward and medialward under the lateral wall of the nose, and then turn upward to supply the skin of the vestibule of the nose.

The **superior labial branches** (rr. labiales maxillares NK), three or four in number, as a rule are larger than the palpebral and nasal branches. They pass downward to supply the skin and mucous membrane of the upper lip and the neighboring part of the cheek.

(3) The Mandibular Nerve or Third Division of the Trigeminus

The **mandibular division** is the largest of the three divisions of the trigeminus (figs. 805 and 809). As a nerve, it is usually described as formed by the union of two distinct nerves, namely, the entire masticator nerve and the large bundle of sensory fibers derived from the semilunar (Gasserian) ganglion which pass peripherally as the third division of the trigeminus. These two nerves remain separate until they pass through the foramen ovale and then unite immediately outside the skull to form a large trunk which almost directly after its formation divides into a small *anterior* and a larger *posterior portion.* The trunk is situated between the pterygoideus externus laterally, and the otic ganglion and the tensor veli palatini medially. In front of it is the posterior border of the pterygoideus internus, and behind it, the middle meningeal artery. Two branches arise from the trunk of the nerve before its division, namely, the spinous (recurrent) nerve and the nerve to the pterygoideus internus.

The **spinuous (recurrent) nerve** (r. meningeus NK), after receiving a vasomotor filament from the otic ganglion, enters the cranium through the foramen spinosum, accompanying the middle meningeal artery, and divides into an anterior and a posterior branch. The anterior branch communicates with the meningeal branch of the maxillary division of the trigeminus, furnishes filaments to the dura mater, and ends in the osseous substance of the great wing of the sphenoid. The posterior branch traverses the petrosquamous suture and ends in the lining membrane of the mastoid cells.

The fibers going to form the *nerve to the internal pterygoid muscle* are almost wholly motor fibers and therefore comprise a branch of the masticator nerve and are described as such under the description of the masticator (fig. 806).

Injection of the mandibular nerve with alcohol, by means of a long stout hypodermic needle, is practised in cases of intractable neuralgia as an alternative to excision of the semilunar ganglion. A vertical line is drawn on the cheek downward from the junction of the posterior and middle thirds of the zygomatic arch, and the needle is entered on this line at a point 1.5 cm. from the lower border of the zygoma. It is directed upward and medially so as to pass through the lowest part of the mandibular notch. If the mouth is opened the notch is depressed and more room gained. The needle impinges first against the inferior surface of the great wing of the sphenoid bone, and when the point is lowered a little it engages in the foramen ovale at a depth of 4–4.5 cm. In most cases the needle can be passed through the foramen ovale into the semilunar ganglion. (Harris. Lancet, Jan. 23, 1912.)

The **anterior portion** of the mandibular nerve is smaller than the posterior and is chiefly composed of motor fibers which constitute the branches of the masticator nerve that supply the muscles of mastication, the temporalis, masseter, and pterygoideus externus. Practically all of the sensory fibers of the anterior portion (fibers of the mandibular nerve proper) form the buccinator (long buccal) nerve. The latter is accompanied, in the first part of its course, by a small strand of motor or masticator fibers which leaves it to end in the anterior part of the temporal muscle.

The **buccinator (long buccal) nerve** (n. buccalis NK), entirely sensory, passes between the two heads of the external pterygoid muscle and runs downward and forward under cover of or through the anterior fibers of the temporalis to the cheek (fig. 805). As it passes forward it emerges from under cover of the anterior border of the masseter and lies on the superficial surface of the buccinator, where it interlaces with the buccal branches of the facial nerve and gives off filaments to supply the superjacent skin; finally it pierces the buccinator and supplies the mucous membrane on its inner surface as far forward as the angle of the mouth. The fibers of the anterior deep temporal nerve, a branch of the masticator, are frequently associated with the buccinator until the latter has passed between the heads of the external pterygoid; then the anterior deep temporal nerve separates from the buccinator and passes upward on the lateral surface of the upper head of the external pterygoid.

The **posterior portion** of the mandibular nerve divides into three large branches. Two of these, the lingual and the auriculotemporal nerves, are exclusively sensory; the third, the inferior alveolar (dental) nerve, contains a strand of motor fibers, the mylohyoid nerve, which comprise a branch of the masticator nerve.

The **lingual nerve** is the most anterior branch of the posterior portion of the mandibular nerve (figs. 805, 812). It lies in front and to the medial side of the inferior alveolar (dental) nerve and descends at first on the medial side of the pterygoideus externus, then between the pterygoideus internus and the ramus of the mandible to the posterior part of the mylohyoid ridge, where it passes off the anterior border of the pterygoideus internus. At this point it is situated a short distance behind the last molar tooth and is covered in front by the mucous membrane of the posterior part of the mouth cavity. After leaving the ptery-

goideus internus it crosses the superior constrictor, which is attached to the mandible, and turns forward toward the tip of the tongue, crossing the lateral surfaces of the styloglossus, hyoglossus, and genioglossus. It its course across the hyoglossus it lies first above, then to the lateral side of, and finally below Wharton's duct, and as it ascends on the genioglossus it lies on the medial side of the duct.

Communications and branches.—While it is on the medial side of the pterygoideus externus the lingual nerve is joined, at an acute angle, by the chorda tympani (figs. 805, 812), a branch of the glossopalatine nerve, and as it lies between the ramus of the mandible and the pterygoideus internus it is connected by a branch with the inferior alveolar (dental) nerve, and gives off one or two small branches, the **rami isthmi faucium** (rr. palatini NK), which are ditributed as sensory fibers to the tonsil and the mucous membrane of the posterior part of the mouth (fig. 812).

While it is above the duct it gives a branch, which contains many sensory and visceral efferent chorda tympani fibers, to the submaxillary ganglion (see pp. 1022, 1039), and it receives branches, chiefly sympathetic, from that ganglion. A little further forward it is connected by

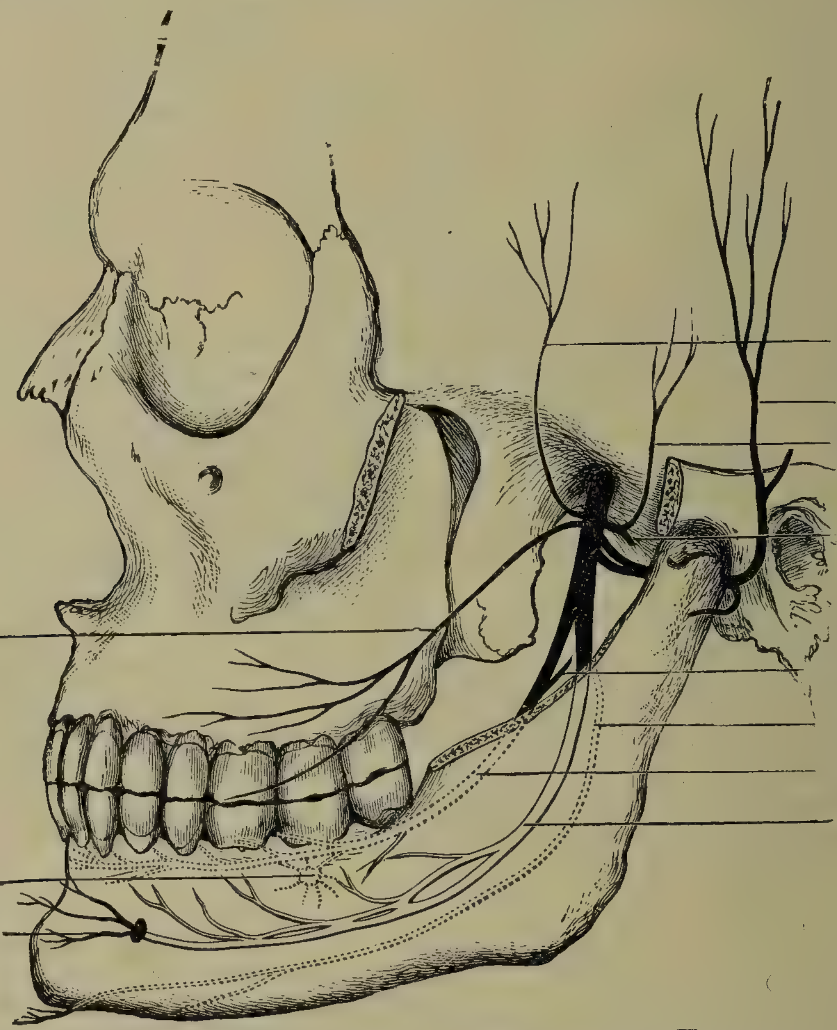


Fig. 805.—Distribution of the Mandibular Division of the Trigeminus Combined with Branches of the Masticator Nerve. (Henle.)

one or two branches, which run along the anterior border of the hyoglossus, with the hypoglossal nerve (fig. 812). It then gives off the **sublingual nerve**, which runs forward to supply the sublingual gland and the neighboring mucous membrane. Its terminal (**lingual**) **branches** are derived chiefly from the glossopalatine nerve. They pierce the muscular substance of the tongue and are distributed to the mucous membrane of its anterior two-thirds. They interlace with similar branches of the other side and with branches of the glossopharyngeal nerve.

The **inferior alveolar (dental) nerve** (n. alveolaris mandibularis NK) is the largest branch of the posterior portion of the mandibular nerve. It commences on the medial side of the external pterygoid muscle and descends to the interval between the sphenomandibular ligament and the ramus of the mandible, where it receives one or two communicating branches from the lingual nerve. Opposite the middle of the medial surface of the ramus it enters the mandibular (inferior dental) canal, accompanied by the inferior alveolar (dental) artery, which lies in front of the nerve, and it runs downward and forward through the ramus and the body of the mandible (fig. 805). At the mental foramen it divides into two parts, one of which, the *mental nerve*, passes out through the mental foramen, the other, commonly called the *incisive branch*, continues forward in the canal,

and supplies, through the inferior dental plexus, the inferior canine and incisor teeth and the corresponding regions of the gums.

Branches.—The branches of the inferior alveolar (dental) nerve are branches forming the inferior dental plexus, and the mental nerve. A bundle of motor fibers, the *mylohyoid nerve*, a branch of the masticator nerve, is given off just before the inferior alveolar nerve enters the mandibular canal.

The **inferior dental plexus** (plexus dentalis mandibularis NK) is formed by a series of branches which communicate with one another within the bone, giving rise to a fine network. From this plexus two sets of branches are given off: the **inferior dental branches**, corresponding in number to the roots of the teeth, enter the minute foramina of the apices of the roots and end in the pulp; the second set, the **inferior gingival branches**, supply the gums. In operating to relieve neuralgia affecting this plexus, the trephining is done midway between the margins of the mandible at the level of the first molar.

The **mental nerve** is a nerve of considerable size which emerges through the mental foramen (fig. 805). It communicates, near its exit from the bone, with branches of the facial nerve, and then divides into three branches. The smallest branch, turning downward, divides into several twigs, the *mental branches*, which supply the integument of the chin. The other two, *inferior labial branches* (rr. labiales mandibulares NK), pass upward, diverging as they ascend, and divide into a number of twigs. The stoutest twigs ramify to the mucous membrane which lines the lower lip. Other twigs are distributed to the integument and fascia of the lip and chin.

The **auriculotemporal nerve** usually arises from the posterior portion of the mandibular nerve by two roots which embrace the middle meningeal artery and unite behind it to form the trunk of the nerve. The trunk passes backward on the medial aspect of the pterygoideus externus and between the sphenomandibular ligament and the mandibular articulation, lying in close relation with the capsule of the joint. Behind the joint it enters the upper part of the parotid gland, through which it turns upward and lateralward. It emerges from the upper end of the gland, crosses the root of the zygoma close to the posterior border of the superficial temporal artery, and divides into auricular and temporal terminal branches at the level of the tragus of the pinna (figs. 805, 809).

Communications.—(*a*) Each of the two roots of the nerve receives a communication from the otic ganglion containing fibers derived from the glossopharyngeal nerve. These fibers have passed from the glossopharyngeal through the tympanic plexus and the small superficial petrosal nerve and through the otic ganglion.

(*b*) Sensory filaments pass from the auriculotemporal nerve to the temporofacial branch of the facial nerve.

(*c*) Filaments of connection with the sympathetic plexus on the internal maxillary artery.

(*d*) A communication to the inferior alveolar (dental) nerve.

Branches of the auriculotemporal nerve.—(*a*) An **articular branch** to the mandibular joint, given off as the nerve lies on the medial side of the capsule.

(*b*) **Branches to the external auditory meatus.** Two branches, as a rule, are given off in the parotid gland. They enter the meatus by passing between the cartilage and the bone and supply the upper part of the meatus and the membrana tympani by a fine branch, and occasionally the lower branch gives twigs to the skin of the lobule of the pinna. This innervation is supplemented by a twig from the auricular branch of the vagus to the inner part of the meatus.

With cancer and other painful affections of the tongue, there is often experienced *'referred pain'* in the tympanic membrane, meatus, external ear and side of the head. This may be explained as resulting from bifurcation of sensory (trigeminal) fibers at the level of the origin of the auriculotemporal branch from the mandibular nerve, one part of each bifurcation passing into the lingual nerve to the cancer, the other into the auriculotemporal with the sensory supply for the areas mentioned.

(*c*) **Parotid branches** are distributed to the substance of the parotid gland. Sensory or trigeminal fibers for the gland spring either directly from the nerve or from the communicating branches previously given by it to the glossopalatine nerve. The parotid branches also contain fibers derived from the glossopharyngeal nerve which pass successively through its tympanic branch, the tympanic plexus, the small superficial petrosal nerve, the otic ganglion, and the communicating twigs from the otic ganglion to the roots of the auriculotemporal nerve. The parotid branches are later again mentioned as concerned chiefly with the *gangliated cephalic plexus*.

(*d*) The **anterior auricular branches** (nn. auriculares temporales NK), usually two in number, are distributed to the skin of the tragus and the upper and outer part of the auricle.

(*e*) The **superficial temporal branches** supply the integument of the greater part of the temporal region, and anastomose with the temporal branch of the facial nerve.

THE MASTICATOR NERVE (Fig. 806)

The masticator nerve (*motor root or portio minor of trigeminus*). The fibers of the masticator nerve spring from two nuclei, a slender upper or mesencephalic nucleus and a clustered lower or chief nucleus. The fibers arising in the mesencephalic nucleus descend along the lateral aspect of the nucleus to the pons as the *descending* or *mesencephalic root*, here they join the fibers from the chief motor

nucleus and issue with them from the side of the pons in from six to ten root filaments. These blend to form the nerve, which is from 1½ to 2 mm. broad.

At the point where it emerges from the pons the nerve is in front of and ventral to the root of the trigeminus and it is separated from the latter by a few of the transverse fibers of the pons which constitute the *lingula of Wrisberg.*

From its superficial exit from the pons, the masticator nerve passes upward, lateralward, and forward in the posterior fossa of the cranium, and along the medial and anterior aspect of the trigeminus, to the mouth of Meckel's cave.

In this cavity it runs lateralward below the semilunar (Gasserian) ganglion to the foramen ovale, through which it passes to join the mandibular division of the trigeminus immediately outside and below the base of the skull. The nerve is almost entirely motor and its fibers are devoted almost wholly to the muscles having to do with mastication.

Paralysis of the muscles of mastication may result from heedless operations upon the semilunar ganglion or the trunk of the trigeminus for relief of neuralgia.

Central connections.—The nuclei of origin of the masticator nerve are connected with the lower part of the somesthetic area of the cerebral cortex of the opposite side by the pyramidal

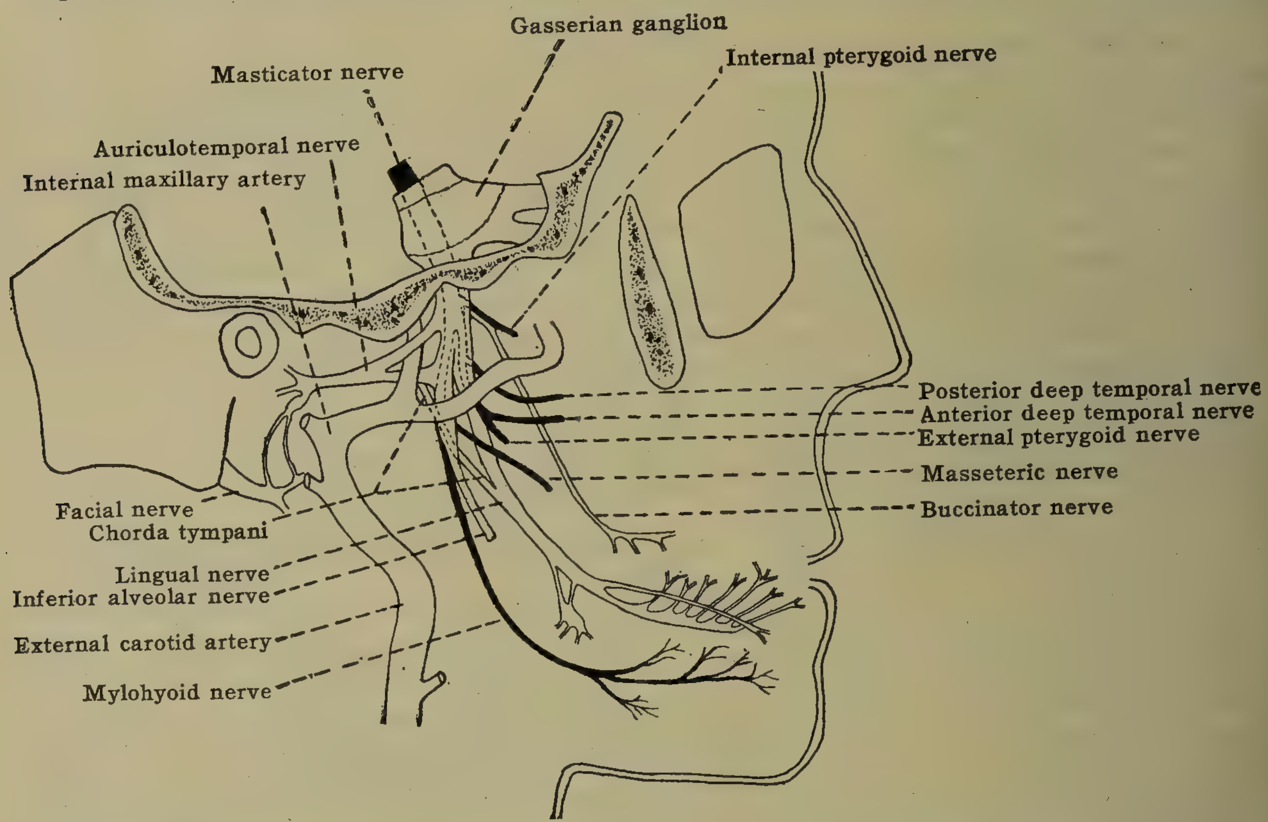


FIG. 806.—DIAGRAM OF THE MASTICATOR NERVE AND ITS BRANCHES (IN HEAVY BLACK).

fibers descending in the genu of the internal capsule, and they are associated with the sensory nuclei of other cranial nerves, especially the trigeminus, through the reticular formation and by the medial longitudinal fasciculus. Recent investigations indicate that the mesencephalic root is not wholly motor but is, at least in part, sensory in character, and that its sensory fibers arise from cell-bodies which have remained within the central system instead of migrating outside to form a ganglion. (See pp. 905, 913.)

Branches.—Almost immediately after joining the trunk of the mandibular nerve, most of the fibers of the masticator leave it to form the greater part of the so-called anterior portion of the mandibular. However, one branch of masticator fibers, the nerve to the internal pterygoid muscle, is given off from the mandibular just before its division into anterior and posterior portions. The masticator branches derived from the anterior portion are the *deep temporal* nerves, the *masseteric* nerve, and the nerve to the *external pterygoid.* One branch, the *mylohyoid* nerve, is carried in the posterior portion of the mandibular and is given off from its inferior alveolar branch.

The **nerve to the internal pterygoid** (n. pterygoideus medialis NK) passes under cover of a dense layer of fascia derived from an expansion of the ligamentum pterygospinosum, and enters the deep surface of the muscle. Near its commencement this nerve furnishes a visceral motor root to the otic ganglion, and small twigs to the tensor tympani and tensor palati.

The **deep temporal nerves**, usually two in number, posterior and anterior, pass between the bone and the upper border of the external pterygoid muscle, and turn upward around the infratemporal crest of the sphenoid bone to end in the deep surface of the temporalis (fig. 805).

The posterior of the two often arises in common with the masseteric nerve. The anterior is frequently associated with the buccinator (long buccal) nerve till the latter has passed between the two heads of the pterygoideus externus. There is frequently a third branch, the **medius**, which passes lateralward above the pterygoideus externus, and turns upward close to the bone to enter the deep surface of the muscle. A small strand of masticator fibers accompanies the buccinator nerve to enter and end in the anterior part of the temporal muscle.

The **masseteric nerve**, which frequently arises in common with the posterior deep temporal nerve, passes between the bone and the pterygoideus externus, and accompanies the masseteric artery through the notch of the mandible to be distributed to the masseter (fig. 805). It is easily traced through the deeper fibers nearly to the anterior border of the masseter. As it emerges above the pterygoideus externus it gives off a twig to the mandibular articulation.

The **nerve to the external pterygoid** (n. pterygoideus lateralis NK), after a course of about 3 mm., divides into twigs which enter the deep surface of the two heads of the muscle. It is usually adherent at its origin to the buccinator nerve.

The **mylohyoid nerve**, carried in the posterior portion of the mandibular nerve, is given off immediately before the inferior alveolar (dental) nerve enters the mandibular (inferior dental) canal. It pierces the lower and back part of the sphenomandibular ligament and runs downward and forward in the mylohyoid groove between the mandible on the lateral side, and the internal pterygoid muscle and the lateral surface of the submaxillary gland on the medial side. In the anterior part of the digastric triangle it is continued forward between the anterior part of the submaxillary gland and the mylohyoideus, and it breaks up into branches which supply the mylohyoideus and the anterior belly of the digastric (fig. 805).

THE FACIAL NERVE

The facial (or seventh) nerve is purely motor and almost entirely somatic motor. It is accompanied a short distance by a bundle usually called its *sensory root* or the *intermediate nerve*. This latter, however, on the basis of its origin, distribution, and mixed instead of sensory character, is described separately below as the *glossopalatine nerve*. It is smaller than the facial, is fused to the trunk of the facial, and the ganglion giving rise to its sensory fibers is situated upon the external genu of the facial (figs. 807, 810).

The fibers of the facial nerve (fig. 807) arise from a nucleus of cells situated laterally in the reticular formation at the level of the lower part of the pons, dorsal to the superior olive, and between the root fibers of the abducens nerve and the laterally placed spinal tract of the trigeminus. From this nucleus the fibers of the nerve pass medially and dorsalward to the floor of the fourth ventricle and just under the floor, they turn anteriorly, passing dorsal to the nucleus of the abducens (fig. 732). At the anterior end of this nucleus they turn sharply ventralward and lateralward, and at this point it is claimed that fibers descending in the near-by medial longitudinal fasciculus from the nucleus of the oculomotor nerve of the same side become intermingled with the fibers of the facial nerve and pass outward with them. This, however, is uncertain. Continuing ventralward through the reticular formation the fibers of the facial emerge from the brain-stem at the inferior border of the pons, lateral to the superficial attachment of the abducens. At the point of its emergence, the facial nerve pierces the pia mater, from which it receives a sheath, and then proceeds forward and lateralward in the posterior fossa of the cranium to the internal auditory meatus, which it enters in company with the glossopalatine nerve and with the cochlear and vestibular nerves. As it lies in the meatus it is situated above and in front of the latter nerves, from which it is separated by the glossopalatine, and it is surrounded, together with these three nerves, by sheaths of both the arachnoid and the dura mater and by prolongations of the subarachnoid and subdural spaces. While it is still in the meatus it blends with the glossopalatine and thus the combined trunk is formed. At the outer end of the meatus this trunk pierces the arachnoid and the dura mater and enters the facial canal (aqueduct of Fallopius), in which it runs forward and slightly lateralward to the hiatus Fallopii, where it makes an angular bend, the external genu [geniculum], around the anterior boundary of the vestibule of the inner ear; this bend is enlarged by the adhesion of the geniculate ganglion (of the glossopalatine) upon its anterior border (fig. 808). From the geniculum the facial nerve runs backward in the facial canal along the lateral wall of the vestibule and the medial wall of the tympanum, above the fenestra vestibuli (ovalis), to the junction of the medial and posterior walls of the tympanic cavity; then, bending downward, it descends in the posterior wall to the stylomastoid foramen. As soon as it emerges from the stylomastoid foramen it turns forward around the lateral side of the base of the styloid process, and plunges into the substance of the parotid gland, where it divides into its cervicofacial and temporofacial terminal divisions. Before its

terminal divisions, the nerve gives off three, and sometimes four, small branches: one, the nerve to the stapedius muscle before it leaves the skull, the others after it leaves the skull.

The **nerve to the stapedius** is given off from the facial nerve as it descends in the posterior wall of the tympanum behind the pyramidal eminence. It is stated that filaments are also given off from the facial to the internal auditory artery (probably visceral motor from the glossopalatine) while the nerve is passing through the internal auditory meatus.

After it leaves the skull the facial nerve (fig. 809) gives off two or three collateral branches and its two terminal divisions, the temporofacial and cervicofacial. The collateral branches are the posterior auricular nerve, a branch to the posterior belly of the digastric, and sometimes a lingual branch.

(1) The **posterior auricular nerve** (n. retroauricularis NK) is the first branch of the extracranial portion of the facial nerve. It passes between the parotid gland and the anterior border of the sternomastoid muscle and runs upward in the deep interval between the external auditory meatus and the mastoid process. In this situation it communicates with the auricular branch of the vagus. It supplies the auricularis posterior, sends a slender twig upward to the auricularis superior, and ends in a long slender branch, **the occipital branch,** which passes backward to supply the occipitalis muscle. It also receives filaments from the small occipital and great auricular nerves, and supplies the intrinsic muscles of the auricle (pinna).

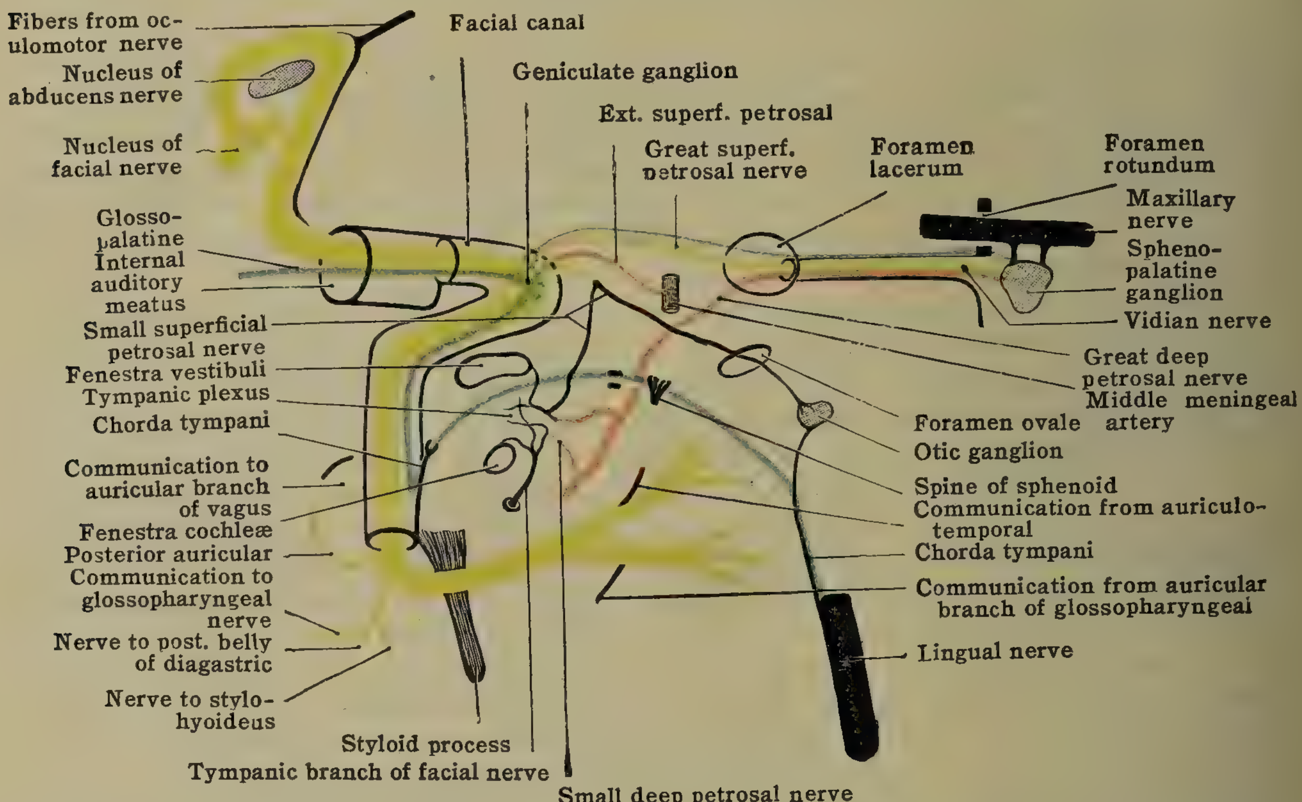


Fig. 807.—Diagram of the Facial (Yellow) and Glossopalatine Nerve (Blue).

(2) The **nerve to the posterior belly of the digastric** arises from the facial nerve close to the stylomastoid foramen and enters the muscle near its center, or sometimes near its origin. It usually gives off two branches: the **nerve to the stylohyoid,** which sometimes arises directly from the facial nerve and passes to the upper part of the muscle that it supplies, and the **anastomotic branch,** which joins the glossopharyngeal nerve below its petrous ganglion.

(3) The **lingual branch,** first described by Cruveilhier, is not commonly present. It arises a little below the nerve to the stylohyoideus and runs downward and medialward to the base of the tongue. In its course it passes to the medial sides of the styloglossus and stylopharyngeus, and runs downward along the anterior border of the latter muscle to the wall of the pharynx. It pierces the superior constrictor, insinuates itself between the tonsil and the anterior palatine arch, and it is stated that it gives filaments to the base of the tongue and to the styloglossus and glossopalatinus (palatoglossus) muscles.

The terminal divisions.—In the substance of the parotid gland the two terminal divisions of the facial nerve lie superficial to the external carotid artery and to the posterior facial (temporomaxillary) vein. The way in which these terminal divisions give off their branches varies much in different subjects and often on the opposite sides of the same subject. One of the more common forms is here described.

The **temporofacial** or upper division runs upward and forward, and, after receiving communicating twigs from the auriculotemporal nerve, gives off temporal and zygomatic (malar) branches. The **cervicofacial** or lower division runs downward and forward, receives branches from the great auricular nerve, and

gives off—(1) *buccal branches*, comprising what have been called infraorbital and buccal branches; (2) the *marginal mandibular* (supramandibular) branch; and (3) the *ramus colli* (inframandibular branch). These branches from the two terminal divisions anastomose freely to form the **parotid plexus** (pes anserinus).

The **temporal branches** of the temporofacial, (rr. temporofrontales NK), passing upward, communicate freely with each other and with the zygomatic branches. They also communicate with the zygomaticotemporal branch of the zygomatic nerve (the orbital branch of the maxillary nerve) and with the supraorbital nerve. They supply the frontalis, orbicularis oculi, corrugator supercilii, and auricularis anterior and superior (fig. 809).

The **zygomatic (malar) branches** passing upward and forward, communicate with the buccal branches of the facial nerve; with the zygomaticofacial branch of the zygomatic nerve (the orbital branch of the maxillary nerve); with the supraorbital and lacrimal branches of the ophthalmic nerve, and with the palpebral twigs of the maxillary. They supply both eyelids, the orbicularis oculi, and the zygomaticus (fig. 809).

The **buccal (infraorbital and buccal) branches** of the cervicofacial division arise sometimes from the lower terminal division and sometimes from both the upper and the lower terminal

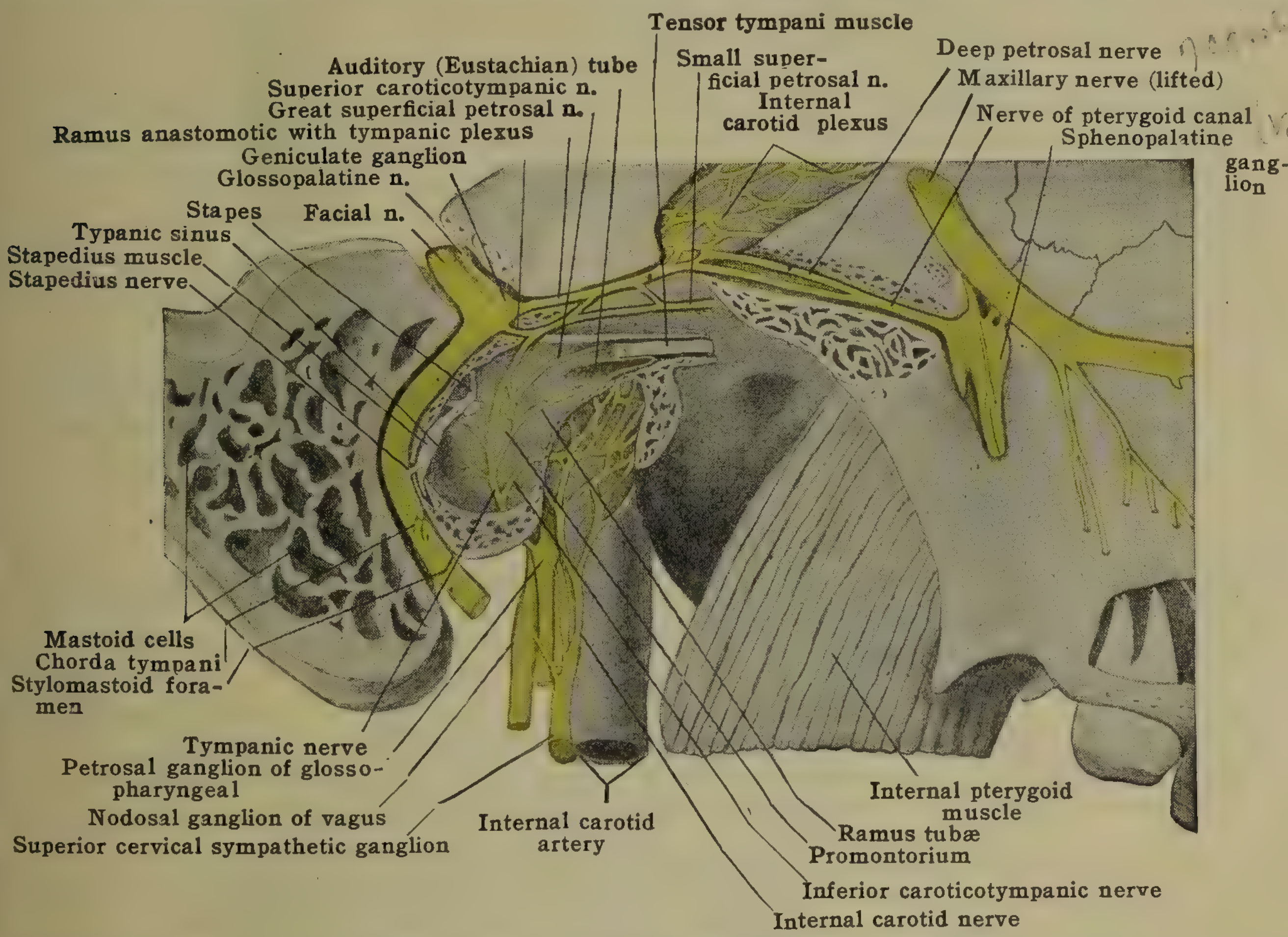


Fig. 808.—The Right Facial Nerve, within the Skull, and the Relations of the Glossopalatine and Glossopharyngeal Nerves with the Tympanic and Internal Carotid Plexuses. (From Sobotta's Atlas, modified.)

divisions. The buccal branches, passing forward upon the masseter and underneath the zygomaticus and quadratus labii superioris, interlace with the zygomatic and marginal mandibular (supramandibular) branches of the facial nerve, with the buccinator (long buccal) branch of the trigeminus, and with the terminal branches of the maxillary nerve, forming with the last-named nerve the **infraorbital plexus.** They supply the zygomaticus, risorius, quadratus labii superioris, caninus, buccinator, incisivi, orbicularis oris, triangularis, quadratus labii inferioris, and the muscles of the nose (fig. 809).

The **marginal mandibular (supramandibular) branch,** passing downward and forward under cover of the risorius and the depressors of the lower lip, communicates with the buccal branches and with the ramus colli of the facial nerve, and with the mental branch of the mandibular nerve. It supplies the quadratus labii inferioris and mentalis.

The ramus colli (inframandibular branch) runs downward and forward under cover of the platysma, which muscle it innervates (fig. 809). Beneath the platysma it forms one or more communicating loops, near its commencement, with the great auricular nerve, and longer loops, lower down, with the superficial cervical nerve.

Central connections.—The nucleus of origin of the facial in the rhombencephalon includes an anterior and a posterior group of cells which give rise respectively to its upper and lower terminal divisions. They are associated with the somesthetic area (lower third of the anterior central gyrus) by way of the pyramidal fasciculi of the opposite and same sides, and with the nuclei of the other cranial nerves, including the nucleus of termination of the trigeminus and glossopalatine, by way of the reticular formation and the medial longitudinal fasciculus.

Clinical aspects.—Operations upon the parotid gland and its ducts require care lest facial palsy result from severing terminal branches of the facial nerve. The buccal branch spreads out just below the main parotid (Stensen's) duct. If the cause of a facial paralysis lies within

the cerebrum (above the pons), the frontal, corrugator supercilii and orbicularis oculi muscles are not affected; while paralysis of the abducens and a hemiplegia of the opposite side of the body will be manifest. Destruction of the trunk of the facial or of its nucleus of origin in the rhombencephalon results in paralysis of the whole side of the face (Bell's paralysis), with drooping angle of the mouth, open eyelids, inability to whistle, frown etc.

GLOSSOPALATINE NERVE

The **glossopalatine nerve** (*sensory root or pars intermedia of facial; nerve of Wrisberg*) (n. intermedius NK) contains both sensory and motor fibers. While it

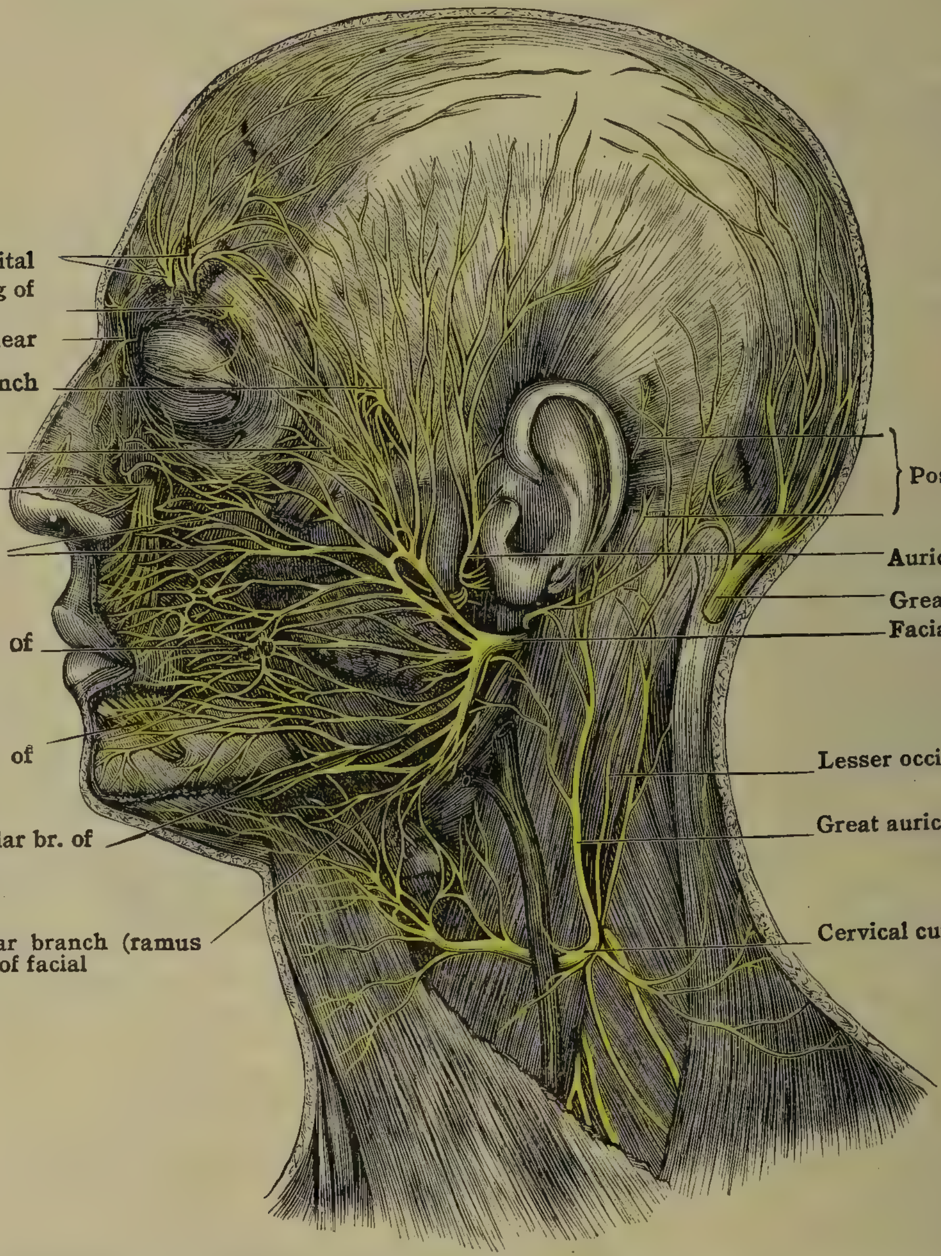


Fig. 809.—Superficial Distribution of the Facial and Other Nerves of the Head. (After Hirschfield and Leveillé.)

has a separate attachment to the medulla, it courses in close company with the facial and, in the internal auditory meatus, it is involved in the same sheath with the facial, which relation is maintained by its larger part thence through the facial canal till a short distance above the stylomastoid foramen (figs. 807, 808, 810). Here this larger part leaves the trunk of the facial as the *chorda tympani* nerve. The origin, central connections and peripheral distribution of the glossopalatine are similar to those of the glossopharyngeal nerve and suggest that it may be considered an aberrant portion of that nerve.

The **sensory portion** is much greater than the motor. Its fibers arise from cells situated in the geniculate ganglion which thus corresponds to a spinal ganglion. The *central processes* from these cells pass medialward in the facial canal (aqueduct of Fallopius) enclosed in the sheath of the facial nerve, which they leave in passing through the internal auditory meatus, to turn slightly downward in the posterior fossa of the cranium and enter the medulla at the inferior border of the pons, between the attachments of the facial and vestibular nerves. They course through the reticular formation of the medulla, medianward and dorsal-

ward to terminate about cells which comprise a superior extension of the nucleus of termination of the glossopharyngeal nerve (nucleus of ala cinerea). The *peripheral processes* from the geniculate ganglion are distributed chiefly to the epithelium covering the soft palate, portions of the glossopalatine arches, and the anterior two thirds of the tongue, the sensory innervation of which latter it shares with the lingual (trigeminal) nerve. It carries some fibers mediating taste sensations.

The **geniculate ganglion** (ganglion geniculi NK) is so named from the fact that it is embedded upon the anterior border of the external genu (*geniculum*) of the facial nerve, behind the hiatus Fallopii. It is somewhat triangular in form. From its superomedial angle leave the central processes of its cells, the root of the nerve; from its inferolateral angle leave the fibers which later leave the sheath of the facial as the chorda tympani, and its anterior angle is connected with the great superficial petrosal nerve (figs. 808 and 810). The geniculate ganglion contains a relatively large number of cell-bodies of sympathetic neurones many of whose processes run in this latter nerve, a relation mentioned below with the gangliated cephalic sympathetic plexus.

The **motor portion** of the glossopalatine consists for the most part of visceral efferent (autonomic) fibers, chiefly secretory. These arise in the medulla oblongata from a small group of cells scattered in the reticular formation dorsomedial to the nucleus of the facial and in line with the dorsal efferent nucleus of the vagus below. It is called the *salivatory nucleus.* The fibers course ventralward and lateralward to their exit, mingle with the entering sensory fibers of the glossopalatine in the sheath of the facial and, through the branches of the glossopalatine, pass to terminate in sympathetic ganglia of the head, large and small. These ganglia send axones which terminate in the smooth muscle of vessels and about the cells of the glands of the lingual and palatine mucous membrane and of the salivary glands proper.

Some of the motor fibers of the nerve terminate in contact with the sympathetic cells remaining in the geniculate ganglion and which give rise to sympathetic fibers issuing from it. Most of the motor fibers pass into the great superficial petrosal nerve and the chorda tympani to terminate in (chiefly) or pass through the sphenopalatine and submaxillary ganglia respectively. Some may pass by the geniculotympanic branch and tympanic plexus to end in the otic ganglion. Many no doubt end in the smaller ganglia involved in the various sympathetic plexuses. It is suggested that the motor part carries secretory impulses destined chiefly for the submaxillary and sublingual glands. A small gangliated plexus on the capsule of the medial side of the parotid gland has been frequently dissected and found to communicate freely with twigs from the facial nerve and twigs concerned with the trigeminus. It is possible that some glossopalatine visceral motor fibers terminate in these ganglia for secretory impulses to the parotid gland as well.

Central connections.—The nucleus of termination of the glossopalatine nerve (superior extension of the nucleus of termination of the sensory portion of the glossopharyngeal) is associated with the somesthetic area of the cerebral cortex of the opposite and same sides by way of the medial lemniscus, and with the salivatory nucleus and motor nuclei of other cranial nerves by way of the reticular formation and medial longitudinal fasciculus. The nucleus of origin of the motor portion (salivatory nucleus) may be associated not only with the nucleus of termination of the sensory part, but with the nuclei of termination of other cranial nerves, and perhaps with the motor area of the cortex of the opposite side by way of the pyramidal fasciculi.

Branches and communications.—Aside from its two or three small collateral twigs of communication, the fibers of the glossopalatine course in two main branches or nerves: (1) the great superficial petrosal nerve, continued through the Vidian nerve, and extended through and beyond the sphenopalatine ganglion as the palatine portion of the glossopalatine (palatine nerve); (2) the chorda tympani, the larger branch, which extends to join and contribute its quota of fibers to the lingual nerve, a branch of the trigeminus.

In the internal auditory meatus the glossopalatine gives two delicate collaterals to the vestibular nerve, and some filaments (visceral motor probably) are described as given to the internal auditory artery and to the temporal bone.

A small **geniculotympanic branch** is given, in the facial canal, from the geniculate ganglion to the small superficial petrosal nerve. This is probably all composed of visceral motor or sympathetic fibers (fig. 810).

There may occur a twig arising from or near the beginning of the chorda tympani and forming a *communication with the auricular branch of the vagus.*

A large part of the **great superficial petrosal nerve** is formed of glossopalatine fibers. This nerve is further described below in its relation to the sphenopalatine ganglion. It arises from the anterior angle of the geniculate ganglion, enters the middle fossa of the cranium

through the hiatus Fallopii, and passes beneath the semilunar ganglion into the foramen lacerum, where it joins with the great deep petrosal nerve to form the Vidian nerve. Thence the glossopalatine portion passes over or through the sphenopalatine ganglion to form the greater part of the small and middle palatine nerves which are distributed to the epithelium and glands of the soft palate, some of the sensory fibers probably terminating in the taste organs found there; the remainder serving as fibers of general sensibility. It is probable that most of the motor glossopalatine fibers in the great superficial petrosal nerve terminate in the sphenopalatine ganglion; some may pass to the carotid plexus and to small ganglia elsewhere.

The chorda tympani consists to a very large extent of sensory fibers (peripheral processes of the cells of the geniculate ganglion), but it also contains motor fibers and is thus also a mixed nerve. It leaves the trunk of the facial nerve a short distance above the stylomastoid foramen, and pursues a slightly recurrent course upward and forward in the canaliculus chordæ tympani (iter chordæ posterius), a minute canal in the posterior wall of the tympanic cavity, and it enters that cavity close to the posterior border of the membrana tympani. It crosses the cavity, running on the medial surface of the tympanic membrane at the junction of its upper and middle

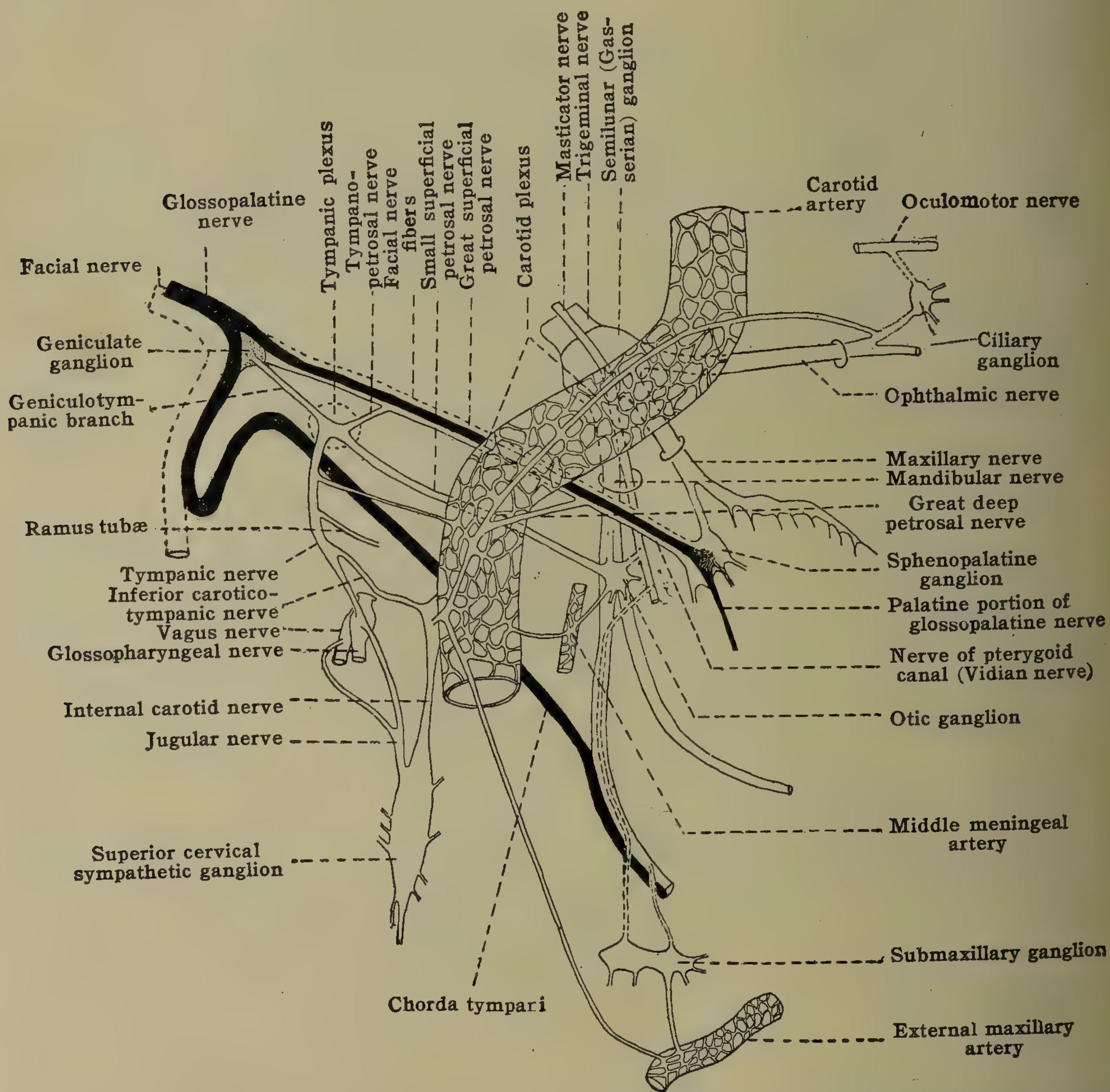


Fig. 810.—Diagram of the Glossopalatine Nerve (Black) and the Relations of the Gangliated Cephalic Plexus to Other Cranial Nerves. (After Bean.) Broken lines, motor; continuous lines, sympathetic; glossopalatine (relatively larger than normal) in solid black. Medial view. Left side.

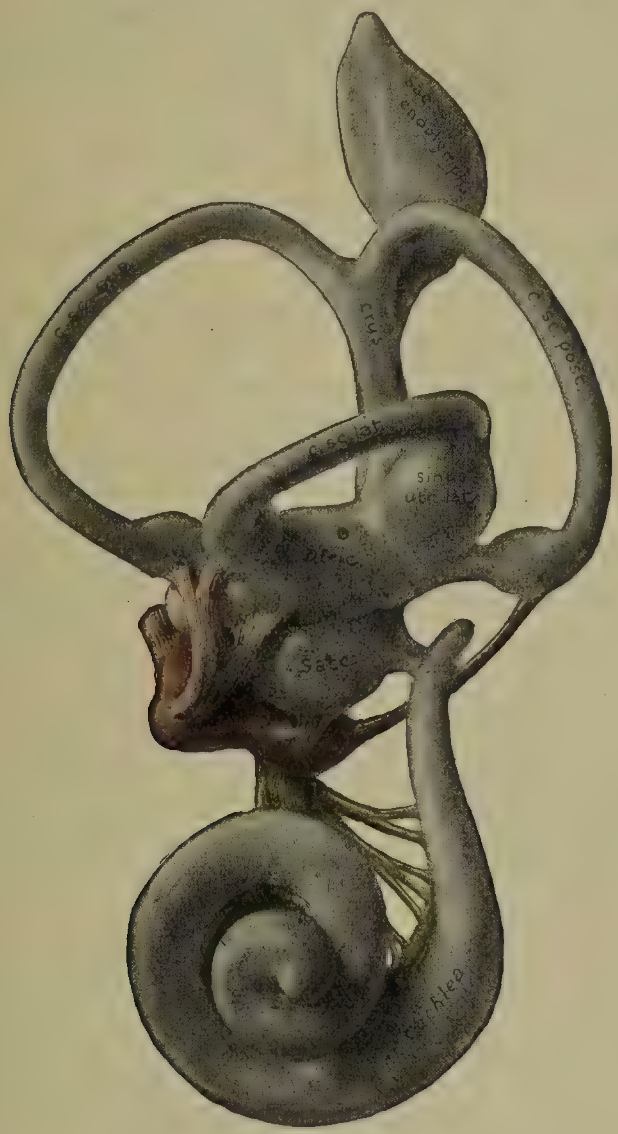
thirds, covered by the mucous membrane lining the tympanic cavity, and passes to the medial side of the manubrium of the malleus above the tendon of the tensor tympani. It leaves the tympanic cavity and passes to the base of the skull through a small foramen (the iter chordæ anterius) at the medial end of the petrotympanic fissure. At the base of the skull it inclines downward and forward on the medial side of the spine of the sphenoid, which it frequently grooves, and, on the medial side of the pterygoideus externus, it joins the posterior border of the lingual nerve at an acute angle. Some of its fibers (visceral motor chiefly) leave the lingual nerve and pass to the submaxillary ganglion, and others (sensory) continue forward to the tongue, where, in company with fibers of the lingual nerve, they terminate in the epithelium covering the anterior two-thirds of the tongue. Some probably serve to convey sensations of taste, most of them are fibers of general sensibility. Before it joins the lingual nerve the chorda tympani receives a communicating twig from the otic ganglion (figs. 807, 810).

Facial paralysis due to injury of the facial nerve within the petrous bone and thus injury of the glossopalatine (chorda tympani) is also known as *petrous paralysis*, that is, facial paralysis

accompanied by deranged salivary secretion, impaired taste and impaired general sensibility of the anterior part of the tongue.

THE VESTIBULAR NERVE

The vestibular (equilibrator) nerve (n. vestibuli or staticus NK) is purely sensory. With the peripheral processes of its ganglion cells of origin ending in the neuroepithelium of the semicircular ducts (canals) and the vestibular maculæ, and their central processes conveying impulses to the gray substance of the medulla, cerebellum and spinal cord, the nerve comprises a most important part of the apparatus for the equilibration of the body. It has been customary to describe the vestibular [radix vestibularis] and the cochlear [radix cochlearis] nerves combined as the **acoustic (auditory) or eighth cranial nerve** (n. statoacusticus NK). While the two are blended in a common sheath from near the medulla to the bottom of the internal auditory meatus, they are likewise partly enclosed in the same sheath with the facial and glossopalatine nerves and the internal auditory artery which accompany them in this meatus. At the bottom of



a. 30mm. lateral.

Fig. 811.—The Left Membranous Labyrinth of a Human Fetus of 10 Weeks (30 mm.), Lateral Aspect. Vestibular ganglion and nerve, red; cochlear nerve, yellow. (Streeter, American Journal of Anatomy.)

the meatus the vestibular and the cochlear are separate; they are separate at their entrance into the lateral aspect of the medulla oblongata; and their central connections, peripheral distributions and functions are different.

The vestibular is preeminently the nerve of body posture; the labyrinth in which it is distributed serves as a terminal organ for the cerebellum, with which it shares a relation to the sympathetic system in maintaining muscular tone.

The vestibular nerve arises as processes of the cells of the **vestibular ganglion** (ganglion of Scarpa), situated upon and blended within the nerve at the bottom of the internal auditory meatus (fig. 811). Unlike a spinal ganglion to which it corresponds, most of the cells of the vestibular ganglion retain an embryonal,

'bipolar,' form. The *central processes* course with the cochlear nerve in the internal auditory meatus medialward, caudad and slightly downward, inferior to the accompanying facial and glossopalatine nerves, and, arching ventrally around the restiform body, they enter the medulla at the inferior border of the pons, lateral to the glossopalatine and facial and medial to the entrance of the cochlear nerve. They find their nucleus of termination spread in the floor of the fourth ventricle and grouped as the median, the lateral (Deiters'), the superior, and the nucleus of the spinal root of the vestibular nerve. In the internal auditory meatus, the vestibular nerve is connected by two small filaments of fibers with the glossopalatine nerve. These are either visceral motor fibers for the vessels of the domain of the vestibular or are aberrant fibers which course only temporarily with the vestibular and return to the glossopalatine.

The *peripheral processes* of the cells of the vestibular ganglion terminate in the neuroepithelium comprising the *maculæ* in the sacculus and the utriculus and the *cristæ* in the ampullæ of the three semicircular ducts. Thus there are five **terminal branches** of the nerve. None of its fibers terminates in the cochlea. The vestibular ganglion has a lobar form, one lobe giving rise to a superior **utriculoampullar** division which divides into three terminal branches; the other or inferior lobe giving a **sacculoampullar** division which gives two terminals (fig. 811).

The superior or **utriculoampullar division** divides into the following terminal branches:

(1) The **utricular branch** passes through the superior macula cribrosa of the vestibule and terminates in the macula acustica of the utriculus.

(2) Accompanying the utricular branch through the superior macula cribrosa is a branch, the **superior ampullar**, to the crista acustica of the ampulla of the superior semicircular duct, and—

(3) A similar branch, the **lateral ampullar**, to the ampulla of the lateral semicircular duct.

The inferior or **sacculoampullar division** accompanies the cochlear nerve a short distance further than the superior, and divides into—

(4) A branch, the **posterior ampullar**, which passes through the foramen singulare and the inferior macula cribrosa and terminates in the ampulla of the posterior semicircular duct, and—

(5) A branch, the **saccular**, which passes through the middle macula cribrosa and terminates in the macula acustica of the sacculus.

The central connections of the vestibular nerve are described in detail on pp. 864, 898–900. Its large nucleus of termination, spread through the area acustica in the floor of the fourth ventricle, and divided into four sub-nuclei, is associated with the nuclei fastigii, globosus, and emboliformis of the cerebellum, with the nuclei of the eye-moving nerves, with the spinal cord, by way of the vestibulospinal fasciculi, and with the cerebral cortex by way of the lemnisci. Experimental work has indicated that fibers of the utriculoampullar division of the vestibular take part chiefly in the reflex chains which have to do with tonic reflexes in the extensors of the forelimbs, while fibers of the sacculoampullar division are concerned chiefly with tonic reflexes for the position of the head.

THE COCHLEAR OR AUDITORY NERVE

The fibers of the cochlear nerve (n. cochleæ or acusticus NK) are distributed to the spiral organ (of Corti) in the cochlea, and so are considered as comprising the auditory nerve proper. They arise from the long, coiled **spiral ganglion** of the cochlea, the cells of which are bipolar. The *peripheral processes* of these cells are shorter than those of the vestibular ganglion. They terminate about the auditory or hair-cells of the spiral organ and thus collect impulses aroused by stimuli affecting these cells. The *central processes* of the ganglion cells continue through the modiolar canal and the tractus spiralis foraminosus of the cochlea, and thence, joining the vestibular nerve through the internal auditory meatus, accompanying the facial nerve and internal auditory artery, they course medialward and downward, approach and enclasp the restiform body (fig. 728) and enter the lateral aspect of brain-stem to terminate in their dorsal and ventral nuclei. A description of these nuclei and the further central connections of the cochlea with the superior olive, the nuclei of the eye-moving nerves, the inferior quadrigeminate bodies, the medial geniculate bodies, and with the cerebellum and temporal lobes of the cerebral hemispheres are given on pages 900, 916.

Experimentation and clinical data suggest that auditory (cochleocortical) sensations are mediated chiefly, if not entirely, by impulses which reach the temporal cortex by way of the

medial geniculate body; that the other connections of cochlear fibers have to do with motor reflexes to sound waves.

THE GLOSSOPHARYNGEAL NERVE

The glossopharyngeal or *ninth* pair of cranial nerves are mixed nerves and each is attached to the medulla by several roots which enter the posterolateral sulcus, dorsal to the anterior end of the olivary body and in direct line with the facial nerve (fig. 800). Some of its sensory fibers are special sensory (taste) and many of its motor fibers are visceral motor (autonomic).

The filaments, when traced lateralward, are seen to blend, in front of the flocculus, into a trunk which lies in front of the vagus nerve, but which passes through a separate opening through the arachnoid and the dura mater and through the jugular foramen. In the foramen this trunk lies in front, and lateral to the vagus nerve and in a groove on the petrous portion of the temporal bone; and in this situation two ganglia are interposed in it, a superior or jugular, and an inferior or petrosal. After it emerges from the jugular foramen the glossopharyngeal descends at first between the internal carotid artery and the internal jugular vein and to the lateral side of the vagus; then, bending forward and medialward, it descends medial to the styloid process and the muscles attached to it, and turning around the lower border of the stylopharyngeus it passes between the internal and the external carotid arteries, crosses the superficial surface of the stylopharyngeus, and runs forward and upward medial to the hyoglossus muscle and across the middle constrictor and the stylohyoid ligament, to the base of the tongue (fig. 812).

Ganglia.—The **superior** or **jugular ganglion** (of Ehrenritter) (g. intracraniale NK), is a small, ovoid, reddish-gray body which lies on the back part of the nerve-trunk in the upper part of the jugular foramen. No branches arise from it. It is sometimes continuous with the petrosal ganglion or it may be absent.

The **inferior or petrosal ganglion** (of Andersch) (g. extracraniale NK), is an ovoid gray body which lies in the lower part of the jugular foramen, and appears to include all the fibers of the nerve.

Branches and communications.—(1) The petrosal ganglion is connected with the superior cervical ganglion of the sympathetic by a fine filament.

(2) It also has a filament of communication with the auricular branch of the vagus which varies inversely in size with the latter branch and sometimes entirely replaces it. This filament may be absent.

(3) An inconstant communication with the ganglion of the root of the vagus.

(4) A short distance below the petrosal ganglion the trunk of the nerve is connected by a twig with that branch of the facial nerve which supplies the posterior belly of the digastric muscle. There is also a small twig (probably sensory) to the stylohyoid.

(5) **From the petrosal ganglion: The tympanic branch** (nerve of Jacobson) arises from the petrosal ganglion and passes through a foramen, which lies in the ridge of bone between the carotid canal and the jugular fossa, into the tympanic canaliculus (Jacobson's canal), where it is surrounded by a small, fusiform mass of vascular tissue, the *intumescentia tympanica.* After traversing the tympanic canaliculus it enters the tympanum at the junction of its lower and medial walls, and, ascending on the medial wall, breaks up into a number of branches which take part in the formation of the **tympanic plexus** on the surface of the promontory (fig. 808). The continuation of the nerve emerges from this plexus as the *small superficial petrosal nerve,* which runs through a small canal in the petrous portion of the temporal bone, beneath the canal for the tensor tympani, and appears in the middle fossa of the cranium through a foramen which lies in front of the hiatus Fallopii. From this foramen it runs forward and passes through the foramen ovale, the canaliculus innominatus, or the sphenopetrosal suture, and enters the zygomatic fossa, where it enters the otic ganglion. While it is in the canal in the temporal bone, the small superficial petrosal nerve is joined by a **geniculotympanic branch** from the geniculate ganglion of the glossopalatine nerve.

(6) **Branches from the tympanic plexus:** (*a*) The **tubal branch** (ramus tubæ), a delicate branch, which runs forward to the mucous membrane of the tuba auditiva (Eustachian tube) and sends filaments backward to the region of the fenestra vestibuli (ovalis) and the fenestra cochleæ (rotunda). (*b*) The **superior and inferior caroticotympanic (carotid) branches** pass medianward to the internal carotid plexus (figs. 808, 810).

The above communications carry fibers almost entirely concerned with the sympathetic plexuses of the head and they will be again mentioned below with the gangliated cephalic plexus.

Branches from the trunk of the nerve: (1) **Pharyngeal branches,** which may be two or three in number, arise from the nerve a short distance below the petrosal ganglion. The principal and most constant of these passes on the lateral side of the internal carotid artery, and after a very short independent course joins with the pharyngeal branch of the vagus and with branches of the superior cervical ganglion to form the pharyngeal plexus (fig. 812).

(2) A **muscular branch** is distributed to the stylopharyngeus muscle. This branch receives a communication from the facial nerve (fig. 812).

(3) The **tonsillar branches** are a number of small twigs which arise under cover of the hyoglossus muscle; they proceed to the tonsil, around which they form a plexus, the **circulus tonsillaris.** From this plexus fine twigs proceed to the glossopalatine arch and to the soft palate.

(4) The **lingual branches** are the terminal branches of the nerve and supply the mucous membrane of the posterior half of the dorsum of the tongue, where, chiefly as taste-fibers, they are distributed to the vallate papillæ. Some small twigs pass backward to the follicular glands of the tongue, and to the anterior surface of the epiglottis. Other twigs are distributed around the foramen cecum, where they communicate with the corresponding twigs of the opposite side.

(5) Hering (Die Karotissinusreflexe, Verlag T. Steinkopff, Dresden u. Leipzig, 1927) describes a '**sinus nerve**,' which is a branch of the glossopharyngeal to the 'carotid sinus,' a slight dilation at the proximal end of the internal carotid artery. The sinus nerve has been found in man, rabbit, dog, cat and monkey. Afferent stimulation of this nerve causes fall in blood pressure and slowing of the heart rate.

The sensory fibers.—The sensory fibers of the glossopharyngeal nerve spring from the superior and petrosal ganglia and pass peripherally and centrally. The **peripheral** processes of the ganglion cells are those which are distributed to the mucous membrane (including taste-buds) of the tongue and pharynx, and the **central** processes pass medialward to the medulla. In the medulla they pass dorsalward and medianward through the reticular formation and, bifurcating into ascending and descending branches, they end in the nucleus of termination of the glossopharyngeal nerve, that is, in the superior part of the nucleus alæ cinereæ and of the nucleus of the tractus solitarius.

The **motor fibers** arise from the nucleus ambiguus in the lateral funiculus of the medulla, in line with the nucleus of origin of the facial nerve. From this nucleus they pass at first dorsalward and then, turning lateralward, they emerge and join the sensory fibers and run with them in the trunk of the nerve (fig. 725).

Van Gehuchten's observations point to the conclusion that one motor nucleus of the glossopharyngeal nerve is separate from and lies above and to the medial side of the nucleus ambiguus, and that a portion of the nucleus of the ala cinerea is also a motor nucleus common to the glossopharyngeal and vagus nerves. It is quite probable that the former motor nucleus is that now considered as the dorsal efferent nucleus of the vagus. An unknown number of the motor fibers are visceral motor and course in the various communications of the glossopharyngeal nerve with the cephalic (sympathetic) plexus.

Central connections.—The nuclei of termination of the glossopharyngeal nerve are associated with the motor nuclei of other cranial nerves by the medial longitudinal fasciculus, and with the somesthetic area of the cortex cerebri of the opposite side by the medial lemniscus (fillet). The motor neurones of the nerve are associated with the somesthetic area by the pyramidal fibers.

THE HYPOGLOSSAL NERVE

The **hypoglossal nerves** are exclusively motor and probably exclusively somatic motor; they supply the geniohyoid and the extrinsic and intrinsic muscles of the tongue (except the glossopalatine). They are usually designated as the twelfth pair of cranial nerves. The fibers of each nerve issue from the cells of an elongated nucleus which lies in the floor of the central canal in the lower half of the medulla and in the floor of the fourth ventricle in the upper half, beneath the trigonum hypoglossi. This nucleus is the upward continuation of the ventromedial group of cells of the ventral horn of the spinal cord. From their origin the fibers run ventralward and somewhat lateralward, probably joined in the medulla by a few fibers from the nucleus ambiguus which is a segment of the upward prolongation of the lateral group of cells of the ventral horn. The conjoined fibers issue from the medulla in the sulcus between the pyramid and the olivary body, in a series of from ten to sixteen root-filaments, which pierce the pia mater and unite with each other to form two bundles (fig. 800). These bundles pass forward and lateralward to the hypoglossal (anterior condyloid) foramen, where they pierce the arachnoid and dura mater. In the outer part of the foramen the two bundles unite to form the trunk of the nerve. At its commencement, at the base of the skull, the trunk of the hypoglossus lies on the medial side of the vagus, but as it descends in the neck it turns gradually around the dorsal and the lateral side of the latter nerve, lying between it and the internal jugular vein, and, a little above the level of the hyoid bone, it bends forward and crosses lateral to the internal carotid artery, the root of origin of the occipital artery, crosses the external carotid, and the loop formed by the first part of the lingual artery (fig. 812). After crossing the lingual artery it proceeds forward on the lateral surface of the hyoglossus, crossing to the medial side of the posterior belly of the digastric, and the stylohyoid muscles. It disappears in the anterior part of the submaxillary region between the mylohyoid and the hyoglossus, and divides into its terminal branches between the mylohyoid and the genioglossus.

As it descends in the neck the trunk lies deeply between the internal jugular vein and the internal carotid artery under cover of the parotid gland, the styloid muscles, and the pos-

terior belly of the digastric, and it is crossed superficially by the posterior auricular and the occipital arteries. As it turns forward around the root of the occipital artery the sternomastoid branch of that vessel hooks downward across the nerve, and as it turns forward on the hyoglossus muscle it lies immediately above the ranine vein. It is crossed by the posterior belly of the digastric and the stylohyoid muscle, and it is covered superficially, behind the mylohyoid, by the lower part of the submaxillary gland. Many of the twigs described as communications and branches contain few or no fibers of the hypoglossus proper.

Communications.—The hypoglossus is connected with the superior cervical ganglion of the sympathetic, with the ganglion nodosum of the vagus, with the loop between the first and second cervical nerves, and with the lingual nerve; the latter communication is established along the anterior border of the hyoglossus muscle (figs. 812 and 813).

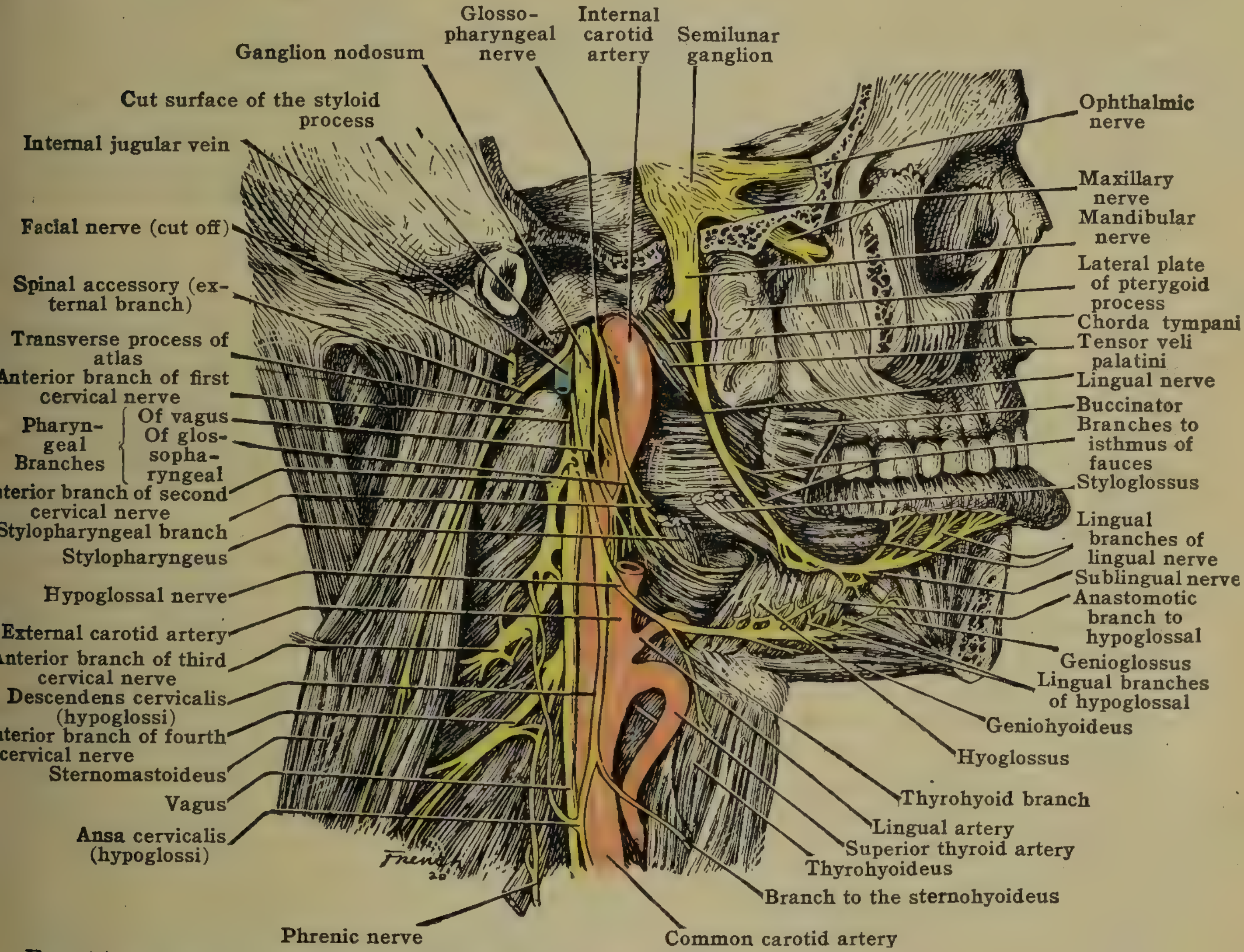


FIG. 812.—THE HYPOGLOSSAL, GLOSSOPHARYNGEAL, AND LINGUAL NERVES. (From Spalteholz, modified.)

Terminal branches.—These include (1) a meningeal branch; (2) branches from the cervical plexus; and (3) branches from the hypoglossus proper.

(1) A meningeal branch, frequently represented by two filaments, is given off in the hypoglossal (anterior condyloid) canal. It passes backward into the posterior fossa of the cranium and is distributed to the dura mater. It does not comprise fibers of the hypoglossus proper. It was believed at one time that the fibers of the meningeal branch were derived from the lingual nerve, but it is now deemed more probable that they are either sensory or visceral motor fibers from the cervical nerves, or from the vagus.

(2) **Branches which consist of fibers derived from the cervical plexus.**—The descendens cervicalis (hypoglossi) and the muscular twig to the thyrohyoid muscle, though apparently arising from the hypoglossal nerve, consists entirely of fibers which have passed into the hypoglossal nerve from the loop between the first two cervical nerves. Therefore, neither of them are branches of the hypoglossus proper. (See fig. 812.)

(a) The **descendens cervicalis (hypoglossi)** (r. descendens NK) parts company with the hypoglossus at the point where the latter hooks around the occipital artery. It runs downward and slightly medialward on the sheath of the great vessels (occasionally within the sheath), and is joined at a variable level by branches from the second and third cervical nerves, forming with them a loop [**ansa hypoglossi**]. The ansa hypoglossi may be placed at any level from a point immediately below the occipital artery to about 4 cm. above the sternum. From this loop all the infrahyoid muscles attached to the hyoid bone are supplied. A twig to the **anterior belly of the omohyoid** arises from the descendens cervicalis in the upper part of its course. The nerves which supply the **sternohyoid, sternothyroid,** and **posterior belly of the omohyoid**

are given off by the cervical loop. Twigs from the first two nerves pass downward in the muscles behind the manubrium sterni and in rare cases communicate with the phrenic nerve within the thorax. The nerve to the posterior belly of the omohyoid runs in a loop of the cervical fascia below the central tendon of the muscle.

(b) **The nerve to the thyrohyoid** leaves the hypoglossus near the tip of the great cornu of the hyoid bone, and runs obliquely downward and medialward to reach the muscle. All the fibers in (a) and (b) are derived from the first, second and third cervical nerves.

(c) **The nerve to the geniohyoid** arises under cover of the mylohyoid, where loops are formed with the lingual nerve from which loops branches pass into the muscle. It probably contains some true hypoglossal fibers.

(3) **The branches of the hypoglossus proper, the rami linguales,** supply the styloglossus hyoglossus, genioglossus, and the intrinsic muscular fibers of the tongue.

The nerve to the styloglossus is given off near the posterior border of the hyoglossus. It pierces the styloglossus, and its fibers pursue a more or less recurrent course within the muscle.

The nerves to the hyoglossus are several twigs which are supplied to the muscle as the hypoglossal nerve crosses it.

The nerve to the genioglossus arises under cover of the mylohyoid in common with the terminal branches to the intrinsic muscles of the tongue. It joins freely with branches (sensory) of the lingual, forming long loops which lie on the genioglossus. From these loops twigs pass into the genioglossus and into the muscular substance of the tongue.

Central connections.—The nucleus of origin of the hypoglossus is associated with the somesthetic area (frontal operculum) of the cortex cerebri of the opposite side by the pyramidal fibers, and it is correlated with the sensory nuclei (nuclei of termination) of other cranial nerves by way of the reticular formation and the medial longitudinal fasciculus.

THE VAGUS NERVE

The vagi (pneumogastric or tenth) nerves are the longest of the cranial nerves, and they are remarkable for their almost vertical course, their asymmetry, and their extensive distribution, for, in addition to supplying the lung and stomach, as the old name 'pneumogastric' indicates, each nerve gives branches to the external ear, the pharynx, the larynx, the trachea, the esophagus, the heart, and the abdominal viscera. The left vagus has a more important distribution than the right.

Each nerve is attached to the side of the medulla, in the posterolateral sulcus, dorsal to the olivary body, by from twelve to fifteen root-filaments which are in linear series with the filaments of the glossopharyngeal nerve (fig. 800). The filaments contain both visceral and somatic sensory and motor fibers. They pierce the pia mater, from which they receive sheaths, and, traced outward, they pass into the posterior fossa of the cranium toward the jugular foramen and unite to form the trunk of the nerve, which passes through openings in the arachnoid and the dura mater which are common to it and to the spinal accessory nerve. In the jugular foramen a small spherical ganglion, the *jugular ganglion* is interposed in the trunk which here turns at right angles to its former course and descends through the neck. As it leaves the jugular foramen it is joined by the internal or accessory portion of the spinal accessory nerve, and immediately below this junction occurs its large ovoid ganglion, the *ganglion nodosum* (fig. 812). As it descends through the neck the nerve passes ventral and somewhat lateral to the superior cervical sympathetic ganglion, and in front of the longus capitis and longus colli, from which it is separated by the prevertebral fascia. In the upper part of the neck it is aligned between the internal carotid artery and the internal jugular vein, and in a plane dorsal to them, the artery being ventral and mesial, and the vein ventral and lateral. In the lower part of the neck it occupies a similar position in regard to the common carotid artery and the internal jugular vein, and the three structures are enclosed in a common sheath derived from the deep cervical fascia, but within the sheath each structure occupies a separate compartment (fig. 812). In the root of the neck and in the thorax the relations of the nerves of the two sides of the body differ somewhat, and they must, therefore, be considered separately (fig. 813).

The right vagus passes in front of the first part of the right subclavian artery in the root of the neck and then descends in the thorax, passing obliquely downward and backward on the right of the trachea, and behind the right innominate vein and the superior vena cava, to the back of the root of the right lung. Just before it reaches the right bronchus it lies close to the medial side of the vena azygos as the latter hooks forward over the root of the lung. At the back of the right bronchus the right vagus breaks up into a number of branches which join with the branches of the sympathetic to form the right **posterior pulmonary plexus**, and from this plexus it issues in the form of one or more cords, combined sensory, visceral motor and sympathetic, which descend on the esophagus and break up into branches which join with branches of the left vagus, forming the **posterior esophageal plexus**. At the lower part of the thorax fibers of this plexus become again associated in one trunk which passes through the diaphragm

on the *posterior* surface of the esophagus, and is distributed to the *posterior* surface of the stomach and to the celiac (solar) plexus and its offsets.

The left vagus descends through the root of the neck between the carotid and subclavian arteries and in front of the thoracic duct. In the upper part of the superior mediastinum it is crossed in front by the left phrenic nerve, and in the lower part of the same region it crosses in front of the root of the subclavian artery and the arch of the aorta and behind the left superior intercostal vein. Below the aortic arch it passes behind the left bronchus and divides into

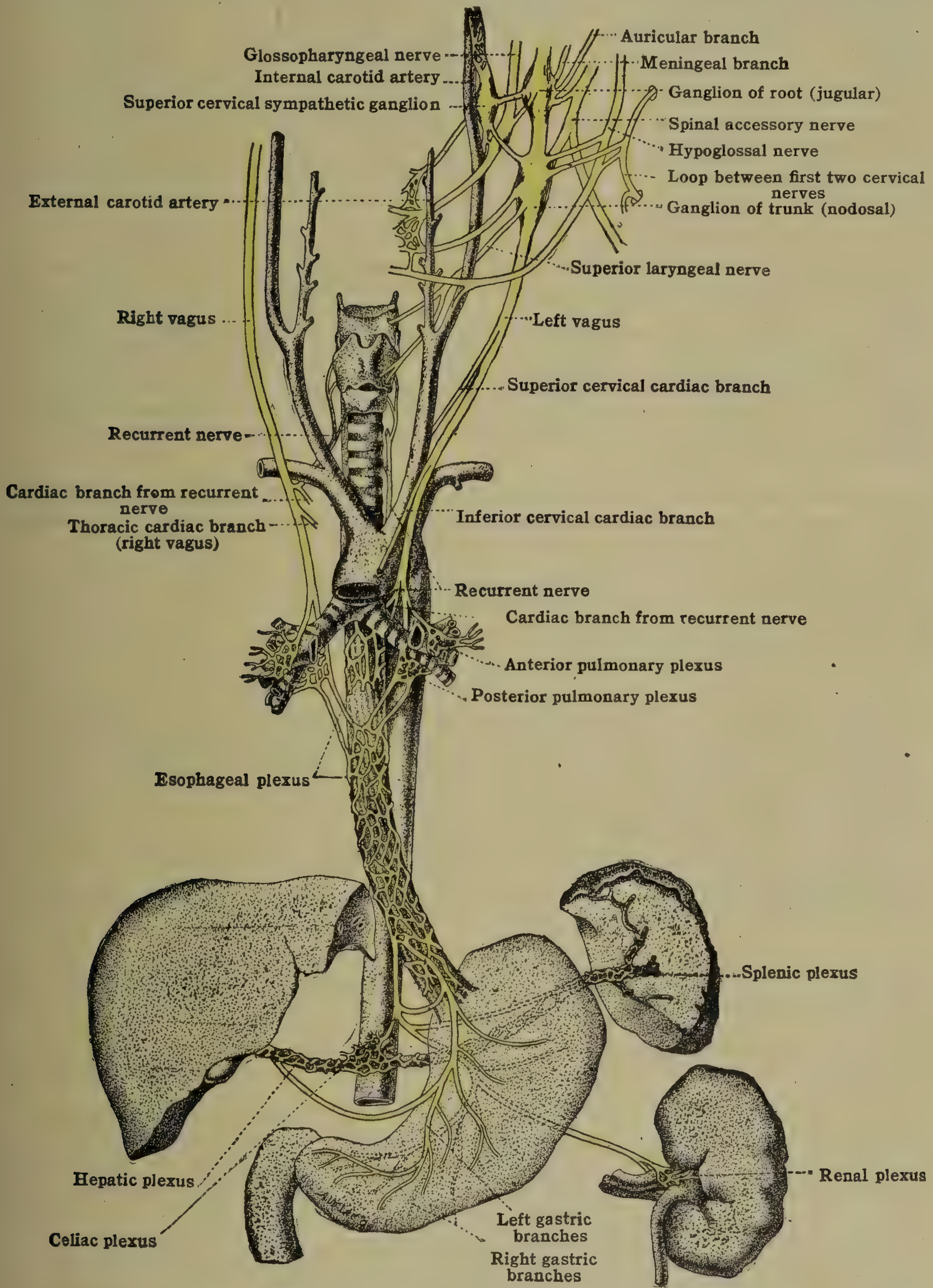


Fig. 813.—Diagram of the Branches of the Vagus Nerves.

branches which unite with twigs of the sympathetic to form the left posterior pulmonary plexus. From this plexus the fibers of the left vagus issue as one or more cords that break up into anastomosing branches to form the anterior esophageal plexus. At the lower part of the thorax this plexus becomes a single trunk, which passes through the diaphragm on the *anterior* surface of the esophagus, and it is distributed to the *anterior* surface of the stomach and to the liver.

In the anastomoses of the two esophageal plexuses fibers from the two vagi are commingled and each of the vagal trunks, assembled below, contains fibers from both the right and left vagus (McCrea).

The **jugular ganglion** (ganglion of the root) is a spherical gray mass about 5 mm. in diameter which lies in the jugular foramen (fig. 813). It is connected with the spinal accessory nerve and with the superior cervical sympathetic ganglion, and it gives off an auricular branch, by means of which it becomes associated with the facial and glossopharyngeal nerves, and a recurrent meningeal branch.

The **ganglion nodosum** (ganglion of the trunk) lies below the base of the skull and in front of the upper part of the internal jugular vein. It is of flattened ovoid form and about 17 mm. long and 4 mm. broad (figs. 812 and 813). It is joined by the accessory part of the spinal accessory nerve, and is associated with the hypoglossal nerve, with the superior cervical ganglion of the sympathetic, and with the loop between the first two cervical nerves, and it gives off a pharyngeal, a superior laryngeal, and a superior cardiac branch. Both ganglia and especially the nodosal retain numerous cell-bodies of sympathetic neurones and the twigs issuing from the ganglia thus contain sympathetic fibers. The greater number of the cell-bodies are of sensory neurones.

It should be remembered that the visceral sensory fibers of the vagus arise in its ganglia and carry to the medulla impulses aroused in the viscera it supplies, chiefly the epithelium of the digestive and respiratory apparatuses; that its visceral motor fibers carry from the medulla efferent impulses which are transferred by synapses to sympathetic ganglion-cells and these in turn send fibers to the smooth and cardiac muscle and the glands of its domain, while its somatic motor fibers carry impulses from the medulla direct to skeletal muscle. Its somatic sensory fibers carry to the medulla impulses aroused, for the most part, in the skin. Some sensory or afferent impulses aroused in the aorta, heart and digestive apparatus take part in reflexes of peculiar nature, meriting for them the name, *depressor impulses*. Most, if not all, such impulses are carried in the left vagus.

Communications.—The vagus nerve is connected with the glossopharyngeal, spinal accessory and hypoglossal nerves, with the sympathetic, and with the loop between the first and second cervical nerves.

(1) Two communications exist between the vagus and glossopharyngeal nerves: one between their trunks, just below the base of the skull, and one, in the region of their ganglia, consisting of one or two filaments. When two filaments are present one passes from the jugular ganglion and the other from the auricular nerve to the petrosal ganglion of the glossopharyngeal nerve. Either or both of these filaments may be absent.

(2) Two twigs pass from the spinal accessory nerve to the ganglion nodosum, and at a lower level the accessory part of the spinal accessory nerve also joins the same ganglion (fig. 813). The majority of the fibers of the accessory part of the spinal accessory nerve merely pass across the surface of the ganglion and are continued into the pharyngeal and superior laryngeal branches of the vagus, but a certain number blend with the trunk of the vagus and are continued into its recurrent laryngeal and cardiac branches.

(3) Two or three fine filaments connect the ganglion nodosum with the hypoglossal nerve as the latter turns around the lower part of the ganglion (fig. 813).

(4) Fibers pass from the superior cervical ganglion of the sympathetic to both ganglia of the vagus (fig. 813).

(5) A twig sometimes passes from the loop between the first two cervical nerves to the ganglion nodosum (fig. 813).

Terminal branches of the vagus.—These are the meningeal, auricular, pharyngeal, superior laryngeal, recurrent (inferior laryngeal), cardiac, bronchial, pericardial, esophageal, and the abdominal branches.

(1) The **meningeal or recurrent branch** is a slender filament which is given off from the jugular ganglion. It takes a recurrent course through the jugular foramen, and is distributed to the dura mater around the transverse (lateral) sinus.

(2) The **auricular branch, or nerve of Arnold,** arises from the jugular ganglion in the jugular foramen. It receives a branch from the petrosal ganglion of the glossopharyngeal, enters the petrous part of the temporal bone through a foramen in the lateral wall of the jugular fossa, and communicates with the facial nerve or merely lies in contact with it as far as the stylomastoid foramen. It usually leaves the temporal bone by the stylomastoid foramen, but it may pass through the tympanomastoid fissure, and it divides, behind the auricle, into two branches, one of which joins the posterior auricular branch of the facial while the other supplies sensory fibers to the posterior and inferior part of the external auditory meatus and the back of the auricle. It also supplies twigs to the osseous part of the external auditory meatus and to the lower part of the outer surface of the tympanic membrane. This branch of the vagus to the meatus and tympanic membrane may explain the vomiting and cough which occasionally accompany infections of the meatus.

(3) The **pharyngeal branches** may be two or three in number. The principal of these joins the pharyngeal branch of the glossopharyngeal on the lateral surface of the internal carotid artery, and after passing with the latter medial to the external carotid artery it turns downward and medialward to reach the posterior aspect of the pharynx. Here the two nerves are joined by branches from the superior cervical ganglion of the sympathetic, with which they form the **pharyngeal plexus** (figs. 812, 813). Branches from this plexus supply sensory fibers to the mucous membrane of the pharynx, somatic motor fibers to the constrictores pharyngis,

levator palatini, uvulæ, glossopalatinus, and pharyngopalatinus and probably visceral motor to sympathetic ganglion cells.

(4) The **superior laryngeal nerve** arises from the lower part of the ganglion nodosum, and passes obliquely downward and medialward, behind and medial to both the internal and external carotid arteries, toward the larynx. In this course it describes a curve with the convexity downward and lateralward and divides into (a) a larger internal and (b) a smaller external branch (fig. 813). Before its division it is joined by twigs with the sympathetic and with the pharyngeal plexus, and it gives a small branch to the internal carotid artery.

(a) The **internal branch** accompanies the superior laryngeal artery to the interval between the upper border of the thyroid cartilage and the great cornu of the hyoid bone. It passes under cover of the thyrohyoid muscle and pierces the hyothyroid membrane to gain the interior of the pharynx, where it lies in the lateral wall of the sinus piriformis and divides into a number of diverging branches. The ascending branches supply the mucous membrane on both surfaces of the epiglottis, and probably that of a small part of the root of the tongue. The descending branches ramify in the mucous membrane lining the larynx, and supply the mucous membrane adjoining the back of the cricoid cartilage. One of the descending branches passes downward on the internal muscles of the larynx to anastomose with the terminal part of the inferior laryngeal nerve.

(b) The **external branch** runs downward on the inferior constrictor to the lower border of the thyroid cartilage, where it ends, for the most part, in the cricothyroid muscle. A few filaments pierce the cricothyroid membrane and are distributed to the membrane lining the larynx. It occasionally gives off a cardiac branch which joins one of the cardiac branches of the sympathetic; it also furnishes twigs to the inferior constrictor, and communicating twigs to the pharyngeal plexus, and it receives a communication from the superior cervical ganglion of the sympathetic.

(5) The **recurrent nerve** of the **right side** arises from the vagus at the root of the neck in front of the right subclavian artery. It hooks around the artery, passing below and then behind that vessel, and runs upward and slightly medialward, crossing obliquely behind the common carotid artery (fig. 813). Having gained the side of the trachea, it runs upward in the groove between the trachea and the esophagus, accompanying branches of the inferior thyroid artery, and, near the level of the lower border of the cricoid cartilage, becomes the inferior laryngeal nerve.

In its course the right recurrent nerve gives off branches to the trachea, esophageal branches to the esophagus and pharynx, and, near its commencement, one or more **inferior cardiac branches**. It communicates with the inferior cervical sympathetic ganglion and with the superior laryngeal nerve.

The **inferior laryngeal nerve**, the continuation of the recurrent, ascends between the trachea and esophagus, enters the larynx under cover of the inferior constrictor of the pharynx, and divides into two branches, anterior and posterior. The *anterior branch* passes upward and forward on the cricoarytenoideus lateralis and thyroarytenoideus, and supplies these muscles and also the vocalis, arytenoideus obliquus, aryepiglotticus, and thyroepiglotticus. The *posterior branch*, passing upward, supplies the cricoarytenoideus posterior and arytenoideus obliquus, and anastomoses with the medial branch of the superior laryngeal nerve.

On the **left side** the recurrent nerve arises in front of the aortic arch and winds around the concavity of the arch lateral to the ligamentum arteriosum. It crosses obliquely behind the root of the left common carotid artery, gains the angular interval between the esophagus and trachea, and corresponds with the nerve of the right side in the remainder of its course and distribution (fig. 813).

Clinical aspects.—In operations involving severance or ligation of the inferior thyroid artery, especial care must be taken lest the accompanying recurrent or inferior laryngeal nerve be injured or ligated with the artery, resulting in laryngeal speech disorders. In about 80 per cent. of cases, the nerve runs anterior to the artery; in 12 per cent. on the right and 7 per cent. on the left of the artery. The artery may branch lower than is common and the nerve pass through its plexus.

(6) **Cardiac branches.**—Of these branches of the vagus there are two sets, the superior and inferior. All the branches of both sets pass to the deep part of the cardiac plexus except a superior branch on the left side that passes to the superficial part of the cardiac plexus. All contain visceral motor, sympathetic and visceral sensory fibers.

(a) The **superior** (**superior** and **inferior cervical**) **cardiac nerves** arise from the vagus and its branches in the neck (figs. 813, 814, 857). Some of these branches on both sides join with the cardiac branches of the sympathetic in the neck and pass with them to the cardiac plexus. Some on the right side pass independently through the thorax to the deep part of the cardiac plexus, and a branch on the left side passes through the thorax to the superficial part of the cardiac plexus.

(b) **The inferior (thoracic) cardiac branches.**—These branches on the right side arise in part from the recurrent nerve and in part from the main trunk of the vagus, while on the left side they usually arise entirely from the recurrent. All these branches pass to the deep part of the cardiac plexus (figs. 813, 814, 857).

(c) **Depressor nerve.**—Since 1876 when a branch of the vagus meriting this name was described for the rabbit by Cyon and Ludwig, many searches have been made for a depressor nerve in other mammals and especially in man. In the rabbit it may arise as a branch of the vagus alone or from the superior laryngeal alone, or, more rarely, from the nodosal ganglion directly. The depressor effects are produced by stimulation of the central stump of the severed nerve. No such effects are produced through the peripheral stump, thus proving the depressor to be a purely afferent nerve. Searches for a depressor nerve in various other mammals, including man, so far indicate that a nerve fully resembling in function and in course that described for the rabbit is of very rare occurrence or even of doubtful existence. Depressor

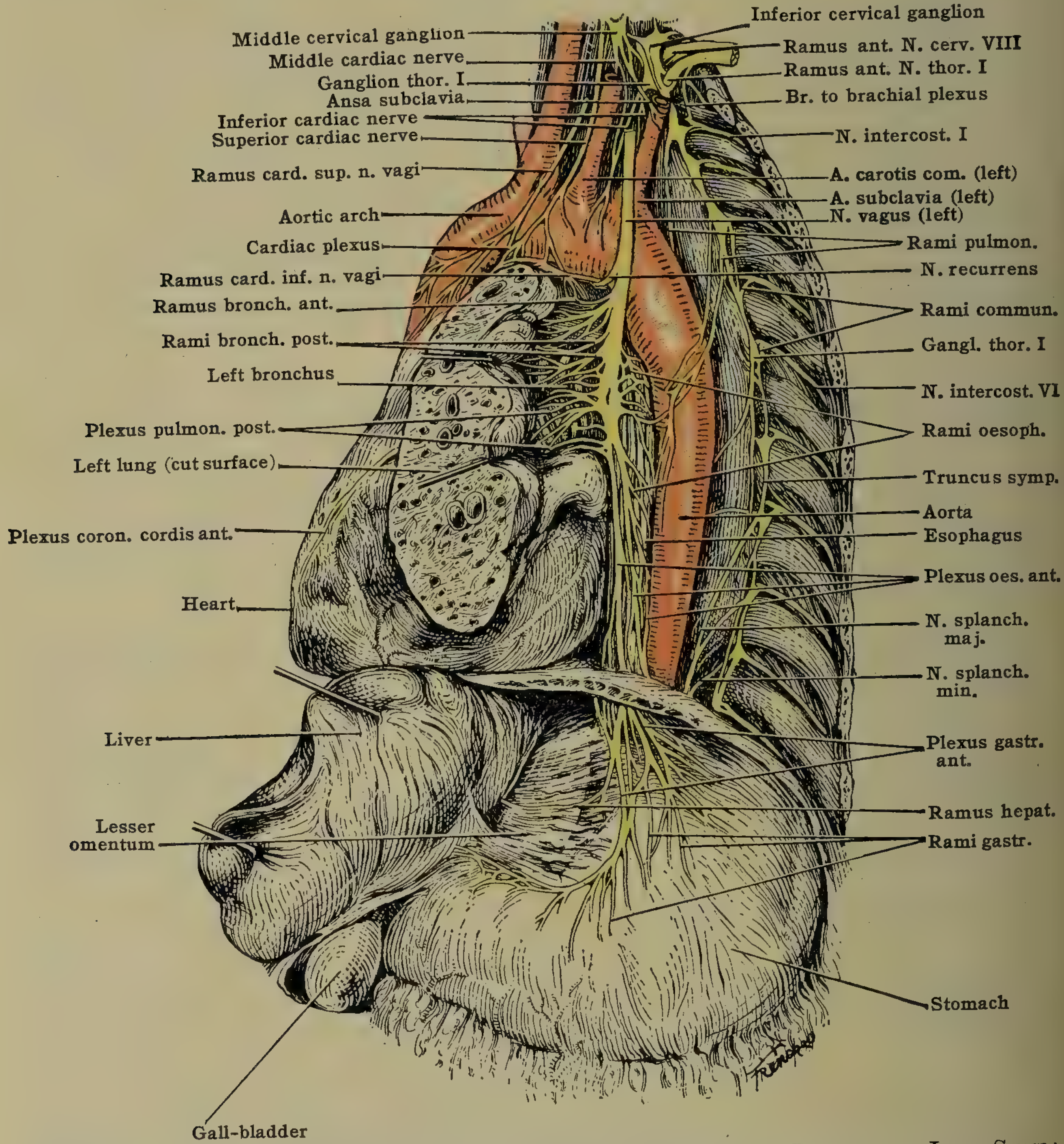


FIG. 814.—THORACIC BRANCHES OF LEFT VAGUS AND OF ABDOMINAL PORTION OF LEFT SYMPATHETIC TRUNK. (After Spalteholz.)

functions have been attributed to certain branches, such as some of the very variable superior cardiac nerves and branches of the vagus, and also branches of the superior laryngeal nerve uniting with one of the cardiac branches of the cervical sympathetic trunk. Bundles arising from fusion of branches of the vagus and superior laryngeal nerve have been found but these almost invariably rejoined the vagus trunk after running very short courses. Doubtless a 'depressor' nerve in man, whenever separate, is but composed of fibers of the same sensory function as possessed by the afferent fibers of the vagus proper, all of which fibers in most mammals are incorporated within the trunk of the vagus, which is known to be the great inhibitory nerve to the heart. Certainly it may be stated that there is in man no other well defined nerve proved to be a cardiac depressor.

While the depressor (sensory) nerve fibers form most important links in neurone chains for heart regulation, it is claimed as quite improbable that impulses conveyed to the central system

via the depressor fibers ever attain the threshold of consciousness. For pain sensations in disease of heart, see p. 1118.

(7) **Bronchial pulmonary branches** are anterior and posterior (figs. 813, 814).

(a) The **anterior bronchial (pulmonary) branches** consist of a few small branches which arise at the upper border of the root of the lung. They pass forward to gain the anterior aspect of the bronchus, where they communicate with the sympathetic and form the **anterior pulmonary plexus,** from which fine twigs pass along the bronchus.

(b) The **posterior bronchial (pulmonary) branches.**—Almost the entire remaining trunk of the vagus usually divides into these branches, which join with branches from the second, third, and fourth thoracic ganglia of the sympathetic trunk to form the **posterior pulmonary plexus** (figs. 813, 814). The plexuses of the two sides join freely behind the bifurcation of the trachea, and branches from the plexus pass along each bronchus into the lung.

(8) The **pericardial branches** pass from the trunk of the vagus or from the bronchial or esophageal plexuses to the anterior and posterior surfaces of the pericardium. They are chiefly sensory.

(9) **Esophageal branches,** given off by the trunk of the nerve above the bronchial plexuses and from the esophageal plexuses lower down, pass to the wall of the esophagus.

(10) **Abdominal branches.**—The terminal part of the left vagus (anterior vagal trunk) divides into many branches, some of which communicate freely along the lesser curvature of the stomach with filaments from the gastric plexus of the sympathetic, and to some extent with branches of the right vagus, to form the elongated **anterior gastric plexus** (figs. 813, 814). From this plexus as well as from the nerve-trunk, **gastric branches** are given to the anterior surface of the stomach. **Hepatic branches** from the trunk or from this plexus pass in the lesser omentum to the hepatic plexus (figs. 813, 814). The terminal part of the right vagus (posterior trunk) divides into many branches, and forms along the lesser curvature of the stomach an elongated **posterior gastric plexus** by communications with branches from the gastric plexus of the sympathetic and with branches from the left vagus. **Gastric branches** are given off by the trunk of the nerve and from this plexus. **Celiac branches** are given by the trunk to the celiac (solar) plexus, and **splenic** and **renal branches,** either directly or through the celiac (solar) plexus, are given to the splenic and renal plexuses (fig. 813). The main gastric branches of both vagi course near the lesser curvature of the stomach. The pyloric canal and sphincter and the superior flexure of the duodenum are chiefly supplied from the hepatic branches instead of direct from the main gastric branches.

Central connections.—The **sensory fibers** of the vagus are processes of the cells of the jugular ganglion and the ganglion nodosum. The peripheral fibers from these cells bring in sensory impulses from the periphery, and their central fibers convey the impulses to the brain. The latter fibers enter the medulla in the filaments of attachment in the posterolateral sulcus, and, in the reticular formation, they bifurcate into ascending and descending branches which end in the nuclei of termination of the vagus, namely, in the nucleus alæ cinereæ in the floor of the fourth ventricle and in the nucleus tractus solitarii. The tractus solitarius consists largely of the descending branches. These and the axones arising from the nuclei of termination of the vagus descend the spinal cord to terminate about ventral horn cells which give origin to the phrenic nerve and to motor fibers supplying other muscles of respiration, and they also convey impulses which are distributed to visceral motor neurones along the spinal cord.

The **motor fibers** spring from the nucleus ambiguus and from the dorsal efferent (visceral motor) nucleus of the vagus, described on page 898. They join the sensory fibers in the reticular formation. Some of the motor fibers, especially those from the dorsal efferent nucleus, are visceral motor fibers.

The central connections of the vagus are similar to those of the glossopharyngeal nerve (fig. 726). Van Gehuchten's observations point to the conclusion that the chief nucleus of termination of the vagus nerve is that of the tractus solitarius.

THE SPINAL ACCESSORY NERVE

The spinal accessory (or eleventh) nerve [n. accessorius] is exclusively motor. It consists of two parts, the accessory or superior, and the spinal or inferior part.

The fibers of the **accessory or superior portion** [ramus internus] (r. medialis NK) spring chiefly from the inferior continuation of the nucleus ambiguus, in common with the motor fibers of the vagus above, and they pass through the reticular formation to the posterolateral sulcus of the medulla, where they emerge as a series of filaments, below those of the vagus. The filaments pierce the pia mater and unite, as they pass outward in the posterior fossa of the cranium, to form a part of the nerve which enters the aperture in the dura mater common to the vagus and spinal accessory nerves. In the aperture this trunk is joined by the spinal portion of the nerve.

The **spinal** or **inferior portion** [ramus externus] (r. lateralis NK) arises from the cells of the ventral horn of the cord as low as the fifth, and rarely the seventh, cervical segment. The fibers pass dorsalward and lateralward from their origins, chiefly from the lateral part of the ventral horn, through the lateral funiculus of white substance, and they emerge from the lateral aspect of the cord behind the ligamentum denticulatum, along an oblique line, the lower fibers passing out immediately dorsal to the ligament, and the upper close to and sometimes in

association with the dorsal roots of the upper two spinal nerves. As the spinal fibers pass out of the surface of the cord they unite to form an ascending strand (fig. 800) which enters the posterior fossa of the cranium, through the foramen magnum, and, turning lateralward, blends more or less intimately with the accessory portion. Thus combined, the nerve enters the jugular foramen in company with the vagus, but here it is again separated into its two branches, which contain chiefly the same fibers as the original superior and inferior parts.

The **superior branch**, or accessory portion of the nerve, gives one or more filaments to the jugular ganglion (ganglion of the root of the vagus), and then joins either the trunk of the vagus directly or its ganglion nodosum, the fibers of the branch being contributed to the pharyngeal, laryngeal, and cardiac branches of the vagus. Fibers corresponding to the white rami communicantes, absent in the cervical nerves, probably enter the cervical sympathetic ganglion through this ramus of the spinal accessory nerve. The fibers which are accessory to the vagus therefore probably include visceral motor and cardioinhibitory fibers.

The **inferior branch** or the spinal portion runs backward and downward under cover of the posterior belly of the digastric and the sternomastoid. It crosses in front of and to the lateral side of the internal jugular vein and, leaving the lateral border of the vein, it passes either in front of or behind the occipital artery; then it pierces the *sternomastoid*, supplies filaments to it, and interlaces in its substance with branches of the second cervical nerve. It emerges from the posterior border of the sternomastoid slightly above the level of the upper border of the thyroid cartilage, passes obliquely downward and backward across the occipital portion of the posterior triangle, and disappears beneath the trapezius at about the junction of the middle and lower thirds of the anterior border of that muscle (fig. 812). In the posterior triangle it receives communications from the third and fourth cervical nerves, and beneath the trapezius its fibers form a plexus. Its terminal filaments are distributed to the *trapezius* and they can be traced almost to the lower extremity of that muscle.

Clinical aspects.—As it emerges from the posterior border of the sternomastoid muscle, this spinal portion of the accessory is often in intimate relation with the small occipital and great auricular nerves, calling for additional care in operations on the upper deep cervical lymph nodes and in all deeper operations in the posterior triangle of the neck. In cases of confirmed facial paralysis, this spinal portion is sometimes anastomosed to the facial with the hope that it may send fibers to the facial muscles along the disintegrating branches of the facial nerve. Also this spinal portion is sometimes resected as a remedy for spasmotic torticollis. Naturally, 'drop shoulder' may result from severing the nerve.

Central connections.—The nuclei of origin, like other motor nuclei, are connected with the somesthetic area of the cerebral cortex of the opposite side by the pyramidal fibers, and they are associated with the sensory nuclei of other cranial nerves by the medial longitudinal fasciculus, and with sensations brought in by the spinal nerves directly and by the fibers of the fasciculi proprii.

THE GANGLIATED CEPHALIC PLEXUS

The Sympathetic Ganglia of the Head and Their Associations with the Cranial Nerves

The sympathetic system of the head, like that of the remainder of the body described below, is arranged in the form of a continuous gangliated plexus subdivided into subplexuses. Unlike the great unpaired prevertebral plexuses in the thoracic and abdominal cavities, all the larger sympathetic ganglia of the head are paired, ganglia corresponding to each other being found on either side. Thus, possibly, they may be considered as an upward extension of the series of paired lumbar, thoracic and cervical ganglia belonging to the sympathetic trunks lying along either side of the vertebral column. Numerous small ganglia, many of them microscopic, occur in the subplexuses throughout the head. These are irregular in size and position and those in the region of the median line are no doubt unpaired.

In origin, the ganglia of the cephalic plexus consist of cell-bodies which, in the early stages of development, migrated from the fundaments of the ganglia of the vagus, glossopharyngeal and glossopalatine nerves, and most especially from that of the semilunar (Gasserian) ganglion of the trigeminus—a developmental relation identical with that of the remainder of the sympathetic system to the ganglia of the spinal nerves. Just as is known for the spinal ganglia, some cell-bodies destined to develop into sympathetic neurones, instead of migrating, remained within the confines of the ganglia of the above nerves, in company with the cell-bodies of their sensory neurones. This is thought to be especially true for the geniculate, the petrosal and the jugular ganglion. Therefore these ganglia must be considered as in small part sympathetic ganglia.

The gangliated cephalic plexus could properly be included as a division of the general sympathetic system described later. However, because its larger ganglia are so intimately associated with branches of the oculomotor, trigeminal, masticator, glossopalatine, glossopharyngeal and vagus nerves, it is customary to describe it in connection with the cranial nerves.

The larger **ganglia**, one on either side of the head, comprise the ciliary ganglion, the sphenopalatine (Meckel's) ganglion, the otic and the submaxillary ganglion.

To these must be added portions of the geniculate, petrosal, jugular and the ganglion nodosum, and a part of the superior cervical sympathetic ganglion. The chief relations of the gangliated cephalic plexus to the cranial nerves are shown in fig. 810.

The so-called **roots and branches of the ganglia** carry three varieties of fibers: (1) Sensory, visceral and somatic, (2) Motor (visceral motor or preganglionic), and (3) Sympathetic proper. Most roots and branches are mixed, the name of a root being determined only by the variety of fibers predominating in it, or by its length. Fibers arising from the cells of a ganglion and passing out of it, usually in one of its branches, are often referred to as postganglionic fibers (sympathetic proper).

A bundle of sensory fibers going to a ganglion is called its **sensory root.** Such, however, cannot comprise a true root since none of its fibers arises in the ganglion and very few or none may terminate in it. The only sensory fibers terminating in a ganglion are the few which may approach it in any of the roots to terminate in its capsule or the capsules of its cells and convey impulses of general sensibility from the ganglion to the central nervous system. Almost all of the fibers of a 'sensory root' merely pass around or through a ganglion and into its branches beyond, which they borrow as paths for reaching their allotted fields of distribution. In this relation it should be realized that while the ciliary, sphenopalatine, otic and submaxillary ganglia are customarily described under the discussion of the trigeminus, this nerve has functionally less to do with them than any of the other cranial nerves with which they are associated.

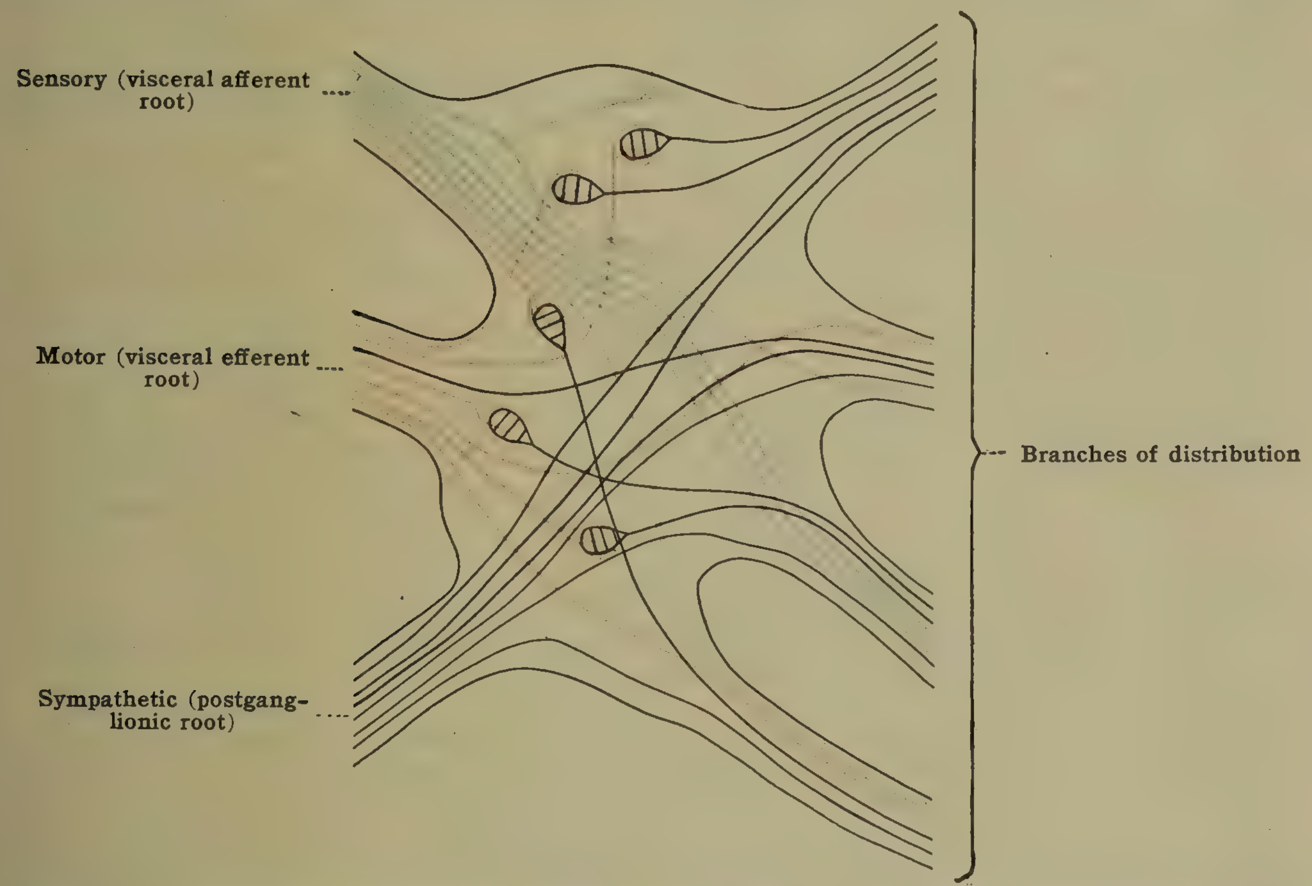


Fig. 815.—Diagram to Illustrate the Structural Relations of the Three Roots and the Branches of a Cephalic Sympathetic Ganglion. Sensory fibers, blue; motor, red; sympathetic, black.

Bundles of trigeminal (sensory) fibers, traceable in gross anatomy because medullated and of appreciable size, pass to the ganglia, but only to pass through them as continuations of the terminal branches of the trigeminus.

The so-called **motor root** of a ganglion may carry two kinds of fibers: (a) visceral motor (preganglionic) fibers, arising in the nuclei of origin in the central system and passing in the trunk and branches of a cranial nerve (oculomotor, masticator, etc.) to enter and terminate in contact with the cell-bodies of the ganglion, which, in their turn, give fibers to the branches of the ganglion; (b) fibers of the same origin, name and course but which may pass through the ganglion to terminate in contact with the cells of a more distant ganglion. Any root, the motor especially, may contain somatic motor fibers, that is, fibers of central origin which pass through the ganglion uninterrupted and into its branches to terminate directly upon the fibers of skeletal muscle.

A **sympathetic root** carries chiefly fibers conforming to the name: fibers arising in other sympathetic ganglia which pass through the ganglion in question to enter its branches and terminate upon their allotted muscular or glandular elements. Obviously it may possibly also carry somatic motor and sensory and visceral sensory fibers. The larger ganglia of the head are described as each possessing the three roots above mentioned.

The **branches of distribution** of the ganglia, the larger of them often called nerves, are those bundles in which the fibers, both arising in or passing through the ganglia, course toward their

terminations upon their allotted tissue elements of the head. In the branches pass fibers (1) motor to the smooth muscle of the vessels of the head, to the intrinsic muscles of the eyeball, to the lacrimal glands, to the mucous membranes (gland cells) of the nasal and oral cavities and to the salivary glands, and (2) sensory fibers conveying impulses from these structures.

The plexuses into which the gangliated cephalic plexus is divided, including the roots and branches which connect the ganglia to form it, are numerous and vary greatly in size. They underlie the mucous membranes and they surround all the vessels, ducts and glands. They are named according to their locality. The largest of them are the tympanic plexus and the carotid and cavernous plexuses. They have been repeatedly referred to in their relations to the branches of the cranial nerves.

Of the numerous branches described from the **superior cervical sympathetic ganglion**, the two large ones which pass upward associate it especially with the gangliated cephalic plexus. That branch known as the internal *carotid nerve* may be considered as the direct continuation upward of the gangliated sympathetic trunk ('vertebral ganglia') of the body. Through the branches of this nerve, the caroticotympanic and the deep petrosal nerves, and through the plexuses derived from it, the superior cervical ganglion may be associated with practically all the other sympathetic ganglia of the head (figs. 808 and 810). The other branch from the superior cervical ganglion, the *jugular nerve*, associates it with the ganglia of the glossopharyngeal and vagus nerves, with the petrosal ganglion by a direct branch and with the ganglia of the vagus through the nodosal plexus. These latter ganglia (and the nerves to which they belong) are connected, chiefly by way of the tympanic nerve, which is from the petrosal ganglion, with the tympanic plexus (fig. 810).

The **tympanic plexus** serves as a common point of distribution of fibers from the superior cervical spmpathetic ganglion, the ganglia of the vagus, the petrosal ganglion, and the geniculate ganglion, to the cavernous and carotid plexuses and to the sphenopalatine and otic ganglia. The superior cervical ganglion is associated with the cavernous and carotid plexuses direct by the internal carotid nerve and with the tympanic plexus by the inferior and superior caroticotympanic nerves. The tympanic plexus receives fibers from the geniculate ganglion by a small *geniculotympanic branch*, and it is connected with the sphenopalatine ganglion by a small anastomotic or *tympanopetrosal branch* to the great superficial petrosal nerve. It is connected with the otic ganglion by the small superficial petrosal nerve. It is not directly connected with either the ciliary or the submaxillary ganglion. However, these latter ganglia, as well as the sphenopalatine and otic, are connected with the carotid plexus either directly by named branches or indirectly by way of plexuses derived from the carotid. The geniculotympanic branch, the tympanic nerve, and twigs of the nodosal plexus may be considered as analogous to the rami communicantes of the spinal nerves.

The *parotid branches*, described above as branches of the auriculotemporal nerve (from the trigeminus) and as containing fibers from the glossopharyngeal, should be mentioned here as belonging to the gangliated cephalic plexus. These branches consist chiefly of sympathetic fibers arising in the otic ganglion (postganglionic) and passing as branches of the ganglion to the auriculotemporal in which they remain till this nerve enters the parotid gland and then they are distributed to the gland. The visceral motor or preganglionic fibers which terminate about their cells of origin in the otic ganglion are derived from the glossopharyngeal nerve and pass successively through the tympanic nerve, the tympanic plexus, and the small superficial petrosal nerve to the otic ganglion.

The *tympanic nerve* (tympanic branch of the glossopharyngeal, or nerve of Jacobson), the branch to the Eustachian tube (*ramus tubæ*), and the superior and inferior *caroticotympanic branches* are also described as branches of the glossopharyngeal nerve. These must likewise be considered as belonging to the gangliated cephalic plexus.

For purposes of dissection, it may be more expedient to consider separately, with its roots and branches, each of the larger ganglia of the gangliated cephalic plexus. Under this heading belong in part the *geniculate ganglion* of the glossopalatine nerve, and the *ganglia of the glossopharyngeal and vagus*, especially the petrosal ganglion of the former and the jugular ganglion of the latter, from the fact that these ganglia contain numerous cell-bodies of sympathetic neurones as well as those of the sensory neurones of their nerves.

These latter ganglia, however, have been described with their corresponding cranial nerves. The sensory and motor roots of their sympathetic portions are contained in the roots of their nerves. The geniculate probably has no sympathetic root. The sympathetic roots of the petrosal and jugular ganglia are contained in the branches of the jugular nerve. The chief branches of distribution of the geniculate are the geniculotympanic branch, the great superficial petrosal nerve and the external superficial petrosal nerves. The branches of the petrosal ganglion are the tympanic nerve and its branches of the tympanic plexus. The chief branch of distribution from the jugular ganglion is contained in the auricular branch of the vagus, or nerve of Arnold, supplemented by sympathetic fibers in the trunk of the vagus itself.

The principal cephalic sympathetic ganglia are the ciliary, the sphenopalatine (Meckel's), the otic and the submaxillary.

The Ciliary Ganglion

The ciliary (lenticular, or ophthalmic) ganglion lies in the posterior part of the orbital cavity, about 6 mm. in front of the superior orbital (sphenoidal) fissure, to the lateral side of the optic nerve, and between the optic nerve and the lateral

rectus muscle. It is a small, reddish, quadrangular body, compressed laterally, and it measures about 2 mm. from before backward (fig. 803).

Roots.—(*a*) Its motor or short (preganglionic) root enters its lower and posterior angle and is a visceral motor branch derived from the branch of the inferior division of the oculomotor nerve which supplies the inferior oblique muscle. The fibers of the motor root probably all terminate in the ciliary ganglion by synapses with the cell-bodies of its sympathetic neurones.

(*b*) The sensory or long root passes through the upper and back part of the ganglion. It is a branch of the nasociliary (nasal) nerve and is, therefore, composed of fibers from the trigeminus passing through the ganglion. This root also carries many sympathetic fibers, some of which arise from cell-bodies of the superior cervical sympathetic ganglion and gain the nasociliary nerve by way of the internal carotid nerve and the internal carotid and cavernous plexuses. All sympathetic fibers passing to the ganglion pass through it without interruption.

(*c*) The sympathetic root consists of fibers derived from the cavernous (and internal carotid) plexus of the sympathetic; it passes to the ganglion with the long root, and usually also as a separate sympathetic root carrying fibers similar to the sympathetic fibers of the long root.

Branches.—From three to six **short ciliary nerves** emerge from the anterior border of the ganglion; they divide as they pass forward and eventually form about twenty nerves which are arranged in an upper and a lower group, and the latter group is joined by the long ciliary branches of the nasociliary (nasal) nerve, now sensory and sympathetic (fig. 803). When they reach the eyeball, the ciliary nerves pierce the sclerotic around the optic nerve, and pass forward in grooves on the inner surface of the sclera. The sympathetic fibers contained are distributed as motor fibers to the ciliary muscle, the sphincter of the iris, and to the vessels of these and of the cornea. The dilator pupillæ or radial muscle of the iris is innervated by the fibers which arise in the superior cervical sympathetic ganglion and pass through the ciliary ganglion from either its long or its sympathetic root to enter the short ciliary nerves. These fibers are concerned in the '*skin-pupillary*' (*ciliospinal*) reflex chain by which the pupil dilates in response to stimulus of the skin (fig. 783).

The Sphenopalatine Ganglion

The sphenopalatine (Meckel's) ganglion is associated with the maxillary nerve (figs. 801, 804, 808). It is a small reddish-gray body of triangular form, which is flattened at the sides, and measures about 5 mm. from before backward. It lies deeply in the pterygopalatine (sphenomaxillary) fossa at the lateral side of the sphenopalatine foramen and in front of the anterior end of the pterygoid (Vidian) canal. It is attached to the maxillary nerve (fig. 810), from which it receives its sensory root, and it is connected with the Vidian nerve, which furnishes it with motor and sympathetic filaments.

The exact position of the ganglion depends upon the size and shape of the sphenoidal air-sinuses. When these are small, or high and narrow, the ganglion lies lateral to them; when they are large, or broad and flat, the ganglion lies inferior to them. Sometimes it may lie anterior to them if the sinuses are short from in front backward. The ganglion may be reached with ease by chipping away the bone around the sphenoidal air-sinuses after the skull is divided sagitally.

Roots.—(*a*) Its **motor root,** consisting of visceral motor fibers of the glossopalatine nerve, is contained in the great superficial petrosal nerve which is incorporated in the Vidian nerve. It springs from the anterior angle of the geniculate ganglion and passes through the hiatus of the facial canal (hiatus Fallopii) into the middle fossa of the cranium, where it runs forward and medialward, in a groove on the upper surface of the petrous part of the temporal bone, to the foramen lacerum, and in this part of its course it passes beneath the semilunar (Gasserian) ganglion and the masticator nerve. In the foramen lacerum it joins with the great deep petrosal nerve to form the Vidian nerve (nerve of the pterygoid canal), which passes forward through the pterygoid (Vidian) canal, and its visceral motor fibers terminate in the sphenopalatine ganglion in the pterygopalatine (sphenomaxillary) fossa. The great superficial petrosal nerve contains sensory as well as sympathetic and motor fibers. The *sensory fibers* pass through the ganglion and, in the small palatine nerve, descend to the soft palate, where they terminate in the epithelium covering it and some are probably concerned with taste organs found there. They arise from the cells of the geniculate ganglion and therefore belong to the glossopalatine nerve.

(*b*) The **sympathetic root** is the great deep petrosal portion of the Vidian nerve. This root, which is of reddish color and of soft texture, springs from the carotid plexus which lies on the outer side of the internal carotid artery in the carotid canal. It enters the foramen lacerum through the apex of the petrous portion of the temporal bone, and unites with the great superficial petrosal branch of the glossopalatine nerve to form the Vidian nerve. The great superficial petrosal nerve also carries sympathetic fibers derived from the geniculate ganglion and from the tympanic plexus as well as from the carotid plexus.

The **Vidian nerve** [**n. canalis pterygoidei**] commences by the union of the great superficial and deep petrosal nerves in the foramen lacerum, and runs forward through the pterygoid (Vidian) canal into the pterygopalatine (sphenomaxillary) fossa to the sphenopalatine ganglion. The Vidian nerve often may be seen in a ridge of bone along the floor of the sphenoidal cells and its direction there depends upon the position of the sphenopalatine ganglion. While it is in the pterygoid canal the Vidian nerve is joined by a sphenoidal filament from the otic ganglion, and it gives branches to the upper and back part of the roof and septum of the nose and to the lower end of the Eustachian tube.

(c) The **sensory roots** consist of the sensory fibers mentioned above in the great superficial petrosal nerve and of (usually) two sphenopalatine branches from the maxillary nerve. The majority of the fibers of these roots do not join the ganglion, but pass by its medial side and enter the palatine branches.

Branches.—The branches of distribution, containing sensory and vasomotor and secretory fibers, are orbital or ascending, internal or nasal, descending or palatine, and posterior or pharyngeal.

Ascending branches.—The **orbital** or **ascending branches** are two or three small twigs which enter the orbit through the inferior orbital (sphenomaxillary) fissure and proceed, within the periosteum, to the inner wall of the orbit, where they pass through the posterior ethmoidal foramen and through the foramina in the suture behind that foramen to be distributed to the mucous membrane which lines the posterior ethmoidal cells and the sphenoidal sinus.

Internal branches.—The internal or nasal branches are derived in part from the medial side of the ganglion, but are also largely made up of sensory fibers which pass from the spheno-palatine branches of the maxillary nerve without traversing the ganglionic substance. They are disposed in two sets, the lateral and the medial (septal) posterior superior nasal branches.

The **lateral posterior superior nasal branches** (rr. nasales aborales laterales NK) are six or seven small twigs which pass through the sphenopalatine foramen, and are distributed to the mucous membrane covering the posterior parts of the superior and middle nasal conchæ (turbinated bones) (fig. 801). They also furnish twigs to the lining membrane of the posterior ethmodial cells.

The **medial posterior superior nasal (septal) branches** (rr. nasales aborales mediales NK), two or three in number, pass medialward through the sphenopalatine foramen. They cross the roof of the nasal fossa to reach the back part of the nasal septum, where the smaller twigs terminate. The largest nerve of the set, the **nasopalatine nerve (nerve of Cotunnius)** runs downward and forward in a groove in the vomer between the periosteum and the mucous membrane to the incisive (anterior palatine) canal, where it communicates with the nasal branch of the anterior superior alveolar nerve. The two nasopalatine nerves then pass through the foramina of Scarpa in the intermaxillary suture, the left nerve passing through the anterior of the two foramina. In the lower part of the incisive (anterior palatine) canal the two nerves form a plexiform communication (formerly described as Cloquet's ganglion) and they furnish twigs to the anterior or premaxillary part of the hard palate behind the incisor teeth. In this situation they communicate with the anterior palatine nerves.

Descending branches.—The descending branches are the great or anterior, the posterior, and the middle (external) palatine nerves. Like the internal set of branches, they are in part derived from the ganglion and in part are directly continuous with the sphenopalatine nerve (fig. 801).

The **great or anterior palatine** nerve, (n. palatinus major NK), its sensory fibers derived from the maxillary nerve, arises from the inferior angle of Meckel's ganglion, and passes downward through the pterygopalatine canal, accompanied by the descending palatine artery. Emerging from the canal at the greater (posterior) palatine foramen it divides into two or three branches, which pass forward in grooves in the hard palate and supply the glands and mucous membrane of the hard palate and the gums on the inner aspect of the alveolar border of the upper jaw. During its course through the pterygopalatine canal the anterior palatine nerve gives off the **posterior nasal nerves.** These nerves pass through small openings in the perpendicular plate of the palate bone to supply the mucous membrane covering the posterior part of the inferior nasal concha (turbinated bone) and the adjacent portions of the middle and inferior meatuses of the nose.

The **posterior** or **small palatine nerve** (n. palatinus minor NK) passes downward through a lesser palatine foramen (accessory palatine canal), and enters the soft palate, distributing branches to that organ, to the uvula, and to the tonsil. Its sensory fibers are derived from the glossopalatine nerve, through the great superficial petrosal nerve, and pass through the sphenopalatine ganglion. It was formerly believed to convey motor fibers from the facial nerve to the levator veli palatini and azygos uvulæ, but it is now asserted that these muscles are supplied by the spinal accessory nerve through the vagus branches to the pharyngeal plexus.

The **middle (external) palatine nerve** (n. palatinus medius NK), the smallest of the three, in part, likewise from the glossopalatine nerve, traverses a lesser palatine foramen and supplies twigs to the tonsil and to the adjacent part of the soft palate (fig. 801).

Posterior branch.—The small **pharyngeal branch** of the ganglion passes backward and somewhat medialward through the pharyngeal canal accompanied by a pharyngeal branch of the sphenopalatine artery. It is distributed to the mucous membrane of the uppermost part of the pharynx, to the upper part of the choanæ, to the opening of the Eustachian tube, and to the lining of the sphenoidal sinus. Its sensory fibers are derived from the maxillary nerve.

Nerves to the parotid gland.—Of the several possible sources of fibers to the parotid gland, it is thought that its visceral efferent, mostly secretory, fibers are contributed mostly by the glossopalatine and glossopharyngeal nerves. Those fibers from the glossopalatine, the chief secretory supply, arise from its salivatory nucleus and pass via its geniculotympanic branch to terminate in the otic ganglion; those from the glossopharyngeal reach the otic ganglion, some via the tympanic nerve and plexuses but most via the small superficial petrosal nerve. There are very few if any terminal sympathetic ganglia in the parotid gland. The cells in the otic ganglion concerned in the chains give axones which terminate upon the secretory cells of the gland. The *sensory* supply of the parotid is also uncertainly known. Without doubt, most of the sensory fibers are contributed from the trigeminus, via the parotid branches of the auriculotemporal branch of the mandibular nerve. Most of these fibers are distributed directly to the substance of the gland; others pass through the tympanic plexus and through the otic ganglion to the gland. It is held that the glossopharyngeal nerve contributes some sensory fibers via the paths of its visceral efferent supply to the parotid. It is improbable that the gland receives any sensory fibers from the glossopalatine nerve. (See p. 1021.)

The Otic Ganglion

The otic (Arnold's) ganglion (g. oticum NK) is a small reddish-gray body which is associated with the mandibular nerve. It lies deeply in the zygomatic fossa, immediately below the foramen ovale, on the inner side of the trunk of the mandibular nerve. It is in relation medially with the tensor veli palatini, which separates it from the Eustachian tube. In front of it is the posterior border of the pterygoideus internus, and behind it lie the middle and small meningeal arteries. It is compressed laterally, and its greatest diameter, which lies antero-posteriorly, is about 3 mm.

Roots.—The ganglion is closely connected with the nerve to the pterygoideus internus, through which it may receive a motor root from the masticator nerve. Through the small superficial petrosal nerve, which joins the upper and back part of the ganglion, it receives a motor root from the glossopalatine nerve and sensory and motor fibers from the glossopharyngeal nerve. It receives also a slender *sphenoidal filament* from the Vidian nerve. The **sympathetic roots** are derived from the small superficial petrosal nerve and from the sympathetic plexus on the middle meningeal artery.

Branches.—The communicating branches which pass from the ganglion are: (1) The filaments to the chorda tympani, some of whose fibers probably pass through the otic to terminate in the submaxillary ganglion; (2) filaments to the auriculotemporal nerve; (3) filaments to the spinous nerve (the recurrent branch of the mandibular nerve). The branches of distribution are sympathetic to the vessels and somatic motor branches to the tensor tympani, and tensor veli palatini, with sensory fibers (probably) to all of these.

The Submaxillary Ganglion

The submaxillary ganglion (ganglion submandibulare NK) is suspended from the lingual division of the mandibular nerve by anterior and posterior branches (fig. 810). It is a small reddish body of triangular or fusiform shape, which lies between the mylohyoideus and hyoglossus and above the duct of the submaxillary gland.

Roots.—The **sensory root** is received from the lingual nerve. The **motor root** (preganglionic) is from both the masticator nerve by way of the lingual nerve, and from the glossopalatine nerve by way of the chorda tympani. The motor fibers pass from the chorda tympani after it has joined the lingual, and the sensory fibers come directly from the lingual nerve. The **sympathetic root** is formed by filaments from the sympathetic plexus on the facial artery.

Branches.—(*a*) Five or six glandular (postganglionic) branches are given to the submaxillary gland and to Wharton's duct. (*b*) Branches to the lingual nerve and the sublingual gland. (*c*) To the mucous membrane of the floor of the mouth.

II. THE SPINAL NERVES

The spinal nerves are arranged in pairs, the nerves of each pair being symmetrical in their attachment to either side of their respective segment of the spinal cord, and, in general, symmetrical in their course and distribution. There are usually thirty-one pairs of functional spinal nerves. For purposes of description these are topographically separated into *eight* pairs of *cervical* nerves, *twelve* pairs of *thoracic* nerves, *five* pairs of *lumbar*, *five* pairs of *sacral*, and *one* pair of *coccygeal* nerves. Occasionally the coccygeal or thirty-first pair is rudimentary, while, on the other hand, there may be found small filaments representing one or even two additional pairs of coccygeal nerves below the thirty-first pair. These **rudimentary coccygeal nerves** are probably not functional. They never pass outside the vertebral canal, and often even remain within the tubular portion of the filum terminale. There sometimes occurs an increase in the number of vertebræ in the vertebral column and in such cases there is always a corresponding increase in the number of the spinal nerves.

Origin and attachment.—Each spinal nerve (unlike the cranial nerves) is attached to the spinal cord by two roots: a sensory or afferent **dorsal root** [radix posterior] and a motor or efferent **ventral root** [radix anterior]. Each dorsal root has interposed in its course an ovoid mass of nerve-cells, the **spinal ganglion,** and the nerve-fibers forming the root arise from the cells of this ganglion and are thus of peripheral origin. The fibers composing the ventral root, on the other hand, are of central origin; they arise from the large motor cells of the ventral horn of the gray column within the spinal cord (figs. 816, 818).

Each dorsal root-fiber upon leaving its cell of origin pursues a short tortuous course within the spinal ganglion and then undergoes a T-shaped bifurcation, one product of which passes toward the periphery, where it terminates for the collection of sensations and is known as the

peripheral branch, or, since it conveys impulses toward the cell-body, the *dendrite* of the spinal ganglion neurone. It is more correct, however, to consider the T-fiber as a bifurcated axone. The other product of the bifurcation, the *central branch*, passes into the spinal cord and in its course toward the cord contributes to form the dorsal root proper.

The central branches, upon emerging from the spinal ganglion, form a single compact bundle at first, which passes through the dura mater of the spinal cord and then breaks up into a series of root-filaments [fila radicularia]. These thread-like bundles of fibers spread out vertically in a fan-like manner and enter the cord in a direct linear series along its posterolateral sulcus. The fibers of the ventral root emerge from the cord in a series of more finely divided root filaments, which, unlike the entering filaments of the dorsal root, are not arranged in direct linear series, but make their exit over a strip of the ventrolateral aspect of the cord in some places as much as 2 mm. wide.

As they enter the spinal cord the fibers of the dorsal roots undergo a Y-shaped division, both products of which course in the cord longitudinally, as ascending and descending branches. The descending or caudal branches are usually shorter than the ascending, and soon enter and terminate about cells within the gray column of the cord, forming either associational, commissural, or immediate reflex connections, or about cells whose fibers form cerebellar or cerebral connections. The ascending or cephalic branches are either short, intermediate, or long. The short and intermediate branches are similar in function to the descending branches, save that they transfer impulses to the gray substance of segments of the cord above rather than below the level of their entrance. The long branches convey impulses (chiefly proprioceptive) destined

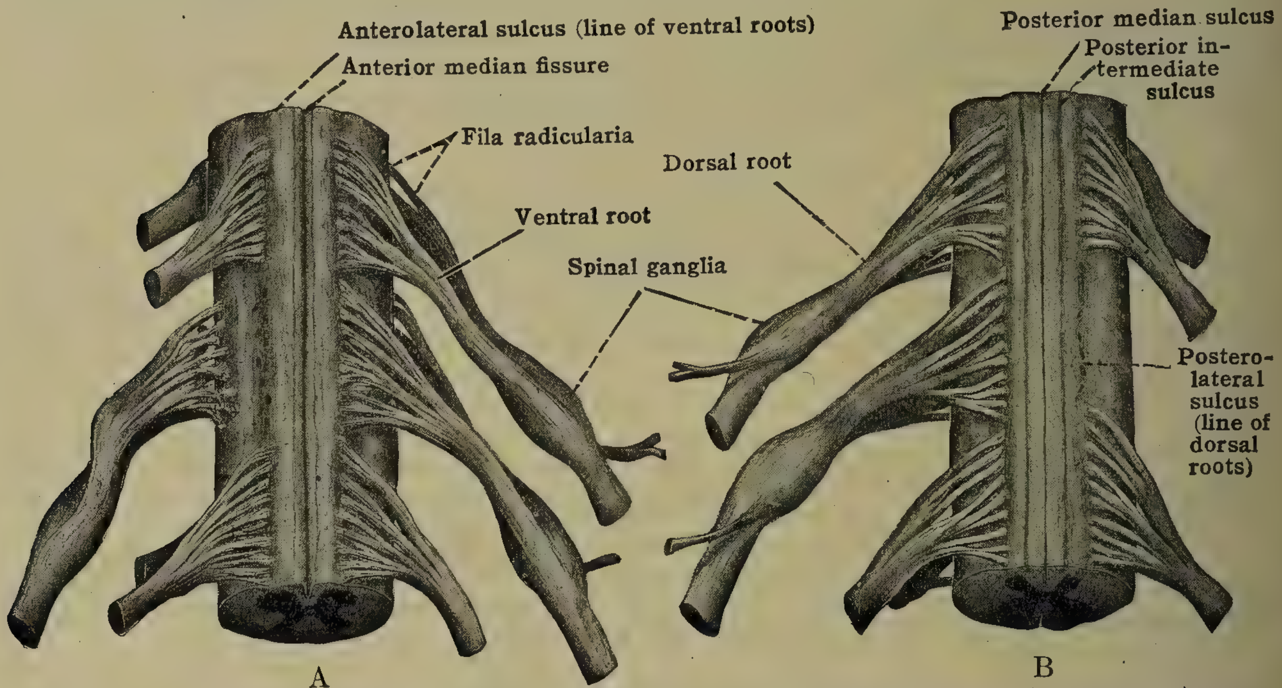


Fig. 816.—A, Ventral and B, Dorsal Views of Spinal Cord Showing Manner of Attachment of Dorsal and Ventral Roots.

for the structures of the brain, and pass upward in the fasciculus gracilis or fasciculus cuneatus of the cord, and terminate in the nuclei of these fasciculi in the medulla oblongata (figs. 697 and 699).

Aberrant spinal ganglia.—In serial sections on either side of the spinal ganglion of a nerve there may often be found outlying cells either scattered or in groups of sufficient size to be called small ganglia. Such are more often found in the dorsal roots of the lumbar and sacral nerves. These cells are nothing more than spinal ganglion-cells displaced in the growth processes, and have the same origin and function as those in the ganglion. In some animals occasional cells very rarely have been found in the outer portion of the ventral root. These probably represent afferent fibers which enter the cord by way of the ventral root. Likewise, especially in the birds and amphibia, it has been shown that occasional efferent fibers may pass from the gray substance of the cord to the periphery by way of the dorsal instead of the ventral root.

Relative size of the roots.—The sensory or dorsal root, with one constant exception, is larger than the ventral root, indicating that the sensory area to be supplied is greater and perhaps more abundantly innervated than the area requiring motor fibers.

It has been shown that in the entire thirty-one spinal nerves of one side of the body of man the dorsal root-fibers number 653,627, while all the corresponding ventral roots contain but 203,700 fibers, a ratio of 3.2 : 1. (Ingbert.) In the increase in the size of the nerves for the supply of the limbs the gain of dorsal root or sensory fibers is far greater than the gain of ventral root-fibers. The first cervical or the suboccipital nerve is an exception to the general rule; its dorsal root is always smaller than its ventral, and in rare cases may be rudimentary or entirely absent. The spinal ganglion and, therefore, the sensory root of the coccygeal nerve, is also quite frequently absent. Ranson and his collaborators have shown that there are far more nonmedullated fibers in the roots than was once supposed, and that there is a greater proportion of these in the dorsal than in the ventral roots. These nonmedullated fibers were not included in Ingbert's counts.

The dorsal and ventral root-fibers of each spinal nerve proceed outward from their segment of attachment to the spinal cord, pierce the pia mater and arachnoid, collect to form their respective roots, and pass into their respective intervertebral foramina. On the immediate peripheral side of the spinal ganglion the two roots blend, giving origin to the thus mixed **nerve-trunk.** As the trunk, the sensory and motor fibers make their exit from the vertebral canal through the intervertebral foramen.

Relation to the meninges.—The root-filaments of each nerve receive connective tissue support from the pia mater and arachnoid in passing through them. In the subarachnoid cavity they become assembled into their respective nerve-roots; and the roots, closely approaching each other, pass into the dura mater, from which they receive separate sheaths at first, but at the peripheral side of the ganglion these sheaths blend into one, which, with the subsequent blending of the roots, becomes the sheath or epineurium of the nerve-trunk. By means of the sheaths derived from the meninges, especially the dura, the nerve-roots and the trunk are attached to the periosteum of the margins of the intervertebral foramina and thus are enabled to give some lateral support to the spinal cord in the upper portion of the canal.

The majority of the spinal ganglia lie in the intervertebral foramina, closely ensheathed, and thus outside the actual sac or cavity of the dura mater. The ganglia of the last lumbar and first four sacral nerves lie inside the vertebral canal, but since the sheath derived from the dura mater closely adheres to them, they are still outside the sac of the dura mater. The ganglia of the last sacral and of the coccygeal nerves (when present) lie in tubular extensions of the subdural cavity, and thus not only within the vertebral canal, but actually within the sac of the dura mater. The trunk of the first cervical nerve is assembled within the sac of the dura mater, and, therefore, the spinal ganglion of this nerve, when present, may lie within the sac.

Course and direction of emergence.—Invested with the connective tissue sheath derived from the meninges, each thoracic, lumbar and sacral nerve emerges from the vertebral canal through the intervertebral foramen below its corresponding vertebra, and all the nerves are in relation with the spinal rami of the arteries and veins associated with the blood-supply of the given localities of the spinal cord.

The first cervical nerve does not pass outward in an intervertebral foramen proper, but between the occipital bone and the posterior arch of the atlas and beneath the vertebral artery. Thus the eighth or last cervical nerve emerges between the seventh cervical and the first thoracic vertebra.

The first and second pairs of cervical nerves pass out of the vertebral canal almost at right angles to the levels of their attachment to the spinal cord. During the early periods of development the level of exit of each pair of spinal nerves is opposite the level of its attachment to the cord, but, owing to the fact that in the later periods the vertebral column grows more rapidly than the cord and increases considerably in length after the cord has practically ceased growing, all the spinal nerve roots, with the exception of the first two pairs, pass downward as well as outward. The obliquity of their course from the level of attachment to the level of exit increases progressively from above downward, and, as the cord ends at the level of the first or second lumbar vertebra, the roots of the lower lumbar and of the sacral nerves pass at first vertically downward within the dura mater, and form around the filum terminale a tapering sheaf of nerve-roots, the **cauda equina** (horse's tail) (fig. 692).

Topography of attachments.—It is of much practical importance to be familiar with the relations of the spinous processes of the vertebræ to the levels of attachment of the spinal nerves to the cord and to the levels of their exit from the vertebral canal. These relations are of especial need in determining localities affected by disease or injury of the spinal cord or of the spinal nerves.

Levels of attachment.—The relations between the levels of attachment of the spinal nerves to the cord and the spinous processes of the vertebræ situated opposite these levels have been worked out in greater detail by Nuhn and by Reid. The following table, compiled by Reid, gives the extreme limits of attachment as observed in six subjects.

Clinical aspects.—In palpation to determine the level of a nerve, it will be found that the tips of the spinous processes of the upper cervical vertebræ can be scarcely made out even by deep pressure. That of the epistropheus may be detected in a lean subject. The first prominent spine is that of the seventh cervical vertebra, 'vertebra prominens.' The superior cervical sympathetic ganglion lies at the level of the spines of the second and third cervical vertebræ. The levels of attachment of the eight cervical nerves to the cord correspond to the interval between the occiput and the tip of the sixth cervical spine. The third thoracic spine is to be noted as on a level with the medial end of the spine of the scapula while the seventh thoracic spine is in line with the lower angle of the scapula. The upper six thoracic nerves are attached to the cord extending in the level between the tip of the sixth cervical spine and the spine of the fifth thoracic vertebra. Most of the thoracic spines, projecting obliquely downward, are below the heads of their corresponding ribs and thus below the levels of exit of their

Table of Topography of Attachment of Spinal Nerves to the Spinal Cord. (Reid.)

(A) signifies the highest level at which the root filaments of a given nerve are attached to the cord, and (B) the lowest level observed. For example, the root filaments of the sixth thoracic nerve *may* be attached as high as the lower border of the spinous process of the second thoracic vertebra, or some may be attached as low as the upper border of the spinous process of the fifth thoracic vertebra, but in a given subject they do not necessarily extend either as high or as low as either of the levels indicated.

Nerves		
Second cervical	(A)	A little above the posterior arch of atlas.
	(B)	Midway between posterior arch of atlas and spine of epistropheus.
Third "	(A)	A little below posterior arch of atlas.
	(B)	Junction of upper two-thirds and lower third of spine of epistropheus.
Fourth "	(A)	Just below upper border of spine of epistropheus.
	(B)	Middle of spine of third cervical vertebra.
Fifth "	(A)	Just below lower border of spine of epistropheus.
	(B)	Just below lower border of spine of fourth cervical vertebra.
Sixth "	(A)	Lower border of spine of third cervical vertebra.
	(B)	Lower border of spine of fifth cervical vertebra.
Seventh "	(A)	Just below upper border of spine of fourth cervical vertebra.
	(B)	Just above lower border of spine of sixth cervical vertebra.
Eighth "	(A)	Upper border of spine of fifth cervical vertebra.
	(B)	Upper border of spine of seventh cervical vertebra.
First thoracic	(A)	Midway between spines of fifth cervical and sixth cervical vertebra.
	(B)	Junction of upper two-thirds and lower third of interval between seventh cervical and first thoracic vertebra.
Second "	(A)	Lower border of spine of sixth cervical vertebra.
	(B)	Just above lower border of spine of first thoracic vertebra.
Third "	(A)	Just above middle of spine of seventh cervical vertebra.
	(B)	Lower border of spine of second thoracic vertebra.
Fourth "	(A)	Just below upper border of spine of first thoracic vertebra.
	(B)	Junction of upper third and lower two-thirds of spine of third thoracic vertebra.
Fifth "	(A)	Upper border of spine of second thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine of fourth thoracic vertebra.
Sixth "	(A)	Lower border of spine of second thoracic vertebra.
	(B)	Just below upper border of spine of fifth thoracic vertebra.
Seventh "	(A)	Junction of upper third and lower two-thirds of spine of fourth thoracic vertebra.
	(B)	Just above lower border of spine of fifth thoracic vertebra.
Eighth "	(A)	Junction of upper two-thirds and lower third of interval between spines of fourth thoracic and fifth thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine of sixth thoracic vertebra.
Ninth "	(A)	Midway between spines of fifth thoracic and sixth thoracic vertebra.
	(B)	Upper border of spine of seventh thoracic vertebra.
Tenth "	(A)	Midway between spines of sixth thoracic and seventh thoracic vertebra.
	(B)	Middle of the spine of eighth thoracic vertebra.
Eleventh "	(A)	Junction of upper quarter and lower three-quarters of spine of seventh thoracic vertebra.
	(B)	Just above spine of ninth thoracic vertebra.
Twelfth "	(A)	Junction of upper quarter and lower three-quarters of spine of eighth thoracic vertebra.
	(B)	Just below spine of ninth thoracic vertebra.
First lumbar	(A)	Midway between spines of eighth thoracic and ninth thoracic vertebræ.
	(B)	Lower border of spine of tenth thoracic vertebra.
Second "	(A)	Middle of spine of ninth thoracic vertebra.
	(B)	Junction of upper third and lower two-thirds of spine of eleventh thoracic vertebra.
Third "	(A)	Middle of spine of tenth thoracic vertebra.
	(B)	Just below spine of eleventh thoracic vertebra.
Fourth "	(A)	Just below spine of tenth thoracic vertebra.
	(B)	Junction of upper quarter and lower three-quarters of spine of twelfth thoracic vertebra.
Fifth "	(A)	Junction of upper third and lower two-thirds of spine of eleventh thoracic vertebra.
	(B)	Middle of spine of twelfth thoracic vertebra.
First sacral	(A)	Just above lower border of spine of eleventh thoracic vertebra.
Fifth "	(B)	Lower border of spine of first lumbar vertebra.
Coccygeal	(A)	Lower border of spine of first lumbar vertebra.
	(B)	Just below upper border of spine of second lumbar vertebra.

corresponding spinal nerves. Each spine from the second to the tenth thoracic projects more nearly in line with the exit of the nerve in the second foramen below it. The attachments to the cord of the lower six of the thoracic nerves lie in the level between the fourth and ninth thoracic spines. The spines of the eleventh and twelfth thoracic project more at right angles

to the vertebral column and their caudal borders are in line with the levels of exit of their corresponding nerves. The five lumbar nerves are attached to the cord in the level between the eleventh and twelfth thoracic spines. The second lumbar spine marks the level of termination of the spinal cord. The levels of attachment of the sacral nerves to the cord correspond to the body of the first lumbar vertebra (first lumbar spine). For more detailed study, see the table of topography of attachments of the nerves given above and fig. 819.

In making **lumbar puncture** for anesthesia of the spinal nerves or for relieving pressure of cerebrospinal fluid, the needle is inserted in the midline of the back between the spines of the third and fourth, or the fourth and fifth, lumbar vertebræ and directed slightly upward. Since the cord terminates above this level, the needle can penetrate merely the bulbous ending of the dural sac containing only the nerve roots forming the cauda equina. The absence of spinous processes and the deficiency of dorsal lamina for the fourth and fifth segments of the sacrum, resulting in the sacral hiatus, offers a weak point in the protection of the spinal cord and nerves. Infections about the hiatus may ascend to involve to meninges and thus the cord. Injections for local anesthesia are sometimes made through the hiatus, mayhap puncturing a dural sac around the roots of a sacral nerve.

Relative size of the nerves.—The size of the different spinal nerves varies greatly. Just as the spinal cord shows marked enlargements in the cervical and lumbar regions necessitated by the greater amount of innervation required of these regions for the structures of the upper and lower limbs, so the nerves attached to these regions are considerably larger than elsewhere.

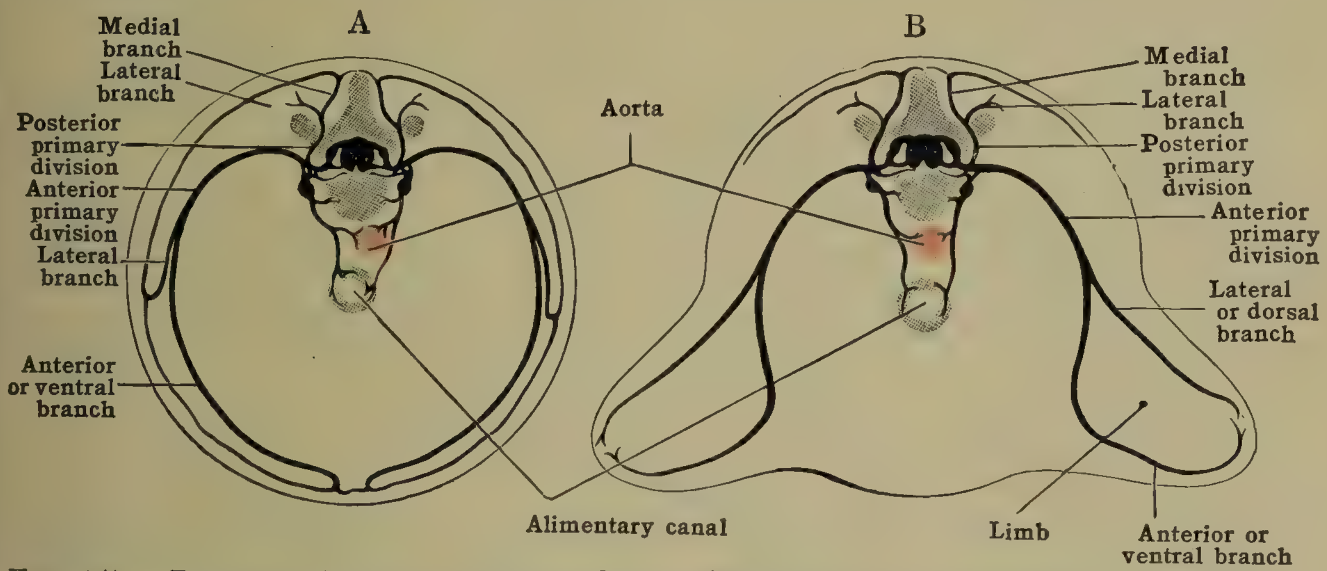


Fig. 817.—Diagrams Illustrating the Origin, Branches and Distribution of a Typical Spinal Nerve.

A, in thoracic region; B, in region of a limb (highly schematic).

The smaller nerves are found at the two extremities of the cord and in the midthoracic region. The smallest nerve is the coccygeal, and the next in order of size are the lower sacral and the first two or three cervical nerves. The largest nerves are those which contribute most to the great nerve trunks for the innervation of the skin and muscles of the limbs:—the lower cervical and first thoracic for the upper limbs and the lower lumbar and first sacral for the lower limbs. The nerves gradually increase in the series in passing from the smaller toward the larger.

The primary divisions of the nerve-trunk (figs. 817, 834).—A typical spinal nerve (middle thoracic, for example), just as it emerges from the intervertebral foramen, divides into four branches:—the two large primary divisions; viz., the **posterior primary division** [ramus posterior] and the **anterior primary division** [ramus anterior]; third, the small **ramus communicans,** by which it is connected with the sympathetic; and fourth, the smaller, **ramus meningeus** (*recurrent branch*), which immediately turns centralward for the innervation of the membranes and vessels of the spinal cord.

In general, the **posterior primary division** passes dorsalward between the arches or transverse processes of the two adjacent vertebræ and in relation with the anterior costotransverse ligament, and then divides (with the exception of the first cervical, the fourth and fifth sacral, and the coccygeal nerves) into a **medial branch** and a **lateral branch.** The medial branch turns toward the spinous processes of the vertebræ, and supplies the bones and joints and the muscles about them, and may or may not supply the skin overlying them. The lateral branch turns dorsalward and also supplies the adjacent muscles and bones, and, if the medial branch has not supplied the overlying skin, it also terminates in cutaneous twigs.

In the upper half of the spinal nerves the medial branches supply the skin; in the lower half, it is the lateral branches which do so. Both branches of almost all the posterior divisions, especially those of the lower nerves, show a tendency to run caudalward and thus are distributed to muscles and skin below the levels of their respective intervertebral foramina. They never supply the muscles of the limbs, though their cutaneous distribution extends upon the buttock, the shoulder, and the skin of the back of the head as far upward as the vertex. The posterior primary divisions, with the exception of those of the first three cervical nerves, are much smaller than the anterior primary divisions.

As their mixed function suggests, the posterior primary divisions contain nerve-fibers both from the ventral roots and the peripheral processes of the spinal ganglion-cells. If the nerve-trunk on the immediate peripheral side of the spinal ganglion be teased, bundles of ventral root-fibers may be seen crossing the trunk obliquely to enter the posterior division, and fibers from the spinal ganglion may be also traced into it. Also the sympathetic fibers, derived chiefly by way of the ramus communicans, are known to course in it for distribution in the walls of the blood-vessels, etc., of the area it supplies (fig. 818).

The anterior primary divisions run lateralward and ventralward. With the exception of those of the first two cervical nerves, which contribute the hypoglossal loop, they are larger than the posterior primary divisions, and appear as direct continuations of the nerve-trunks. Only in case of most of the thoracic nerves do they remain independent in their course. In these they run lateralward and ventralward in the body-wall. In general, these divisions supply the

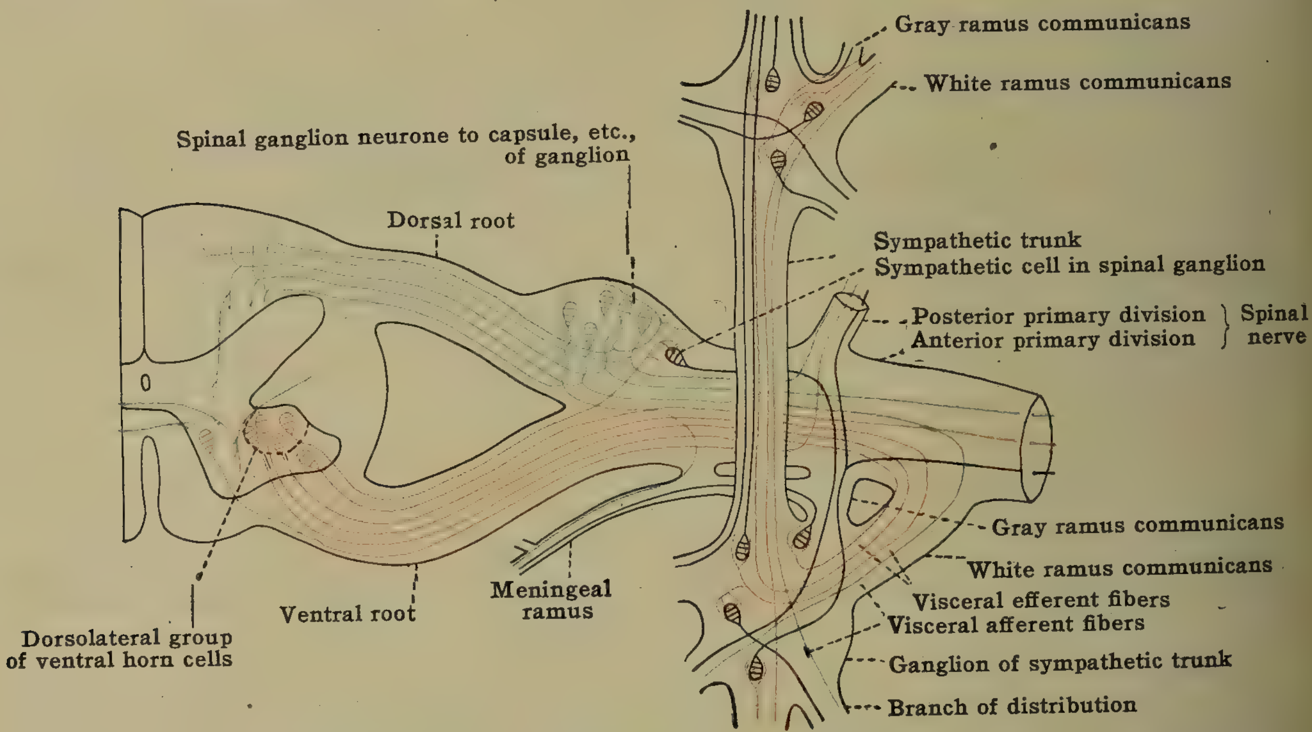


Fig. 818.—Diagram Illustrating the Origin of the Component Nerve-fibers of the Primary Divisions of a Typical Thoracic or Lumbar Spinal Nerve.

lateral and ventral parts of the body, the limbs, and the perineum. In the cervical, lumbar, and sacral regions they lose their anatomical identity by dividing, subdividing, and anastomosing with each other so as to give rise to the three great spinal plexuses of the body—the **cervical,** the **brachial,** and the **lumbosacral plexuses.** The majority of the thoracic nerves retain the typical or primitive character in both their anterior and posterior primary divisions. In them the anterior division (intercostal nerve) divides into a **lateral** and an **anterior** (or ventral) branch, both of which subdivide. The lateral branch is chiefly cutaneous; it pierces the superficial muscles and, in the subcutaneous connective tissue, divides into a smaller posterior and a larger anterior ramus, which respectively supply the skin of the sides and the lateral part of the ventral surface of the body. The anterior branch continues ventralward in the body-wall, giving off twigs along its course to the adjacent muscles and bones, and, as it approaches the ventral midline of the body, it turns sharply lateralward and sends rami medialward and lateralward to supply the skin of the ventral aspect of the body. In the region of the limbs the typical arrangement is interfered with in that what corresponds to the lateral and anterior branches of the division are carried out into the limbs for the skin and muscles there, instead of supplying the lateral and ventral parts of the body-wall.

Nerve-fibers arising in the spinal ganglion and fibers from the ventral root pass directly from the nerve-trunk into the anterior primary division of the spinal

nerve. This division also receives sympathetic nerve-fibers by way of the ramus communicans. These latter accompany the division and are distributed to their allotted elements in the territory it supplies.

The rami communicantes are small, short, thread-like branches by which the nerve-trunks are connected with the nearest ganglion of the vertically running gangliated cord of the sympathetic (sympathetic trunk). The trunk or anterior primary division of every spinal nerve has at least one ramus; most of the nerves have two, and sometimes there are three. The nerves of the cervical region usually have but one, and this is composed largely of sympathetic fibers (gray ramus). Where there are two, one usually contains medullated fibers, chiefly visceral motor from the ventral root, sufficient to give it a whiter appearance (white ramus).

In the upper cervical and in the sacral regions one sympathetic ganglion may be connected with two or more spinal nerves, and sometimes one nerve is connected with two ganglia. The rami communicantes of the spinal nerves are equivalent to the communicating rami connecting certain of the cranial nerves with the sympathetic system (trigeminus, glossopharyngeal, vagus). The medullated fibers of the rami and, therefore, the white rami consist chiefly of fibers from the spinal nerves, viz,, fibers from the spinal ganglion-cells which enter and course to their distribution through branches of the sympathetic nerves, **visceral afferent fibers,** and fibers from the ventral roots of the spinal nerves which terminate in the sympathetic ganglia, **visceral efferent** (preganglionic) **fibers.** Thus the white rami have been termed the **visceral divisions** of the spinal nerves. The gray rami consist chiefly of sympathetic fibers, most of which are non-medullated or partially medullated, and which course to their distribution by way of the spinal nerves. The usual absence of white rami communicantes from the cervical nerves is explained on the grounds—(1) that probably relatively fewer visceral efferent fibers are given to the sympathetic from this region of the cord; (2) that many of the visceral efferent fibers which do arise from this region of the cord probably join the rootlets of the spinal accessory nerve and pass to the sympathetic system through the trunk of this nerve, and through the vagus with which it anastomoses; and (3) that such of these fibers, as are given off, especially from the lower segments of the cervical region, descend the cord and pass out by way of the upper thoracic nerves which give very evident white rami to the sympathetic. In general, the white rami (visceral efferent fibers) of the thoracic and lumbar nerves terminate in the ganglia of the sympathetic trunk, while such fibers of the cranial and sacral nerves stream across the trunk to terminate in more distant sympathetic ganglia.

The meningeal or recurrent branch (figs. 817, 818, and 834) is very small and variable, and is often difficult to find in ordinary dissections. It is given off from the nerve-trunk just before its anterior and posterior primary divisions are formed. It consists of a few peripheral branches of spinal ganglion cells (sensory fibers) which leave the nerve-trunk and re-enter the vertebral canal for the sensory innervation of the meninges, and which are joined by a twig from the gray ramus or directly from the nearest sympathetic ganglion (vasomotor fibers). There is considerable evidence, both physiological and anatomical, obtained chiefly from the animals, which shows that at times certain of the peripheral spinal ganglion or sensory fibers may turn backward in the nerve-trunk and pass to the meninges within the ventral root instead of contributing to a recurrent branch. The occurrence of such fibers in the ventral root explains the physiological phenomenon known as '*recurrent sensibility.*' Likewise, sympathetic fibers entering the trunk through the gray ramus may pass to the meninges by way of the ventral root, and at times the recurrent branch is probably absent altogether, its place being taken entirely by the meningeal fibers passing in the ventral root. Possibly, some reach the meninges through nonmedullated fibers by way of the dorsal root.

Areas of distribution of the spinal nerves.—Both the posterior and anterior primary divisions divide and subdivide repeatedly, and their component fibers are distributed to areas of the body more or less constant for the nerves of each pair, but the distribution of the different pairs is very variable. Corresponding to their attachment, each to a given segment of the spinal cord, the nerves have primarily a segmental distribution, but, owing to the developmental changes and displacement of parts during the growth of the body, the segmental distribution becomes greatly obscured and in some nerves practically obliterated. Naturally it is more retained by the nerves supplying the trunk than by those contributing to the innervation of the limbs and head, and the areas supplied by the posterior primary divisions are less disturbed than those supplied by the anterior. The segmental areas of cutaneous distribution of the posterior divisions are more evident than the areas of muscle supplied by these divisions, from the fact that the segmental myotomes from which the dorsal muscles arise fuse together and overlap each other considerably during development. No nerve has a definitely prescribed area of distribution, cutaneous or muscular, for its area is always considerably overlapped by the areas of the nerves adjacent to it. The midthoracic nerves more nearly supply a definitely prescribed belt of the body.

A. DISTRIBUTION OF POSTERIOR PRIMARY DIVISIONS

As above stated, the posterior primary divisions of the spinal nerves spring from the trunks immediately outside the intervertebral foramina, and they pass dorsalward between the adjacent transverse processes. With the exceptions of the first and second cervical nerves they are smaller than the corresponding anterior primary divisions, which in these nerves are smaller

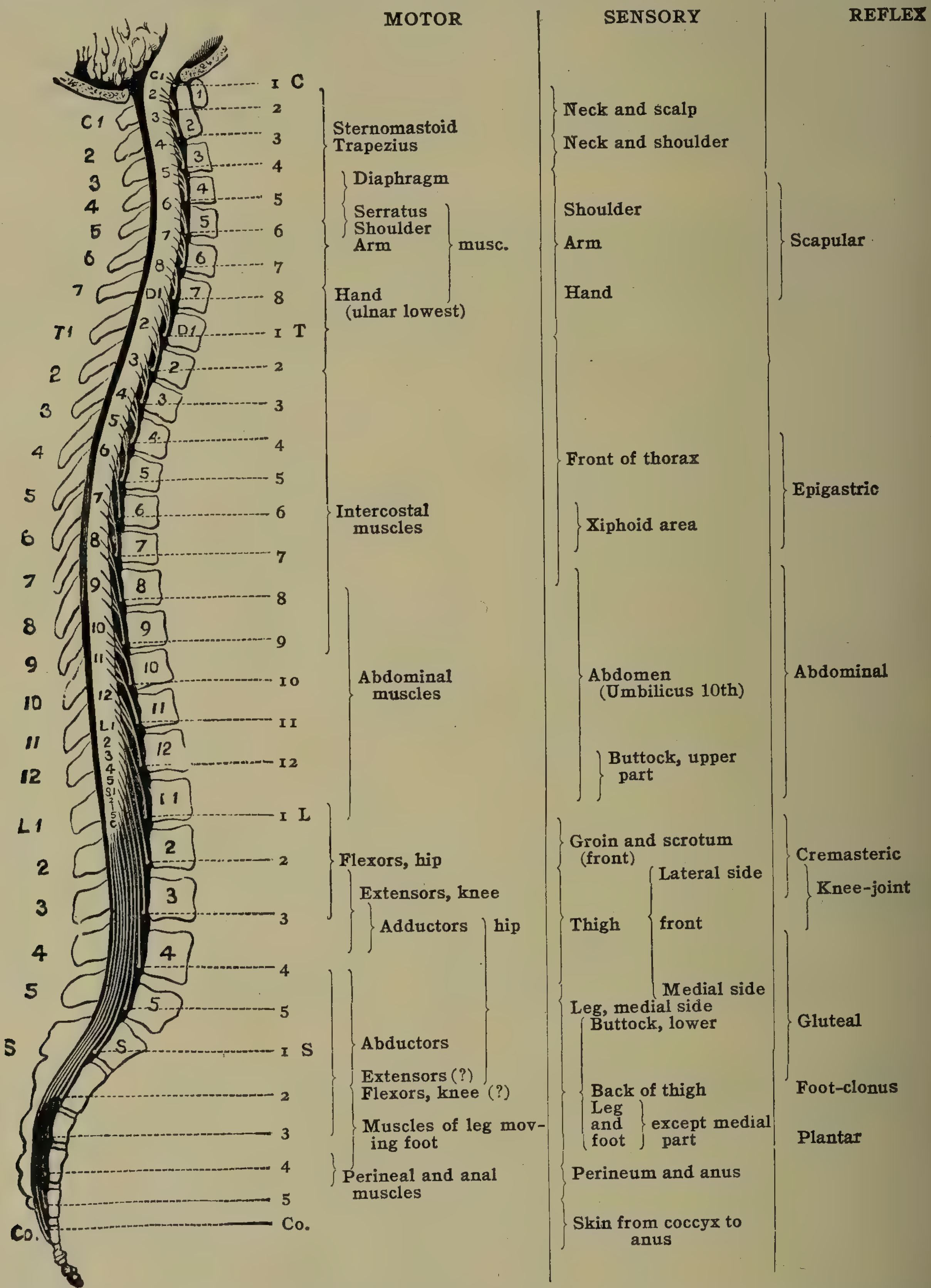


FIG. 819.—TABLE GIVING THE FUNCTIONS AND APPROXIMATE AREAS OF DISTRIBUTION OF THE DIFFERENT SPINAL NERVES WITH A DIAGRAM SHOWING THEIR RESPECTIVE LEVELS OF EXIT FROM THE VERTEBRAL COLUMN. (Arranged by Dr. Gowers.)

from the fact that a large portion of them go over into the hypoglossal (or cervical) loop. The posterior primary divisions, after passing between the transverse processes into the region of the back, divide into medial and lateral branches. This division, however, does not occur in the cases of the first cervical, the last two sacral, and the coccygeal nerves.

1. CERVICAL NERVES (Figs. 820, 821)

The posterior primary division of the first cervical or suboccipital nerve springs from the trunk, between the vertebral artery and the posterior arch of

the atlas, passes dorsalward into the suboccipital triangle, and breaks up into branches which supply the superior oblique, the inferior oblique, and the major rectus capitis posterior muscles, which form the lateral boundaries of the triangle. It also gives a branch across the posterior surface of the major rectus capitis posterior to the minor rectus capitis posterior, and a branch to the semispinalis capitis (complexus) in the roof of the triangle.

It communicates with the medial branch of the posterior primary division of the second cervical nerve, either through or over the inferior oblique muscle, and it occasionally gives a cutaneous branch to the skin of the upper part of the back of the neck and the lower part of the scalp.

The **posterior primary division of the second cervical nerve** is the largest posterior division of all the cervical nerves. It divides into a small lateral branch and a very large medial branch. The **lateral branch** gives a twig to the inferior oblique and terminates in branches which supply the splenius and longissimus capitis (trachelomastoid) muscles. The **medial branch** is the **great occipital nerve** (fig. 823). It turns around the lower border of the inferior oblique, crosses the suboccipital triangle obliquely, pierces the semispinalis capitis (complexus), the tendon of the trapezius, and the deep cervical fascia, passing through the latter immediately below the superior nuchal line of the occipital bone, and it divides into several terminal sensory branches which ramify in the superficial fascia of the scalp.

It gives one or two motor twigs to the semispinalis capitis (complexus), and its terminal branches, which are accompanied by branches of the occipital artery, supply the skin of the scalp, above the superior nuchal line, as far forward as the vertex. Occasionally one branch reaches the pinna and supplies the skin on the upper part of its medial aspect. As it turns around the inferior oblique it gives branches which join with the medial branches of the posterior primary divisions of the first and third cervical nerves, and in this manner a small looped plexus is formed beneath the semispinalis capitis (complexus) muscle, the *posterior cervical plexus of Cruveilhier.*

The **posterior divisions of the third, fourth, and fifth cervical nerves** divide at the lateral border of the semispinalis colli into medial and lateral branches. The **medial branches** of the third, fourth, and fifth nerves run backward between the semispinalis colli and capitis (complexus), supplying both muscles. Then, after passing backward between the semispinalis capitis and the ligamentum nuchæ, they pierce the origin of the trapezius and supply the skin of the back of the neck. The greater part of the medial branch of the third nerve, which runs upward in the superficial fascia to the scalp, is an inconstant branch called the **third occipital nerve**; it interlaces with the great occipital nerve, and it supplies the skin of the upper part of the back of the neck, near the midline, and the skin of the scalp in the region of the external occipital protuberance.

The **medial branches** of the posterior primary divisions of the **sixth, seventh, and eighth cervical nerves** pass to the medial side of the semispinalis cervicis, between it and the subjacent multifidus spinæ, and they end in the neighboring muscles. The **lateral branches** of the posterior primary divisions of the **last five cervical nerves** are small and they are distributed to the longissimus capitis (trachelomastoid), the iliocostalis cervicis (cervicalis ascendens), the longissimus cervicis (transversalis cervicis), the semispinalis capitis (complexus), and the splenius muscles.

2. Thoracic Nerves

The **posterior primary divisions of all the thoracic nerves** divide into medial and lateral branches while in the vertebral groove (fig. 820). The **medial branches of the upper six thoracic nerves** pass dorsalward between the semispinalis dorsi and the multifidus spinæ; they supply the spinalis dorsi, the semispinalis dorsi, the multifidus spinæ, the rotatores spinæ, the intertransversales, and the interspinales muscles; and they end in cutaneous branches which, after piercing the trapezius, turn lateralward in the superficial fascia of the back, and supply the skin as far as the middle of the scapula. The cutaneous branch of the second nerve is the largest; it can be traced lateralward as far as the acromion process. The **medial branches of the lower six thoracic nerves** run dorsalward, between the longissimus dorsi and the multifidus spinæ; they chiefly end in twigs to the adjacent muscles, but not uncommonly they give small cutaneous twigs which

pierce the latissimus dorsi and the trapezius and end in the skin near the midline of the back.

The **lateral branches of the upper six thoracic nerves** pass between the longissimus dorsi and the iliocostalis dorsi (accessorius) and end in those muscles, but the **lateral branches of the six lower nerves** are longer; they pass into the interval

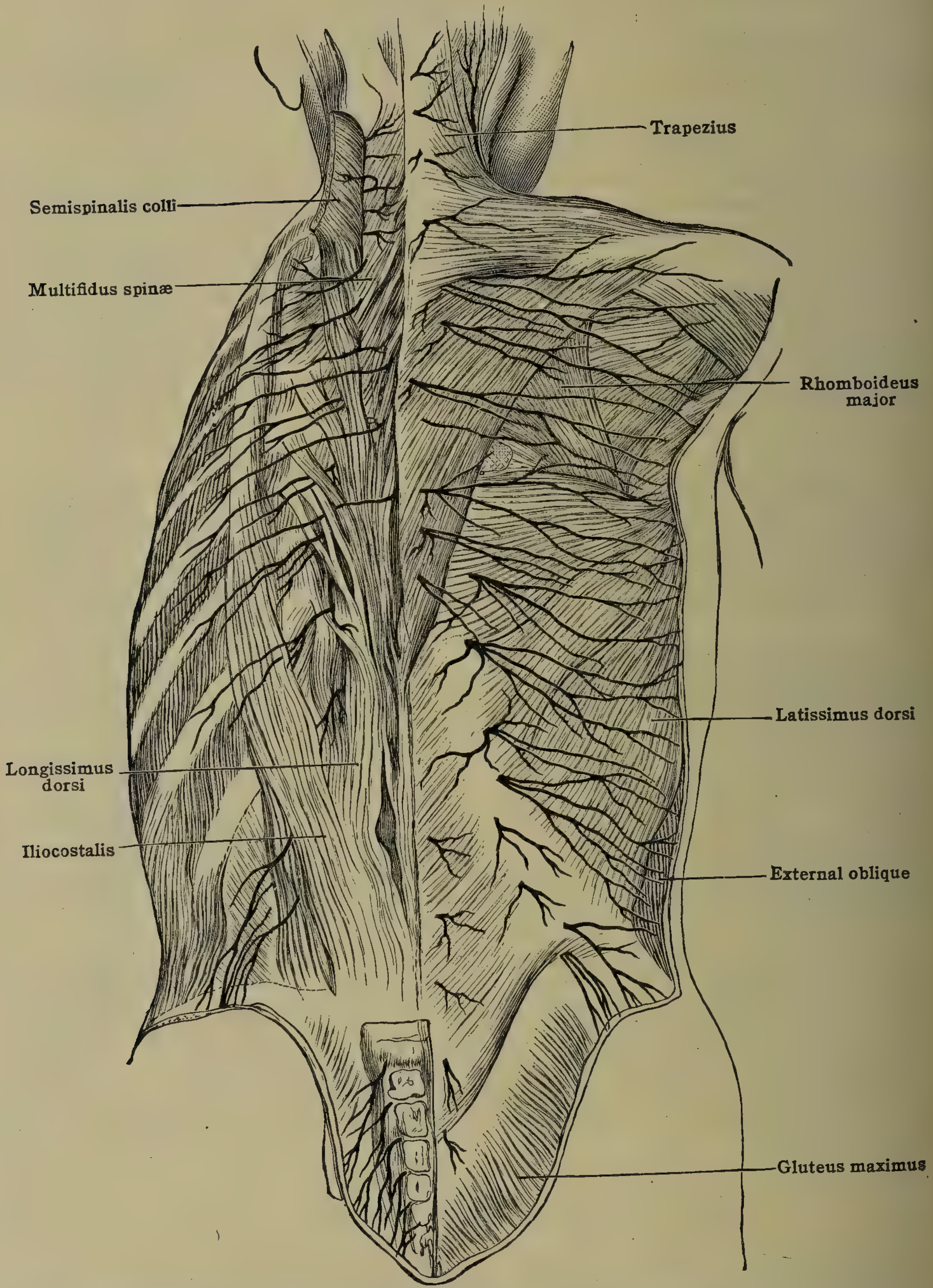


Fig. 820.—Distribution of the Posterior Primary Divisions of the Spinal Nerves. (Henle.)

between the longissimus dorsi and the iliocostalis dorsi and give branches to them, and then they pierce the latissimus dorsi and are distributed to the skin of the lower and lateral part of the back.

3. Lumbar Nerves (Fig. 820)

The **medial branches** of the posterior primary divisions of all the lumbar nerves end in the multifidus spinæ and those of the three lower nerves send very small branches to the skin of the sacral region.

The **lateral branches of the upper three nerves** pass obliquely lateralward, supplying twigs to the adjacent muscles, pierce the posterior layer of the lumbar aponeurosis at the lateral border of the sacrospinalis (erector spinæ) and enter the subcutaneous tissue. They are, for the most part, cutaneous, forming the **superior clunial nerves,** which cross the crest of the ilium and pass downward to occupy different planes in the thick superficial fascia which covers the upper part of the gluteus medius.

The lateral branch from the first lumbar nerve is comparatively small, and occupies the most superficial plane. The second occupies an intermediate position. The lateral branch from the third nerve is the largest of the three, and occupies the lowest position; it distributes branches over the gluteus maximus as far as the great trochanter. The three branches anastomose with one another and also with the cutaneous branches from the posterior primary divisions of the two upper sacral nerves.

The lateral branch of the posterior primary division of the fourth lumbar nerve is of small size and ends in the lower part of the sacrospinalis (erector spinæ). That of the fifth lumbar is distributed to the sacrospinalis and communicates with the first sacral nerve.

4. Sacral Nerves (Fig. 820)

The posterior primary divisions of the upper four sacral nerves escape from the vertebral canal by passing through the posterior sacral foramina; those of the fifth sacral pair pass out through the hiatus sacralis between the posterior sacrococcygeal ligaments. Those of the upper three sacral nerves divide in the ordinary manner into medial and lateral branches. Those of the lower two sacral nerves remain undivided.

The **medial branches** of the upper three sacral nerves are of small size, and are distributed to the multifidus spinæ. The **lateral branches** anastomose with one another and with the lateral branch of the last lumbar nerve, forming loops on the posterior surface of the sacrum from which branches proceed to the posterior surface of the sacrotuberous (great sacrosciatic) ligament, where they anastomose and form a second series of loops, from which loops two or three branches are given off. These branches pierce the gluteus maximus and come to the surface of that muscle in a line between the posterior superior spine of the ilium and the tip of the coccyx. Then, as the **middle clunial nerves,** they are distributed to the integument over the medial part of the gluteus maximus, and communicate, in their course through the superficial fascia, with the posterior branches of the lumbar nerves.

The posterior primary divisions of the **lower two sacral nerves** unite with one another, with the posterior division of the third sacral, and with the coccygeal nerve, forming loops from which twigs pass to the integument over the lower end of the coccyx.

The **posterior primary division of the coccygeal nerve** is also undivided. It separates from the anterior division in the sacral canal and emerges through the hiatus sacralis, pierces the ligaments which close the lower part of that canal, receives a communication from the posterior division of the last sacral nerve, and ends in the skin over the dorsal aspect of the coccyx.

B. ANTERIOR PRIMARY DIVISIONS

The anterior primary divisions of the spinal nerves are larger than the posterior primary divisions, and each is joined near its origin by a gray ramus communicans from the sympathetic trunk (figs. 821, 822, 834). Beginning with the first thoracic nerve and ending with the second or third lumbar nerve, each anterior division sends to the sympathetic trunk a white ramus communicans. The same is true of the second and third or of the third and fourth sacral nerves. All these white rami are approximately designated the **visceral branches** of the spinal nerves, being composed chiefly of visceral efferent (preganglionic) and some visceral afferent fibers. The anterior primary divisions of the cervical, lumbar, sacral, and coccygeal nerves unite with one another to form **plexuses,** but the anterior primary divisions of the thoracic nerves, except the first and last, remain separate, pursue independent courses, and each divides, in a typical manner, into a lateral and an anterior or ventral branch (fig. 817). Separation of anterior primary division into lateral and anterior branches is not confined to the thoracic nerves, however, for it occurs also in the lower cervical, the lumbar, and the sacral nerves. But such a separation cannot be clearly distinguished either in the upper cervical nerves or in the coccygeal nerve.

1. CERVICAL NERVES

The anterior primary divisions of the **upper four cervical nerves** unite to form the **cervical plexus,** and each receives a communicating branch from the superior cervical sympathetic ganglion. The anterior divisions of the **lower four cervical**

nerves are joined by the greater part of the first thoracic nerve and they unite to form the **brachial plexus** (figs. 821, 824, 825). The fifth and sixth cervical nerves receive communicating branches from the middle cervical sympathetic ganglion, and the seventh and eighth from the inferior cervical ganglion, while the first thoracic nerve is connected with the first thoracic sympathetic ('stellate') ganglion by a gray ramus (figs. 821, 858) and also by one or often two white rami communicantes (Johnson and Mason).

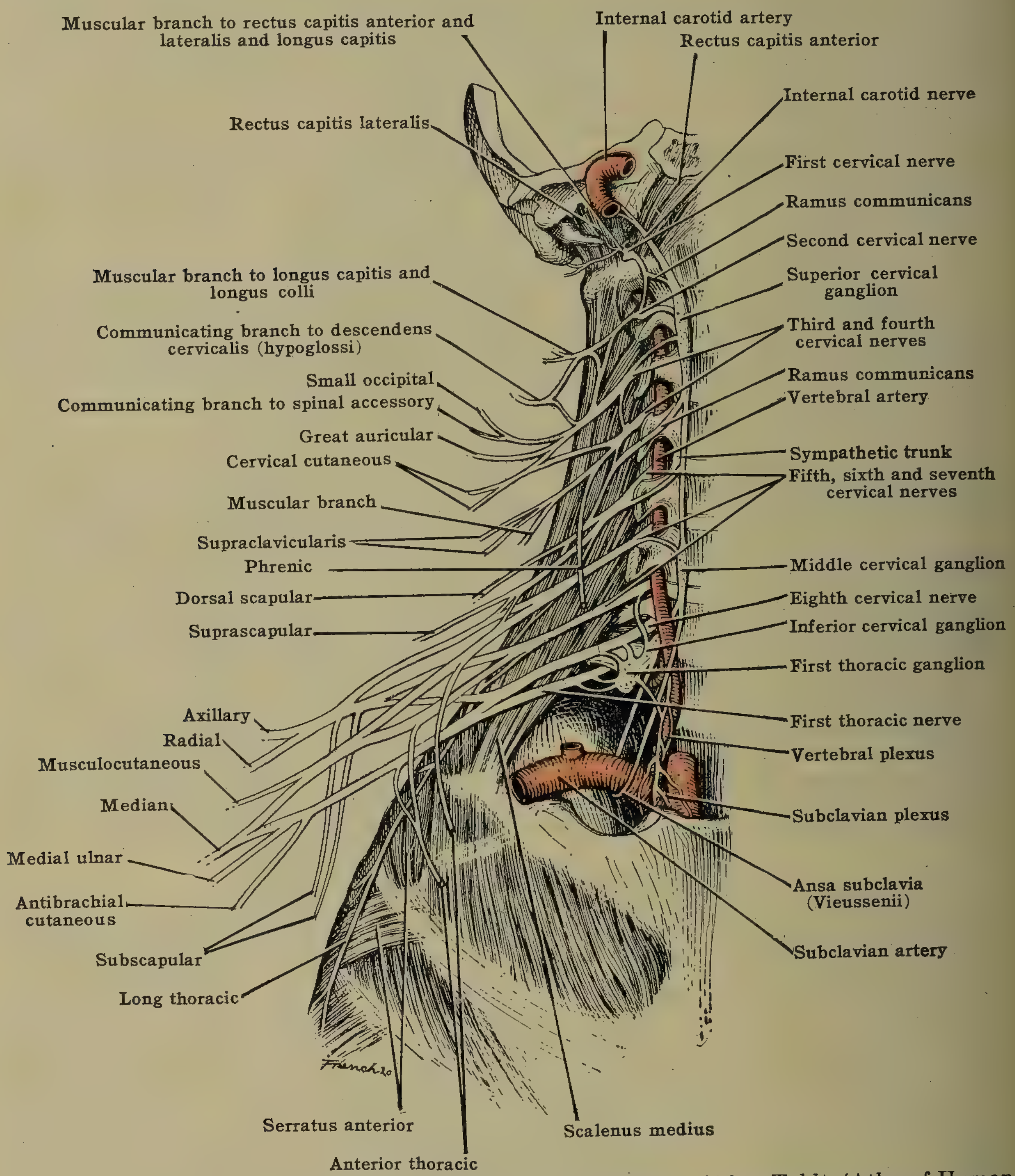


Fig. 821.—Origin of the Cervical and Brachial Plexuses. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

THE CERVICAL PLEXUS

The cervical plexus (figs. 821–823) is formed by the anterior primary divisions of the upper four cervical nerves which constitute the roots of the plexus. It lies in the upper part of the side of the neck, under cover of the sternomastoid, and upon the levator scapulæ and the scalenus medius. It is a looped plexus, consisting of three loops.

A large part of the anterior primary division of the **first cervical nerve** is given to the ansa hypoglossi; the remainder passes to the cervical plexus and in doing so it runs lateralward on the posterior arch of the atlas beneath the vertebral artery, then it turns forward, between the vertebral artery and the outer side

of the upper articular process of the atlas, and finally it descends, in front of the transverse process of the atlas, and unites with the upper branch of the second nerve, forming with it the first loop of the plexus. It gives branches to the rectus capitis lateralis, longus capitis (major rectus capitis anterior), and to the rectus capitis anterior (minor). The division communicates with the ganglion of the trunk of the vagus and with the superior cervical ganglion of the sympathetic system (fig. 822). From the first loop of the plexus, two branches of the division pass over into the sheath of the hypoglossal nerve and descend with it to contribute to the ansa hypoglossi or better, the *cervical loop*. The fibers entering the

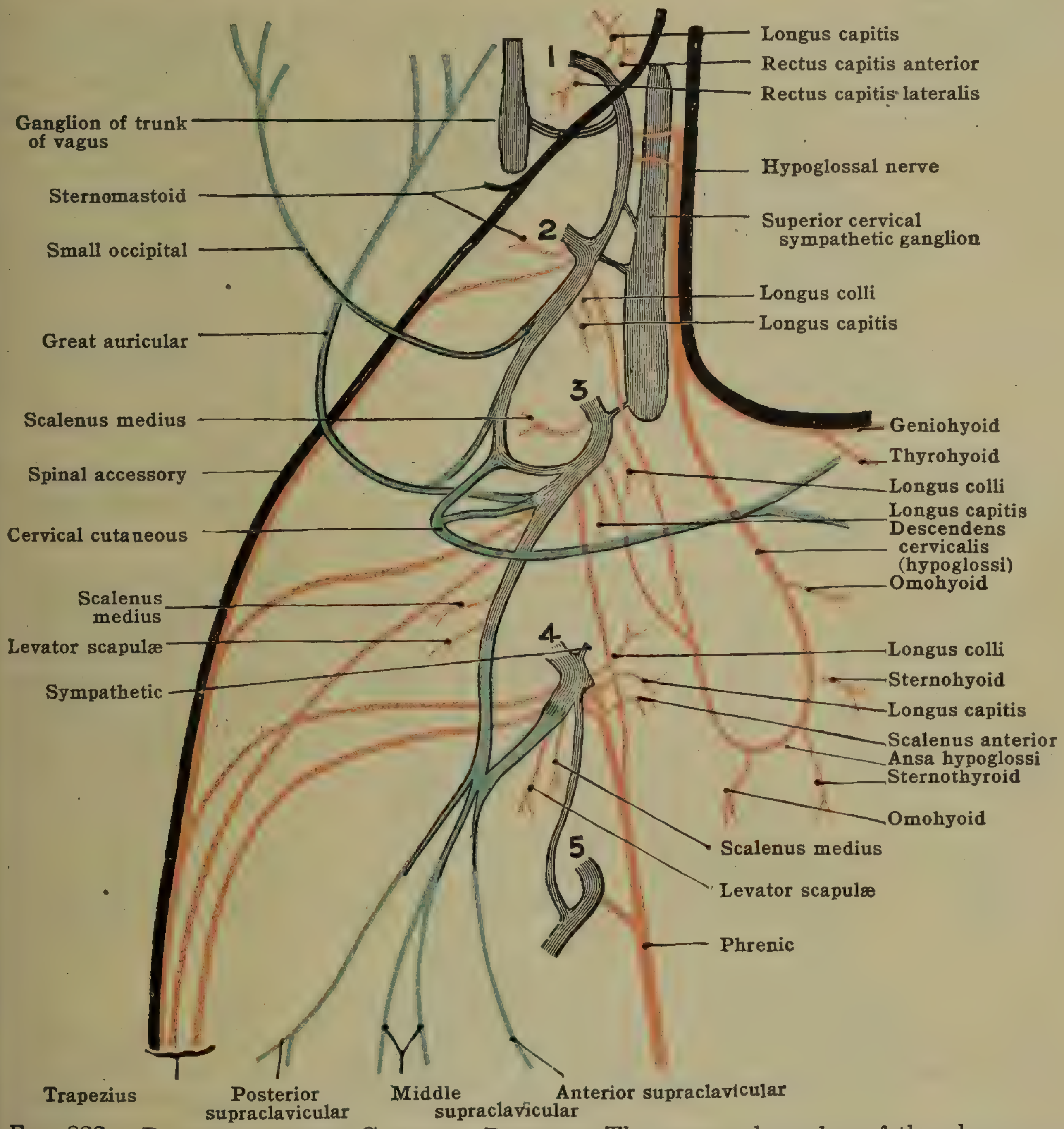


FIG. 822.—DIAGRAM OF THE CERVICAL PLEXUS. The sensory branches of the plexus are in blue, the motor in red (muscles named).

sheath of the hypoglossus, after giving a few twigs to the geniohyoid and thyrohyoid muscles, leave the sheath as the **descendens cervicalis.** This latter joins the *communicans cervicalis*, (the portion of the loop from the second and third cervical nerves) and unites with the ansa hypoglossi.

The ansa usually may be found between the sheaths of the sternomastoid muscle and the carotid artery, superficial to the internal jugular vein; sometimes it may lie in the carotid sheath between the carotid artery and the internal jugular vein; rarely it may lie dorsal to both the artery and vein. Sometimes it is relatively long, descending toward the sternum below the level of the thyroid cartilage; again it is quite short and occurs near the level of the hyoid bone. The descendens cervicalis (hypoglossi) parts company with the hypoglossal nerve at the level at which the nerve curves around the occipital artery. It runs downward and slightly medialward on the sheaths of the great vessels and occasionally within the sheath of one of them.

The **second cervical nerve** (anterior primary division) passes behind the upper articular process of the axis and the vertebral artery, and between the inter-

transverse muscles extending from the first to the second cervical vertebræ, to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where it divides into two parts. The upper part ascends and unites with the first nerve to form the first loop of the plexus, and the lower branch passes downward and dorsalward and joins the upper branch of the third nerve in the second loop of the plexus (figs. 821, 822). This branch gives off the small occipital nerve and a filament to the sternomastoid, which communicates with the spinal accessory nerve in the substance of the muscle, and it gives branches which assist in forming the ansa hypoglossi, the cervical cutaneous and the great auricular nerves.

The anterior primary divisions of the **third and fourth cervical nerves** are about double the size of the preceding. They pass behind the vertebral artery (fig. 821) and between the intertransverse muscles to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where the third unites with the second and fourth nerves and completes the lower two loops of the plexus. The third gives off branches to the hypoglossal loop, one to form the larger part of the great auricular and one to the cervical cutaneous nerves, a branch to the phrenic, a branch to the supraclavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus capitis, and trapezius (fig. 822). The trapezius branch joins the spinal accessory nerve beneath the muscle. The fourth nerve gives a branch to the phrenic, a branch to the supraclavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus colli, and trapezius. The branch to the trapezius unites with the one from the third nerve and joins the spinal accessory nerve beneath the muscle.

The fibers forming the hypoglossal (cervical) loop innervate all the muscles of the infrahyoid group, though twigs to the geniohyoid and thyrohyoid seemingly enter these muscles from the trunk of the hypoglossus (fig. 822).

The nerve to geniohyoid is given off from the trunk of the hypoglossus under cover of the mylohyoid in common with the terminal branches of the hypoglossus proper going to the intrinsic muscles of the tongue. **The nerve to the thyrohyoid** muscle leaves the trunk of the hypoglossus near the tip of the great cornu of the hyoid bone, running obliquely downward and medianward to reach its muscle. A twig to the anterior belly of the **omohyoid** is given from the upper part of the descendens cervicalis and the **nerves for the sternohyoid**, the **sternothyroid** and the posterior belly of the **omohyoid** are supplied from the turn of the loop (fig. 822). The nerves to the sternohyoid and sternothyroid send twigs downward in the muscles behind the manubrium sterni and fibers from these in rare cases join the phrenic nerve in the thorax. The nerve to the posterior belly of the **omohyoid** courses as a loop in the cervical fascia below the central tendon of its muscle.

Each root of the cervical plexus receives a communicating gray ramus from the superior cervical ganglion of the sympathetic, and from the roots and loops of the plexus a number of branches arise which form two main groups, the superficial and the deep.

Superficial Branches of the Cervical Plexus

The superficial branches are described, according to the direction in which they run, as ascending, transverse, and descending branches (fig. 823). The *ascending branches* are the small occipital and the great auricular nerves. There is only one *transverse branch*, the superficial cervical cutaneous (transverse cervical) nerve. The *descending branches* are distinguished as the supraclavicular nerves and the cervical (hypoglossal) loop. For cutaneous distribution see also p. 1099.

The ascending branches.—(1) The **small occipital nerve** (figs. 822, 823) arises from the second and third cervical nerves, or from the loop between them, and runs upward and dorsalward to the posterior border of the sternomastoid, where it hooks around the lower border of the spinal accessory nerve and then ascends along the posterior border of the muscle to the mastoid process. It pierces the deep cervical fascia and passes across the posterior part of the insertion of the sternomastoid into the superficial fascia of the scalp, in which it breaks up into auricular, mastoid, and occipital terminal branches.

(*a*) The **auricular branch** runs upward and slightly forward to reach the integument on the upper median part of the auricle (pinna), which it supplies. (*b*) The **mastoid branch** is distributed to the skin covering the base of the mastoid process. (*c*) The **occipital branches** ramify over the occipitalis muscle and are distributed to the skin of the scalp; they communicate with one another and with the great occipital nerve. The branches of the small occipital nerve

anastomose with twigs of the posterior auricular, great auricular, and great occipital nerves (fig. 823).

(2) The **great auricular nerve** arises from the second and third cervical nerves (figs. 822, 823). It accompanies the small occipital to the posterior border of the sternomastoid, but at that point it diverges from the small occipital and runs upward and forward across the sternomastoid toward the angle of the mandible. When it is about half-way across the muscle it begins to break up into its terminal branches, which are named, according to the area of their distribution, as mastoid, auricular, and facial.

As the nerve ascends obliquely across the sternomastoid it is embedded in the deep cervical fascia, is covered by superficial fascia and by the platysma. It lies parallel with and slightly

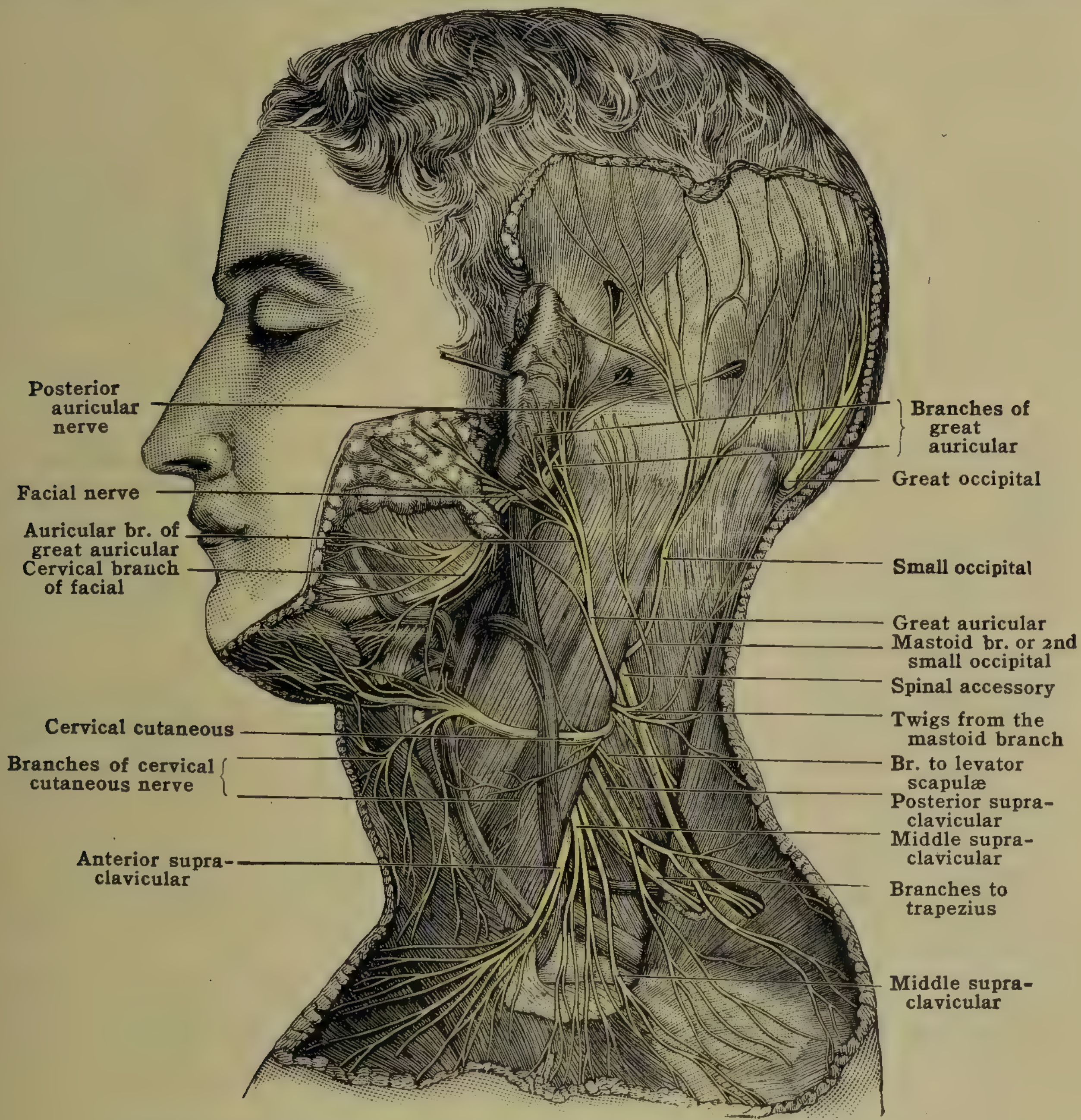


Fig. 823.—Superficial Branches of the Cervical Plexus. (After Hirschfeld and Leveillé.)

dorsal to the external jugular vein. (*a*) The **mastoid branch** is small, and is distributed to the integument covering the mastoid process. It anastomoses with the posterior auricular and small occipital nerves. (*b*) The **auricular branches** are three or four stout twigs which interlace with the branches of the posterior auricular nerve; they cross the superficial surface of the posterior auricular branch of the facial, and are distributed to the skin on the back of the auricle with the exception of its uppermost part. One or two twigs pass through fissures in the cartilage of the auricle, and are distributed to the integument on the lateral surface of the lobule and the lateral surface of the lower part of the helix and anthelix. (*c*) The **facial branches** pass upward and forward among the superficial lobules of the parotid gland, and supply the skin over that gland and immediately in front of it, and they anastomose in the substance of the gland with the cervicofacial division of the facial nerve. In some cases fine twigs may be traced forward nearly to the angle of the mouth.

Transverse branch of the cervical plexus.—The **cervical cutaneous nerve** [n. cutaneous colli] arises from the second and third cervical nerves (figs. 821, 822),

and appears at the posterior border of the sternomastoid, a little below the great auricular nerve. It passes transversely across the sternomastoid under cover of the integument, platysma, and external jugular vein, and divides into a number of twigs which spread out after the manner of a fan, and, as they approach the middle line, extend from the chin to the sternum (fig. 823).

The upper two or three of these twigs unite, beneath the platysma, with the cervical (inframandibular) branch of the facial and thus form loops. From the terminal branches of the nerve numerous twigs arise which pierce the platysma and end in the skin of the front part of the neck.

The descending or supraclavicular branches.—These are derived from the third and fourth cervical nerves (figs. 821, 822), and arise under cover of the sternomastoid. At their commencements they are usually united with the muscular branches destined for the trapezius. They become superficial at the middle of the posterior border of the sternomastoid, and as they pass downward they pierce the deep cervical fascia (fig. 823). They include the following:

(1) The **anterior supraclavicular (suprasternal) branches** are small, and cross over the clavicular attachment of the sternomastoid to reach the integument over the upper part of the manubrium sterni. They also supply the sternoclavicular joint. (2) The **middle supraclavicular nerves** are of considerable size. They cross in front of the middle third of the clavicle under cover of the platysma, and are distributed to the skin covering the upper part of the pectoralis major as low as the third rib. This distribution naturally includes some of the sensory supply for the mammary gland. (3) The **posterior supraclavicular (supra-acromial) branches** cross the clavicular insertion of the trapezius and the acromion process. They are distributed to the skin which covers the upper two-thirds of the deltoid muscle and they supply the acromioclavicular joint.

Deep Branches of the Cervical Plexus

The deep branches of the plexus (figs. 821, 822) pass lateralward and dorsalward, and ventralward and medialward, thus forming two series, the lateral and the medial.

The **lateral branches** of the deep series include communicating branches from the second, third, and fourth cervical nerves to the spinal accessory nerve, and muscular branches to the sternomastoid and to the scalenus medius, levator scapulæ, and trapezius.

The **communicating branches.**—The communicating branch from the second cervical nerve is ultimately distributed to the sternomastoid, and those from the third and fourth nerves end in the trapezius.

1 The **nerve to the sternomastoid** arises from the second cervical nerve. It pierces the deep surface of the sternomastoid, and communicates within the muscle with the spinal accessory nerve.

2. The **nerves to the scalenus medius** are derived from the third or fourth to the eighth cervical nerves close to their exit from the intervertebral foramina.

3. The **nerves to the levator scapulæ** are derived from the third and fourth cervical nerves, and occasionally from the second or fifth. They pierce the superficial surface of the levator scapulæ, and supply the upper three divisions of that muscle.

4. The **branches to the trapezius** are usually in the form of two stout twigs which are given off by the third and fourth cervical nerves. They emerge from under cover of the sternomastoid at its posterior border and cross the posterior superior triangle of the neck at a lower level than the spinal accessory nerve (fig. 823). They pass under cover of the trapezius in company with the last-named nerve, and communicate with it to form the **subtrapezial plexus,** from which the trapezius is supplied.

The **medial branches** of the deep series also comprise communicating and muscular branches.

The **communicating branches** (figs. 821, 822) include (1) branches which connect each of the first four cervical nerves with the superior cervical ganglion of the sympathetic; (2) a branch to the vagus; (3) a branch to the hypoglossus; and (4) branches which pass from the second and third cervical nerves to the *descendens cervicalis* (*hypoglossi*). The ultimate distribution of the twigs connected with the sympathetic and the vagus nerves is not known, but the fibers which pass to the hypoglossal nerve pass from it to the thyrohyoideus muscle and to the descendens cervicalis, and the latter joins with the branches from the second and third cervical nerves, forming with them the cervical or **hypoglossal loop** [ansa hypoglossi] which lies on the carotid sheath. From this loop the two bellies of the omohyoid muscle and the sternohyoid and sternothyroid muscles are supplied as described above.

The **muscular branches** supply the rectus capitis lateralis, the longus capitis (rectus capitis anterior major), the rectus capitis anterior (minor), the scalenus anterior, and the diaphragm. The nerve to the latter muscle is the phrenic.

1. The **branch to the rectus capitis lateralis** is furnished to that muscle by the first cervical nerve as it crosses the deep surface of the muscle.

2. The **nerve to the rectus capitis anterior** (minor) is given off by the first nerve at the upper part of the loop in front of the transverse process of the atlas.

3. The **longus capitis** (rectus capitis anterior major) receives twigs from the upper four cervical nerves.

4. The **longus colli** receives branches from the second, third, and fourth cervical nerves, and additional branches also from the fifth and sixth nerves.

5. The **phrenic nerve** (figs. 821, 822) springs chiefly from the fourth cervical, but it usually receives a twig from the third and another from the fifth cervical nerve, a small communicating branch from the sympathetic, and, rarely, a branch from the vagus. The twig from the fifth cervical nerve is frequently connected with the nerve to the subclavius. After the union of its roots the phrenic nerve passes downward and medialward on the scalenus anterior (figs. 537, 825). In this part of its course it is crossed by the tendon of the omohyoid and by the transverse cervical and transverse scapular (suprascapular) arteries. It is overlapped by the internal jugular vein, and it is covered by the sternomastoid muscle. At the root of the neck the left phrenic nerve lies behind the terminal portion of the thoracic duct, and each nerve passes off the anterior border of the scalenus anterior and descends in front of the first part of the subclavian artery and the pleura immediately below that artery; each nerve passes dorsal to the terminus of the subclavian vein, crosses either in front of or dorsal to the internal mammary artery and gains the medial surface of the pleural sac. From the root of the neck the relations of the phrenic nerves differ (fig. 537).

The **right phrenic nerve** descends along the medial surface of the right pleural sac and crosses in front of the root of the lung. It is accompanied by the pericardiacophrenic artery (comes nervi phrenici), and it is in relation medially, and from above downward, with the right innominate vein, the superior vena cava, and the pericardium, the latter membrane separating it from the wall of the right atrium. The **left phrenic nerve** descends along the medial surface of the left pleural sac accompanied by the pericardiacophrenic artery. In the superior mediastinum it lies between the left common carotid and the left subclavian arteries, and it crosses in front of the left vagus, the left superior intercostal vein, and the arch of the aorta. Below the arch of the aorta it crosses in front of the root of the left lung, and then lies along the left lateral surface of the pericardium, which separates it from the wall of the left ventricle.

Branches.—Both phrenic nerves distribute branches to the pericardium and to the pleura. The right nerve gives off a branch, **pericardiac**, which accompanies the superior vena cava and supplies the pericardium. Each phrenic nerve divides into numerous terminal **phrenico-abdominal** branches. As a rule, the *right phrenic* nerve divides into two main terminal branches, an anterior and a posterior. The *anterior* branch runs forward and one of its terminal filaments anastomoses with the phrenic of the opposite side in front of the pericardium; others descend between the sternal and costal attachments of the diaphragm into the abdomen, where some of them supply the diaphragm and others descend in the falciform ligament to the peritoneum on the upper surface of the liver. The *posterior* branch passes through the vena caval opening and ramifies upon the lower surface of the diaphragm, anastomosing with the diaphragmatic plexus of the sympathetic, and its terminal branches supply the muscular fibers of the right half of the diaphragm, the inferior vena cava, and the right suprarenal gland.

The *left phrenic* nerve divides into several branches. One of the most anterior branches anastomoses with the right phrenic nerve; the others pierce the diaphragm and ramify on its lower surface, where they anastomose with filaments of the left diaphragmatic plexus of the sympathetic and supply the left half of the diaphragm and the left suprarenal gland. The left phrenic nerve is considerably longer than the right nerve, partly on account of the lower level of the diaphragm on the left side, and partly on account of the greater convexity of the left side of the pericardium.

Clinical aspects.—In ligating the subclavian artery, inclusion of a phrenic nerve in the ligature must be guarded against. Ligation of the third part of this artery may include the nerve to the subclavius muscle and this nerve sometimes carries a considerable proportion of phrenic fibers. In pulmonary tuberculosis, division of the phrenic nerve (phrenicotomy) is sometimes made in order to cause a one-sided paralysis with immobilization of the diaphragm

THE BRACHIAL PLEXUS

The **brachial plexus** (figs. 821, 824, 825) is formed by the anterior primary divisions of the **four lower cervical nerves** and the greater part of that of the **first thoracic nerve.** It is usually joined by small twigs from the **fourth cervical** and **second thoracic nerves.**

The anterior primary divisions of the lower four cervical nerves, after passing dorsal to the vertebral artery and between the anterior and posterior parts of the intertransverse muscles, pass into the posterior triangle of the neck between the adjacent borders of the anterior and middle scalene muscles, where those of the fifth and sixth nerves receive a gray ramus communicans each from the middle cervical sympathetic ganglion, and those of the seventh and eighth nerves each

receives a gray ramus from the inferior cervical sympathetic ganglion. The anterior primary division of the first thoracic is connected by two rami communicantes with the first thoracic sympathetic ganglion, and it divides into a smaller and a larger branch. The smaller branch passes along the intercostal space as the first intercostal nerve, and the larger branch, after being joined by a twig from the second thoracic nerve, passes upward and lateralward, in front of the neck of the first rib and behind the apex of the pleural sac, into the lower part of the posterior triangle of the neck, where it takes part in the formation of the plexus.

Trunks and branches.—The anterior primary divisions of those cervical nerves that form the brachial plexus show typically the following relations (fig. 824). The fifth and sixth cervical divisions unite to form the *upper trunk;* the seventh cervical forms the *middle trunk;* the eighth cervical and first thoracic form the *lower trunk* of the plexus. Each of these trunks divides into an *anterior* and a *posterior branch.* Variations in the mode of formation of the trunks and branches are so numerous that many different forms of the plexus have been described.

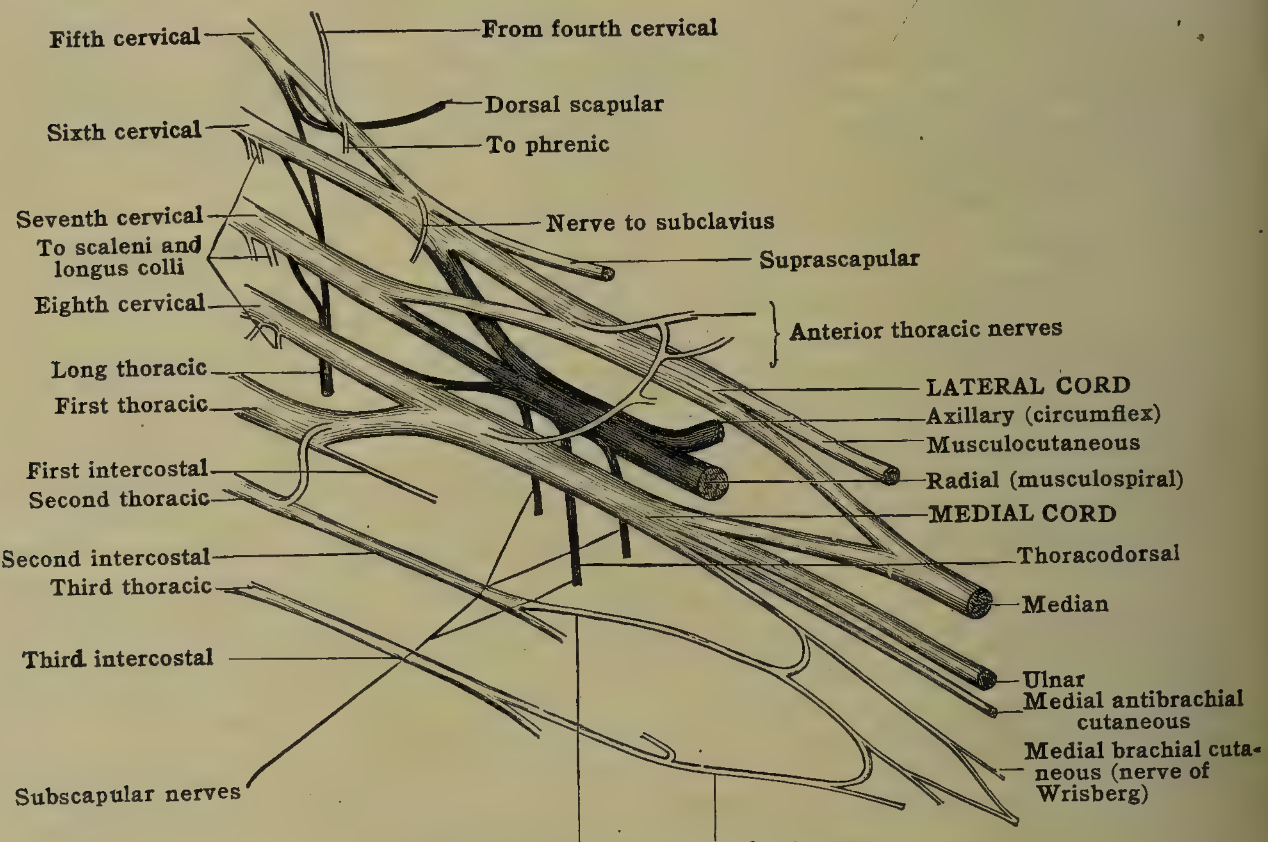


Fig. 824.—Diagram of a Common Form of Brachial Plexus.
The posterior branches and cord of the plexus are darkly shaded.

Three cords [fasciculi] are formed from these branches in the following manner:—(1) The **lateral** (outer) **cord** [fasciculus lateralis] is formed by the anterior branches of the upper and middle trunks (anterior primary divisions of the fifth, sixth, and seventh nerves); (2) the **medial** (inner) **cord** [fasciculus medialis], by the anterior branch of the lower trunk (eighth cervical and first thoracic nerves); and (3) the **posterior cord** [fasciculus posterior], by the posterior branches of all of these trunks and nerves.

In a study of 175 brachial plexuses, Kerr found that over 62 per cent. of them receive a communication from the anterior primary division of the fourth cervical nerve. Of those which receive no branch from this nerve, nearly 30 per cent. of the 175 plexuses studied receive the entire anterior primary division of the fifth cervical nerve. In most of the remaining 10 per cent., a part of the fifth nerve helps to form the cervical plexus. Brachial plexuses receiving the branch from the fourth cervical nerve are found more cephalic with reference to the vertebral column than those which do not receive it. Those which receive the largest part of the fifth cervical nerve are most caudal. He divides the plexuses studied into three groups and within these pictures eight types of forms.

Relations.—The plexus extends from the lateral border of the scalenus anterior, where the roots of its constituent nerves appear, to the lower border of the pectoralis minor, where each of its three cords divides into two terminal branches. It lies in the posterior triangle, in the root of the neck, and in the axillary fossa. In the posterior triangle and in the root of the neck it is in relation behind with the scalenus medius (figs. 821, 825). In the posterior triangle it is covered superficially by the skin and superficial fascia, by the platysma, the supraclavicular

branches of the cervical plexus, and the deep fascia, and it is crossed by the lower part of the external jugular vein, by the nerve to the subclavius, by the transverse cervical vein, the transverse scapular (suprascapular) vein, the posterior belly of the omohyoid muscle and by the transverse cervical artery. At the root of the neck it lies behind the clavicle and the subclavius muscle, and the transverse scapular (suprascapular) artery crosses in front of it. In the axillary fossa the cords are arranged around the axillary artery, the lateral cord lying lateral to the artery, the medial cord medial to it, and the posterior cord dorsal to the artery. In this region the posterior relations of the plexus are the fat in the upper part of the fossa and the subscapularis muscle, and it is covered in front by the pectoral muscles and the coracoclavicular fascia. The lower border of the plexus is in relation in the posterior triangle and at the root of the neck with the pleura and the first rib, and it is overlapped in front by the third part of the subclavian artery. In the axillary fossa the medial cord, which forms the lower border of

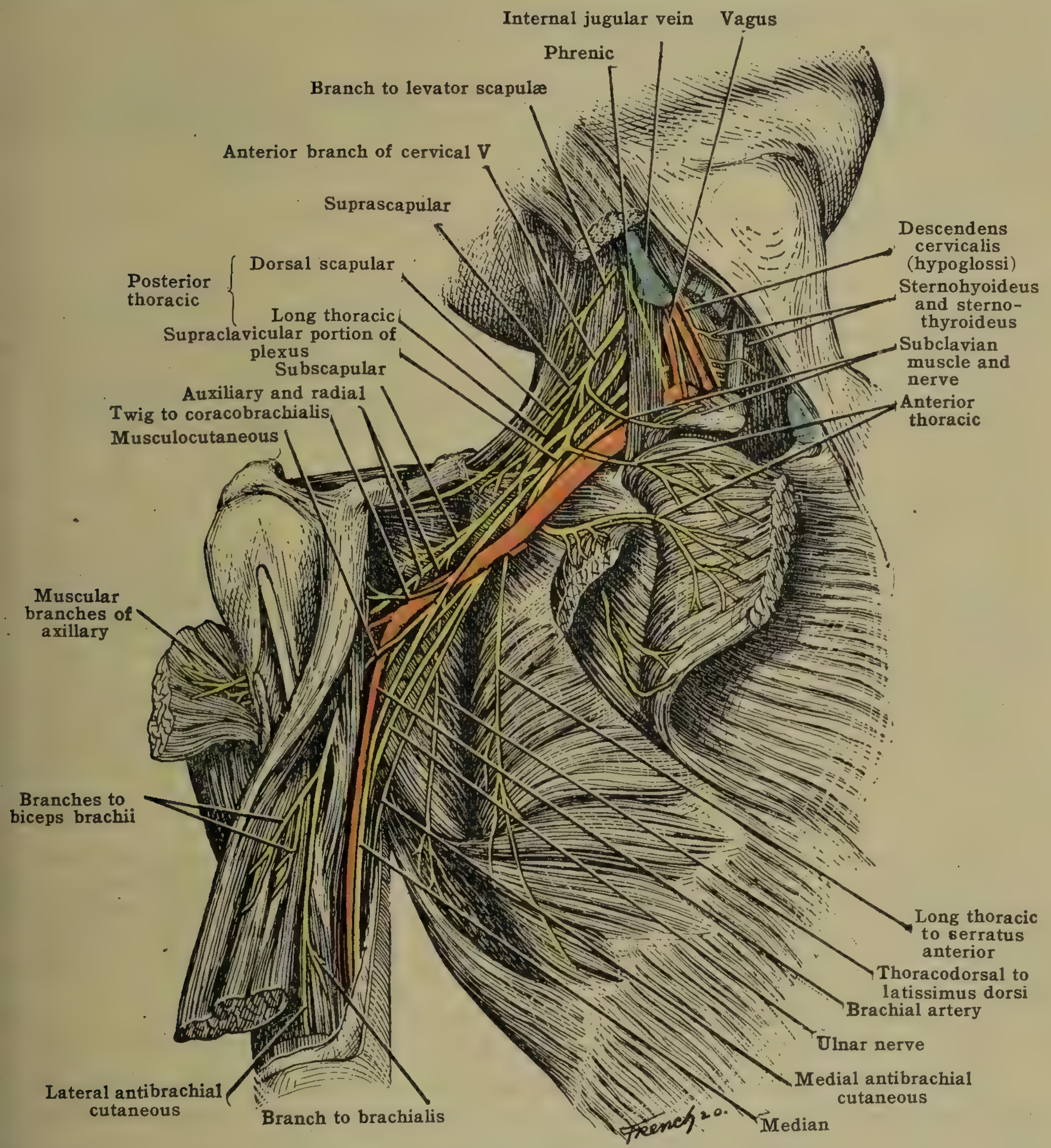


Fig. 825.—The Brachial Plexus and its Branches of the Region of the Neck and Shoulder. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

the plexus, is overlapped anteriorly by the axillary vein. The upper and lateral border of the plexus has no very important relations.

In summary the brachial plexus may be formulated as beginning with five nerves and terminating in five nerves, with its intermediate portions displayed in sets of threes. It begins with the fifth, sixth, seventh and eighth cervical and first thoracic nerves (anterior primary divisions); it terminates as a plexus with the formation of the musculocutaneous, radial, axillary, median, and ulnar nerves. In its intermediate portions, first, three main trunks are formed and these divide into two sets of threes which, by union, give rise to the three cords. The **branches from the cords** are three main lateral branches from each and the terminal

branches of the plexus. The *lateral branches*, according as they are given off above and below the clavicle, are grouped as the *supraclavicular and infraclavicular portions* of the plexus (figs. 824, 825).

The branches of the supraclavicular portion.—After the roots of the plexus have received communications from the sympathetic, which have already been referred to, they give off a series of muscular branches, viz.—the posterior thoracic nerves (the dorsal scapular and the long thoracic nerve), the suprascapular nerve, a twig to the phrenic, the nerve to the subclavius, and small twigs to the scalene muscles and the longus colli muscle.

The **posterior thoracic nerves** are two in number:—(*a*) the **dorsal scapular** (nerve to the rhomboids) arises principally from the fifth cervical nerve, but it frequently receives a twig from the fourth nerve (fig. 821).

It passes downward and dorsalward, across the middle scalene, parallel with and below the spinal accessory nerve to the anterior border of the levator ~~scapulæ~~, under which it disappears. It continues its descent under cover of the levator scapulæ and the rhomboids almost to the lower angle of the scapula, lying a little medial to the posterior border of the bone, and it supplies the lower fibers of the levator and the smaller and larger rhomboid muscles.

(*b*) The **long thoracic nerve** (external respiratory nerve of Bell) supplies the serratus anterior.

It usually arises, by three roots, from the fifth, sixth, and seventh cervical nerves (figs. 821 and 824. The last is sometimes absent. The upper two roots traverse the substance of the scalenus medius; the root from the seventh passes in front of that muscle. Twigs are furnished to the superior portion of the serratus anterior by the upper two roots; lower down they unite and are subsequently joined by the root from the seventh when present. The trunk of the nerve passes downward behind the brachial plexus and the first stage of the axillary artery and runs along the axillary surface of the serratus anterior (magnus), supplying twigs to each of the digitations of that muscle (fig. 825).

The **suprascapular nerve** (figs. 821, 824, 825) supplies the supraspinatus and infraspinatus muscles.

It receives fibers from the fifth and sixth cervical nerves, and in about 50 per cent. of cases also a twig from the fourth nerve. It is a nerve of considerable size, and it passes downward and dorsalward parallel with the dorsal scapular nerve, at first along the upper border of the posterior belly of the omohyoid muscle, then internal to the latter muscle and under cover of the anterior border of the trapezius to the suprascapular notch, where it comes into relation with the transverse scapular (suprascapular) artery. It is separated from the artery at the notch by the superior transverse ligament, the nerve passing through the notch and the artery above the ligament. After entering the supraspinous fossa the nerve supplies branches to the supraspinatus and a branch to the shoulder-joint; then it descends through the great scapular notch between the bone and the inferior transverse ligament to the infraspinous fossa, where it terminates in the infraspinatus muscle.

The **twig to the phrenic** (figs. 821, 824) arises from the fifth cervical nerve close to the point where the latter nerve receives its twig from the cervical plexus.

The **nerve to the subclavius** (figs. 824, 825) is a small twig which arises from the fifth nerve or from the upper trunk of the plexus, but occasionally it receives additional fibers from the fourth and sixth nerves. It runs downward in front of the lower part of the plexus and the third stage of the subclavian artery and, after giving off sometimes a branch to the phrenic, pierces the posterior layer of the coracoclavicular fascia, and enters the subclavius at its lower border.

Variety.—In rare cases the entire phrenic nerve may pass *via* the nerve to the subclavius in front of the third stage of the subclavian artery.

The *scaleni* and *longus colli* (figs. 821, 824) are supplied by twigs which arise from the lower three or four cervical nerves immediately after their exit from the intervertebral foramina.

The lateral branches of the infraclavicular portion of the brachial plexus are the anterior thoracic nerves, from the lateral and medial cords respectively; the medial antibrachial (internal) cutaneous and the medial brachial (lesser internal) cutaneous nerves from the medial cord, and the subscapular and thoracodorsal nerves from the posterior cord.

The **lateral anterior thoracic nerve** joins with the medial to form a loop which supplies the pectoralis major and minor.

It arises from the lateral cord of the plexus and contains fibers from the fifth, sixth, and seventh cervical nerves (figs. 821, 824, 825). After joining the medial anterior thoracic it pierces the coracoclavicular fascia and ends in branches that supply the pectoralis major muscle.

The **medial anterior thoracic nerve** arises from the medial cord (figs. 821, 824, 825), contains fibers from the eighth cervical and first thoracic nerves, and passes forward between the first stage of the axillary artery and the axillary vein. It unites with a branch from the lateral anterior thoracic, to form a loop which is placed in front of the first stage of the axillary artery; it gives branches to the pectoralis minor, and branches which pass through the latter muscle and end in the pectoralis major. From the loop additional branches are furnished to the pectoralis major.

The **medial brachial cutaneous nerve** (n. cutaneus brachii ulnaris NK) (or nerve of Wrisberg, figs. 824, 826), arises from the medial cord of the brachial plexus and in 90 per cent. of the cases contains fibers from the eighth cervical and first thoracic nerves, but sometimes fibers from the first thoracic nerve alone. It runs downward on the medial side of the axillary vein, being separated by that vessel from the ulnar nerve, and it continues downward with a slight inclination dorsalward under cover of the deep fascia on the inner side of the arm. At the middle of the arm it pierces the deep fascia, and near the bend of the elbow it turns somewhat sharply dorsalward to supply the integument which covers the olecranon process (fig. 826).

As it traverses the axilla the medial brachial cutaneous nerve communicates with the intercostobrachial nerve, forming one, or sometimes two loops (fig. 824). In its course down the arm it gives a few fine twigs to the integument. This nerve may be absent, its place being taken by the intercostobrachial or by part of the posterior brachial (internal) cutaneous branch of the radial (musculospiral) or, rarely, by a branch from the first intercostal nerve. It usually leaves the plexus as a single branch, but sometimes it leaves combined with the medial antibrachial cutaneous nerve.

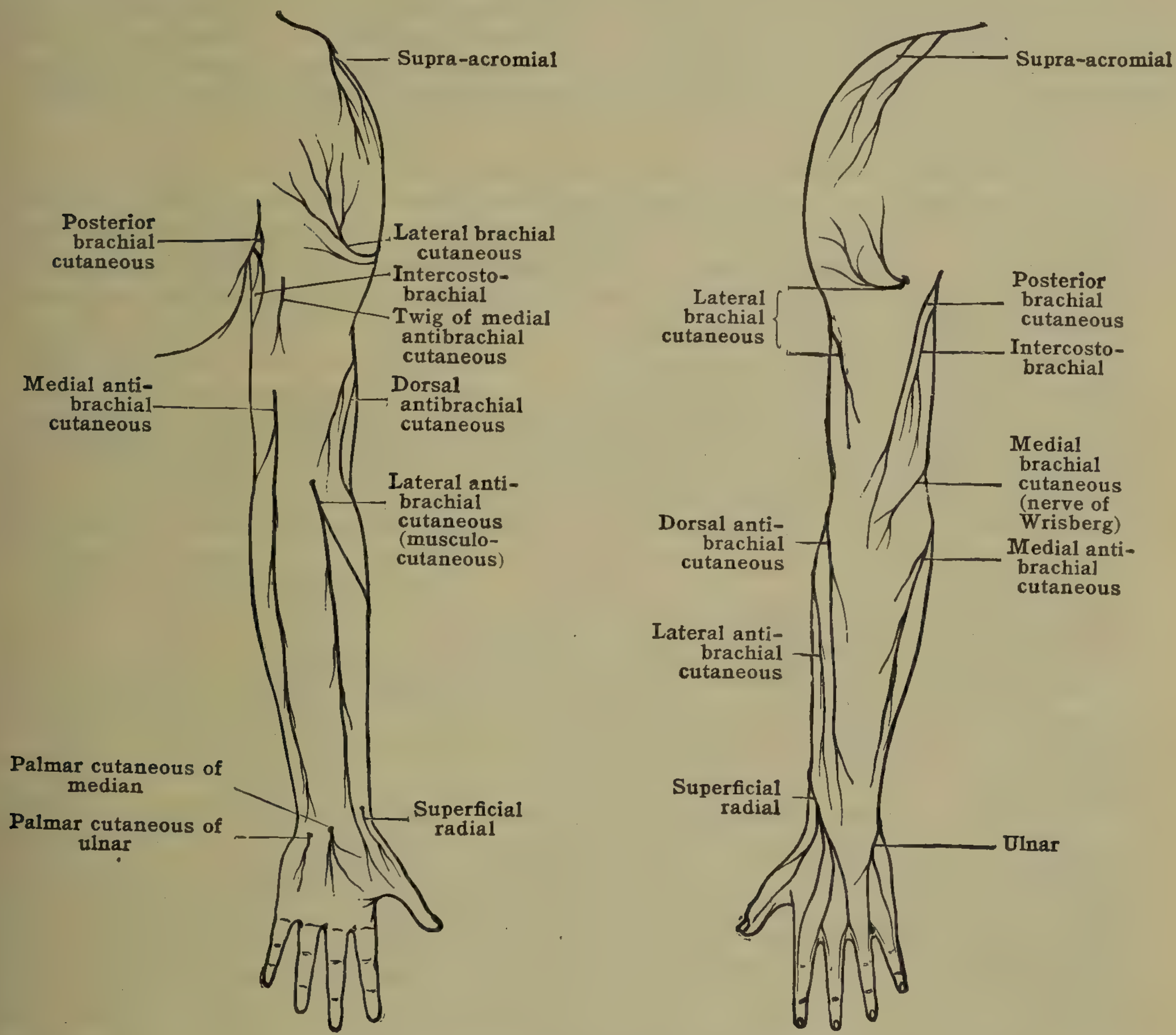


FIG. 826.—DISTRIBUTION OF CUTANEOUS NERVES ON THE ANTERIOR AND POSTERIOR ASPECTS OF THE UPPER EXTREMITY. (Cf. also fig. 831.)

The **medial antibrachial cutaneous nerve** (n. cut. brachioantibrachii ulnaris NK) (figs. 821, 824) arises from the medial cord in close relation with the ulnar nerve. It contains fibers from the eighth cervical and first thoracic nerves. At its origin it lies directly on the medial side of the axillary artery (fig. 825), but it soon becomes more superficial and then lies in the groove between the artery and the vein. In the upper two-thirds of the arm it lies in front and to the medial side of the brachial artery. It divides into two branches (volar and ulnar) which supply the medial aspect of the forearm.

At the junction of the middle and lower thirds of the arm this nerve pierces the deep fascia, in company with the basilic vein, and divides into an anterior and a posterior branch. Previous to its division it gives off twigs which pierce the deep fascia and supply the integument of the upper and medial part of the arm. The **volar (anterior) branch** is larger than the ulnar (pos-

terior); it passes in front of or dorsal to the median basilic vein, and divides into several twigs which run down the forearm, supplying the integument covering its anterior and medial aspect as far as the wrist, and anastomosing with the branches of the ulnar nerve. The ulnar (posterior) **branch** passes downward and dorsalward in front of the medial condyle of the humerus, and divides into branches which supply the skin on the posteromedial aspect of the forearm. It anastomoses with the dorsal antibrachial (inferior external) cutaneous branch of the radial (musculospiral) nerve and the dorsal branch of the ulnar nerve.

The **subscapular nerves** are branches of the posterior cord (fig. 824). They are usually three in number, distinguished as upper, thoracodorsal or middle and lower, and are distributed to the subscapularis, latissimus dorsi, and teres major muscles.

The **upper** or **short subscapular nerve** is derived from the fifth and sixth cervical nerves. It lies in the upper and posterior part of the axillary fossa, and it is distributed exclusively to the subscapularis muscle. It is occasionally double.

The **thoracodorsal (middle, or long subscapular) nerve** consists mainly of fibers from the seventh and eighth cervical nerves, but it may contain fibers from the fifth or the sixth nerve. It passes behind the axillary artery, accompanies the subscapular artery along the axillary margin of the subscapularis muscle, and ends in the latissimus dorsi (fig. 825).

The **lower subscapular nerve**, carrying fibers from the fifth and sixth cervical nerves, passes behind the subscapular artery, below the circumflex branch (dorsalis scapulæ), and is distributed to the teres major, and furnishes to the subscapularis one or two twigs which enter that muscle near its axillary margin. In about 50 per cent. of the cases, the subscapular nerves, especially the upper and lower, may carry fibers from the fourth cervical nerves.

The **terminal branches** of the brachial plexus are two from each cord. The posterior cord divides into the axillary (circumflex) and the radial (musculospiral) nerves. The lateral cord divides into the musculocutaneous nerve, and the lateral root of the median nerve. The medial cord divides into the ulnar nerve and the medial root of the median nerve, the median nerve as a whole being one of the five terminal branches of the plexus.

The **axillary (circumflex) nerve** is the smaller of the two terminal branches of the posterior cord, and contains fibers from the fifth and sixth cervical nerves (figs. 821 and 824). At the lower border of the subscapularis it passes dorsalward and accompanies the posterior circumflex artery through the quadrilateral space, which is bounded by the teres major, long head of triceps, and subscapularis muscles, and the surgical neck of the humerus, and it divides into a smaller superior and a larger inferior division. Previous to its division it furnishes an articular twig to the shoulder-joint. This twig pierces the inferior part of the articular capsule.

The **superior division** accompanies the posterior circumflex artery as it winds around the neck of the humerus under the deltoid muscle, and gives off a number of stout twigs which enter the deltoid (fig. 825). A few fine filaments pierce the deltoid and end in the integument which covers the middle third of that muscle.

The **inferior division** divides into cutaneous and muscular branches. The cutaneous branch, the **lateral brachial cutaneous nerve,** turns around the posterior border of the deltoid, pierces the deep fascia, and supplies the skin covering the lower third of the deltoid and a small area of integument below the insertion of the muscle (fig. 826). One muscular branch is distributed to the teres minor; it swells out into an ovoid or fusiform, reddish, gangliform enlargement before entering the muscle. Other branches supply the lower and posterior part of the deltoid.

The **radial (musculospiral) nerve** [n. radialis] is the largest branch of the brachial plexus. It contains fibers from the sixth, seventh, and eighth cervical and often from the fifth cervical or first thoracic nerve (figs. 821, 824). The fourth cervical nerve also occasionally contributes fibers to it. It commences at the lower border of the pectoralis minor, as the direct continuation of the posterior cord of the brachial plexus, and passes downward and lateralward in the axillary fossa behind the third part of the axillary artery (fig. 825) and in front of the subscapularis, latissimus dorsi, and teres major muscles. From the lower border of the axillary fossa it descends into the arm, where it lies, at first, on the medial side of the upper third of the humerus, behind the brachial artery and in front of the long head of the triceps; then it runs obliquely downward and lateralward behind the middle third of the humerus, in the groove for the radial nerve (musculospiral groove), and between the lateral and medial heads of the triceps. It is accompanied, in this part of its course, by the profunda artery. At the junc-

tion of the middle and lower thirds of the humerus it reaches the lateral side of the arm, pierces the external intermuscular septum, and runs downward and forward between the brachioradialis and extensor carpi radialis longus externally, and the brachialis internally (fig. 828), and it terminates, a short distance above the capitulum, by dividing into deep and superficial terminal branches. In the last part of its course it is accompanied by the anterior terminal branch of the profunda artery.

Branches.—The branches of the radial (musculospiral) nerves are *cutaneous, muscular, articular*, and *terminal*, but for practical purposes it is best to consider them in association with the situations of their origins. While it is in the axillary fossa the radial nerve gives branches to the medial and long heads of the triceps (fig. 828), and a medial cutaneous branch. The branch to the long head of the triceps at once enters the substance of the muscle, that to the medial head breaks into branches which terminate in the muscle at different levels, and one of them, the *ulnar collateral nerve*, accompanies the ulnar nerve to the lower part of the arm. The **posterior brachial cutaneous branch** crosses the tendon of the latissimus dorsi, passes dorsal to the intercostobrachial (intercostohumeral) nerve, pierces the deep fascia, and is distributed to the skin of the middle of the back of the arm below the deltoid.

While it lies behind the middle third of the humerus, the radial nerve gives branches to the lateral and medial heads of the triceps and to the anconeus. The latter branch descends in the substance of the median head of the triceps, close to the bone, and it is accompanied by a small branch of the profunda artery. The **dorsal antibrachial cutaneous branch**, passing down between the lateral and median heads of the triceps, divides near the elbow into its upper and lower branches (fig. 826), each of which perforates either the lateral head of the triceps muscle near its attachment to the humerus or the external intermuscular septum.

The **upper branch**, much the smaller, pierces the deep fascia in the line of the external intermuscular septum; it accompanies the lower part of the cephalic vein, and supplies the skin over the lower half of the lateral and anterior aspect of the arm. The **lower branch** is of considerable size. It pierces the deep fascia a little below the upper branch, runs behind the external condyle, and supplies the skin of the middle of the back of the forearm as far as the wrist, anastomosing with the medial antibrachial (internal) cutaneous and musculocutaneous nerves (fig. 829).

After the radial nerve has pierced the external intermuscular septum it gives branches to the brachioradialis, extensor carpi radialis longus, and to the lateral portion of the brachialis (fig. 829). From one of these branches an articular filament is distributed to the elbow-joint.

The **terminal branches** of the radial nerve are:—a motor branch, the *deep radial*, to the supinator and extensor muscles of the forearm, and a sensory branch, the *superficial radial*, which supplies the dorsal aspect of the radial half of the hand.

The **deep radial nerve** [ramus profundus] runs downward in the interval between the brachialis and extensor carpi radialis longus. It passes in front of the lateral part of the elbow-joint, and after giving off branches to supply the extensor carpi radialis brevis and supinator, it is crossed in front by the radial recurrent artery (fig. 829). It then runs downward and dorsalward through the substance of the supinator, and enters the interval between the superficial and deep layers of muscles at the back of the forearm, where it comes into relation with the posterior interosseous artery, and accompanies it across the abductor pollicis longus. At the lower border of the latter muscle it gives off a branch to the extensor pollicis longus, and another which crosses this muscle to the extensor indicis proprius.

Continuing distalward as the *dorsal interosseous* nerve the deep radial leaves the posterior interosseous artery, dips beneath the extensor pollicis longus, and joins the volar interosseous artery. It accompanies this artery upon the interosseous membrane and, upon the back of the radius, passes through the groove for the extensor digitorum communis and extensor indicis proprius to the dorsum of the wrist, and terminates in a gangliform enlargement which gives branches to the carpal articulations. The muscles supplied by the deep radial nerve are the extensor carpi radialis brevis, brachioradialis (supinator longus), extensor digitorum communis, extensor digiti quinti proprius, extensor carpi ulnaris, extensor indicis proprius, and the extensor muscles of the thumb. The supinator (brevis) receives two twigs, one of which is given off before the nerve pierces the muscle and the other while it is passing through it. The characteristic 'wrist-drop' due to paralysis of the deep radial nerve is shown in fig. 833D.

The **superficial radial nerve** [ramus superficialis n. radialis] is somewhat smaller than the deep radial (posterior interosseous), and is a purely cutaneous nerve. It runs downward under cover of the brachioradialis, passing in front of the elbow-joint, the radial recurrent artery, and the supinator (brevis). At the lower border of the supinator it approaches the radial artery at an acute angle, and runs, parallel to the lateral side of that vessel in the middle third of the forearm, across the pronator teres. At the lower border of the pronator teres it bends dorsalward on the deep surface of the tendon of the brachioradialis, and appears on the back of the forearm. It pierces the deep fascia and is directed

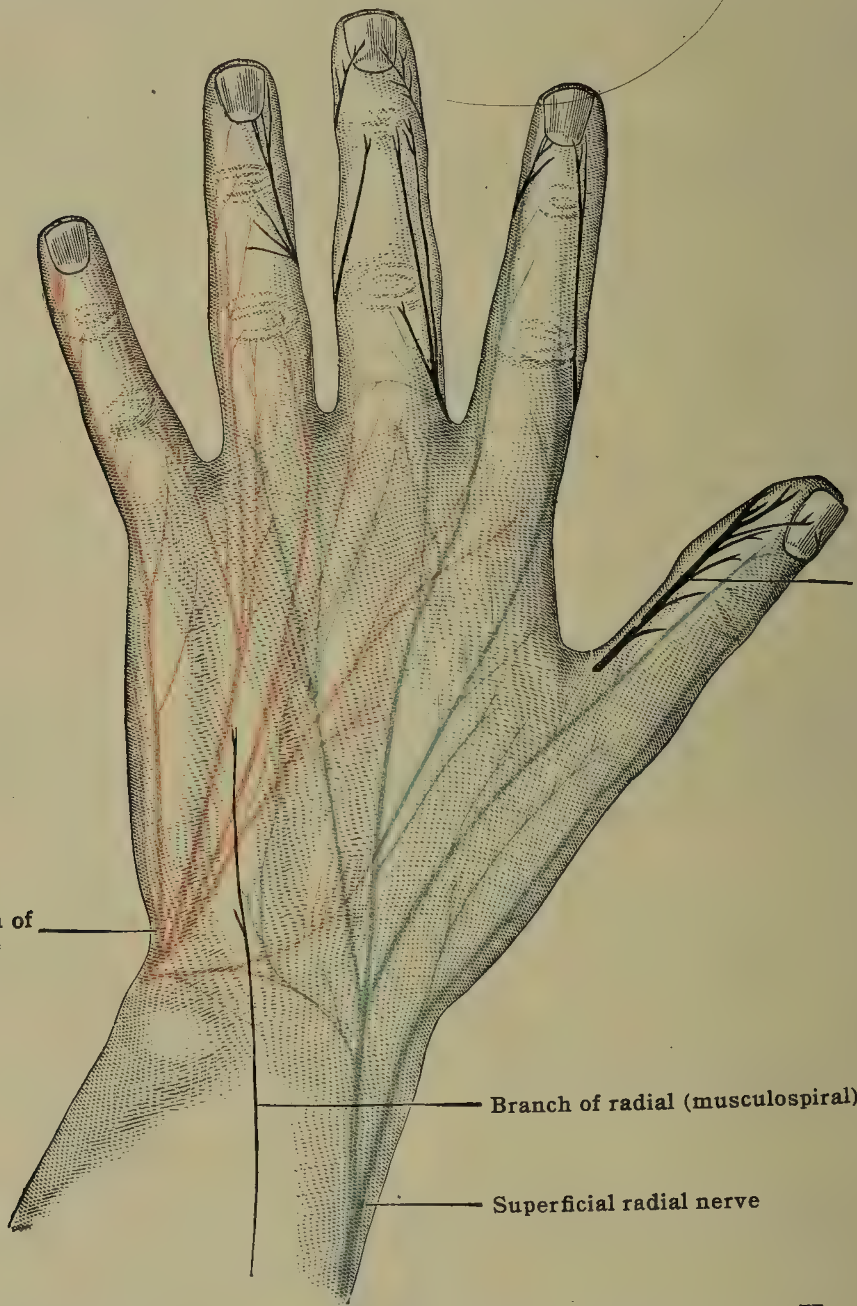


Fig. 827.—The Cutaneous Nerves on the Dorsal Aspect of the Hand and Fingers. (H. St. J. B.)

The branches of the median nerve are shown in black.

across the dorsal carpal (posterior annular) ligament toward the dorsum of the wrist, where it divides into its terminal branches (figs. 827, 831).

The most lateral of these branches supplies the skin on the radial part of the thenar eminence; the most medial, designated the **ulnar anastomotic branch,** communicates with the dorsal branch of the ulnar nerve. The other terminal branches, the **dorsal digital nerves,** supply to a variable extent the skin on the dorsum of the first digit, both sides of the second and the radial side of the third digit. These branches usually extend to the base of the nail of the first digit, to the distal interphalangeal joint of the second, not quite to the proximal interphalangeal joint of the third, and to the metacarpophalangeal joint of the fourth digit.

Clinical aspects.—In general the course of the radial nerve may be traced on the skin by a line beginning in the axillary fossa just behind the third part of the axillary artery, down the arm behind the proximal part of the brachial artery and medial to the upper part of the humerus; and then, just below the posterior border of the axilla, curving backward behind the humerus just below the insertion of the deltoid and running slightly downward along the musculospiral groove of the nerve behind the middle third of the humerus. The line of the main trunk again turns toward the front at about the junction of the middle and lower thirds of the humerus to

reach the lateral side of the arm by piercing the lateral intermuscular septum. It then passes downward, in front of the lateral supracondylar ridge, to the level of the lateral epicondyle, in front of which the nerve terminates by dividing into its deep and superficial branches. The superficial branch accompanies the radial artery to the front of the forearm leaving it about three inches above the wrist joint.

To expose the nerve, the incision should begin below, over the lateral intermuscular septum, in which it courses between the brachioradialis and brachialis muscles. Careless use of splints or tight bandages over the cubital fossa may easily result in paralysis in the forearm, not only ischemic paralysis from compression of the brachial artery and the branches of the basilic and cephalic veins, but also paralyses from pressure upon the median and radial nerves as they traverse this region. The radial nerve may be injured in the region of the axilla by crutch pressure, by the use of Esmarch's bandage, or by careless use of the foot braced in the axilla in the reduction of dislocated shoulder.

The **terminal branches of the lateral cord** of the brachial plexus are the musculocutaneous and the *lateral component* of the median nerve. The latter nerve will be described with the medial cord.

The **musculocutaneous nerve** is composed of fibers derived chiefly from the anterior divisions of the fifth and sixth cervical nerves, together in about 50 per cent. of the cases with some fibers from the fourth and seventh (figs. 821, 824). The nerve to the coracobrachialis usually consists of two or three twigs given off from the nerve close to its origin before it enters the muscle (fig. 825). Sometimes, however the fibers from the seventh cervical nerve pass directly to this muscle without joining the main trunk. The musculocutaneous nerve is placed at first close to the lateral side of the axillary artery (fig. 825), but soon it leaves that vessel and, piercing the coracobrachialis muscle, it passes obliquely downward and lateralward between the biceps and brachialis muscles. Soon after piercing the coracobrachialis it gives off **muscular branches** to each head of the *biceps* and to the *brachialis* (fig. 828). It also gives twigs to the *humerus*, to the *nutrient artery*, and gives the chief supply to the *elbow-joint*. Below the branch to the brachialis the cutaneous portion of the nerve forms the **lateral antibrachial cutaneous nerve** (figs. 826, 828). This portion continues downward between the biceps and brachialis, pierces the deep fascia at the lateral border of the former muscle a little above the bend of the elbow, receives a communication from the upper branch of the dorsal antibrachial (upper external) cutaneous branch of the radial (musculospiral) nerve, passes dorsal to the median cephalic vein, and divides into an anterior and a posterior branch.

The **anterior branch** runs downward on the lateral and anterior part of the forearm, supplying the integument of that region, and it terminates in the skin covering the middle part of the thenar eminence (fig. 829). A short distance above the wrist, after it has received a communicating twig from the superficial radial nerve, it gives off an articular branch to the carpal joints. This branch pierces the deep fascia and accompanies the radial artery to the dorsum of the wrist. The **posterior terminal branch** is small, and is directed downward and backward in front of the external condyle of the humerus, to be distributed to the skin on the lateral and posterior aspect of the forearm as low as the wrist (fig. 826). It anastomoses with the superficial radial and with the lower branch of the dorsal antibrachial (lower external) cutaneous branch of the radial nerve.

Clinical aspects.—Among the *paralyses of the newly born* which sometimes result from violent manipulation of the body during birth, that involving the upper part of the lateral cord is one of the most common. Rending of the fibers from the fifth cervical nerve and others going to the axillary and median nerves may give a partial or total loss of elevation and abduction at the shoulder and loss of flexion of the elbow, known as *upper radiuclar brachial paralysis* or 'Erb's palsy.' Paralysis of the muscles supplied by the medial cord is known as 'Klumpke's palsy.'

The **terminal branches of the medial cord** of the brachial plexus are the ulnar nerve and the *medial component* of the median nerve. Neither of these gives any branches in the upper arm, and thus they differ from the other terminal branches of the plexus. They both supply the muscles and joints of the forearm, and the muscles, joints, and integument of the hand.

The **ulnar nerve,** which is the largest branch of the medial cord of the brachial plexus, contains fibers from the anterior primary divisions of the eighth cervical and first thoracic nerves (figs. 824 and 825). It commences at the lower border of the pectoralis minor and runs downward in the axillary fossa in the posterior angle between the axillary artery and vein. In the upper half of the arm it lies on the medial side of the brachial artery (fig. 825), but at the level of the insertion of the coracobrachialis it passes backward at an acute angle, and, accompanied by the superior ulnar collateral (inferior profunda) artery, it pierces the medial intremuscular septum. After passing through the septum it runs downward, in a groove in the medial head of the triceps (fig. 828), to the interval between the ole-

cranon process and the medial condyle of the humerus, and in this part of its course it is closely bound to the muscle by the deep fascia. Immediately below the medial condyle it passes between the two heads of the flexor carpi ulnaris, along the medial side of the medial collateral ligament of the elbow, and it comes into relation with the dorsal ulnar recurrent artery.

In the upper forearm the ulnar nerve lies on the flexor digitorum profundus, covered by the flexor carpi ulnaris. Near the junction of the upper and middle thirds of the forearm it is joined by the ulnar artery, which accompanies it to its termination, lying throughout on its radial side

Fig. 828.—Nerves of the Right Upper Arm Viewed from in Front. (Spalteholz.)

(fig. 829). In the lower part of the forearm it still rests on the flexor digitorum profundus, but between the flexor carpi ulnaris and flexor digitorum sublimis, and is covered by skin and fascia. At a variable point in this part of the forearm, usually about 5 to 8 cm. from the carpus the nerve divides into its two terminal branches, a dorsal branch to the dorsal aspect of the hand and a volar branch to the volar aspect.

Branches.—The ulnar resembles the median nerve in not furnishing any branches to the upper arm. As it passes between the olecranon process and the medial condyle it gives off two or three fine filaments to the elbow-joint. In the upper part of the forearm it supplies the flexor carpi ulnaris and the medial

portion of the flexor digitorum profundus, and in the lower half it gives off the three cutaneous branches. In the palm of the hand it supplies the integument of the hypothenar eminence, the fifth digit, and half of the fourth digit, and the ulnar half of the skin of the dorsum (fig. 831). It also supplies the short intrinsic muscles of the hand with the exception of the abductor pollicis, the opponens, the lateral head of the flexor pollicis brevis, and the two lateral lumbricales.

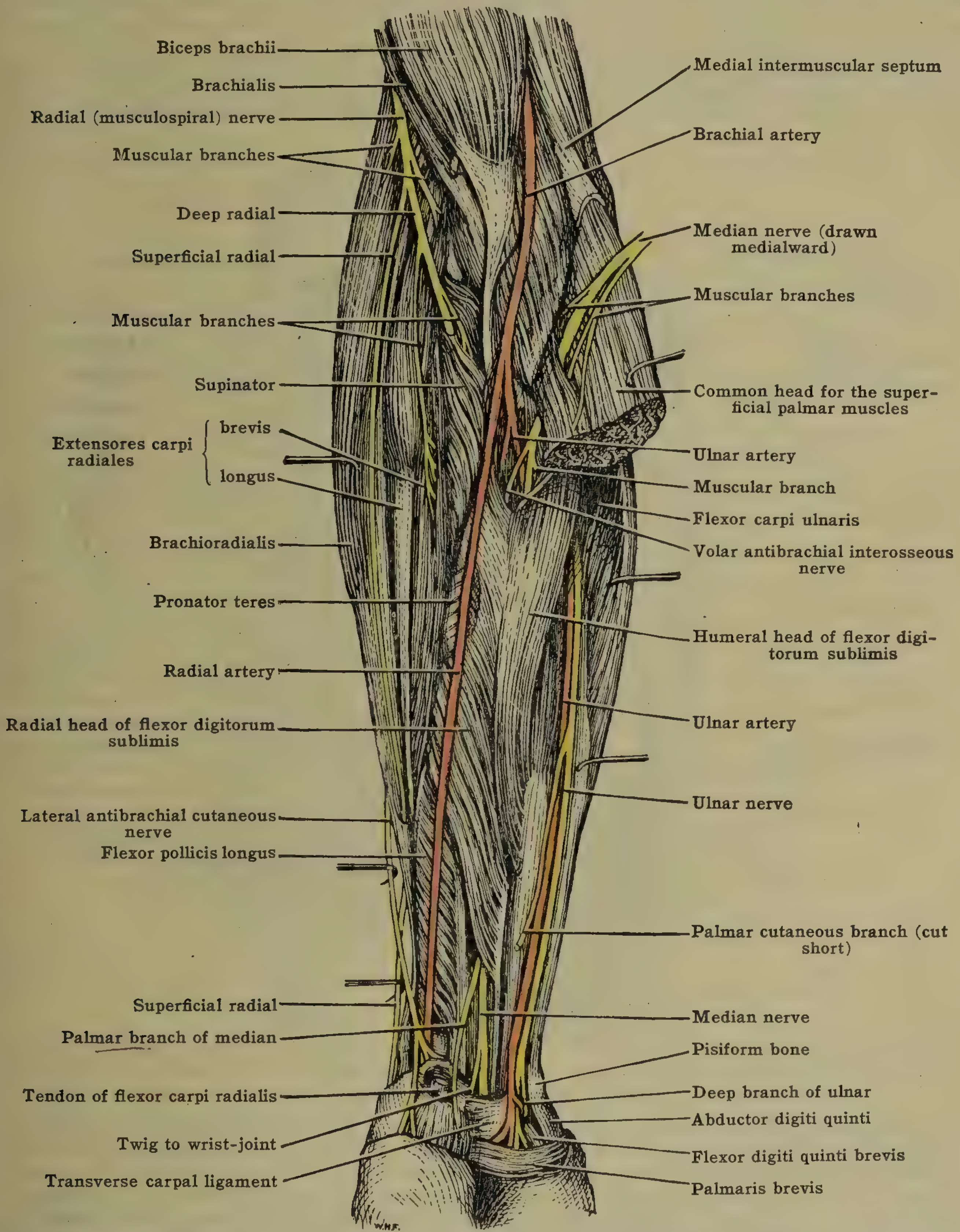


Fig. 829.—Deep Nerves of the Volar Surface of the Forearm. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

The nerves to the flexor carpi ulnaris and to the medial two divisions of the **flexor digitorum profundus** arise from the ulnar nerve in the upper third of the forearm.

Cutaneous branches.—About the middle of the forearm the ulnar nerve gives off two cutaneous branches:—one pierces the fascia and anastomoses with the volar branch of the medial antibrachial (internal) cutaneous nerve, and the other, the **palmar cutaneous branch,** runs downward in front of the ulnar artery (fig. 829) and is conducted by this vessel into the palm (fig. 832). It furnishes some filaments to the vessel, supplies a few twigs to the skin of the hypothenar eminence, and ends in the integument covering the central depressed surface of the palm, sharing this surface with the palmar branches of the median nerve

The **dorsal** or **posterior cutaneous branch**, usually the smaller of the terminal branches, arises about 5 cm. above the wrist-joint, and passes backward under cover of the flexor carpi ulnaris to reach the dorsal aspect of the wrist (fig. 831), where it gives off delicate branches to anastomose with branches of the medial antibrachial (internal) cutaneous, the dorsal antibrachial (external) cutaneous branch of the radial (musculospiral), the lateral antibrachial cutaneous of the musculocutaneous nerve, and with branches of the superficial radial, and then divides into five branches, the **dorsal digitals** (figs. 828 and 831), distributed to the ulnar sides of the third, fourth, and fifth digits and the radial sides of the fourth and fifth digits. These branches usually extend on the fifth digit only as far as the base of the terminal phalanx, and on the fourth digit as far as the base of the second phalanx. The more distal parts of these digits are supplied by palmar digital branches of the ulnar nerve.

The **volar branch**, the other terminal branch of the ulnar nerve, continues its course between the flexor carpi ulnaris and flexor digitorum sublimis, on the medial side of the ulnar artery, to the wrist, where, on the lateral side of the pisiform bone, it divides into a superficial and a

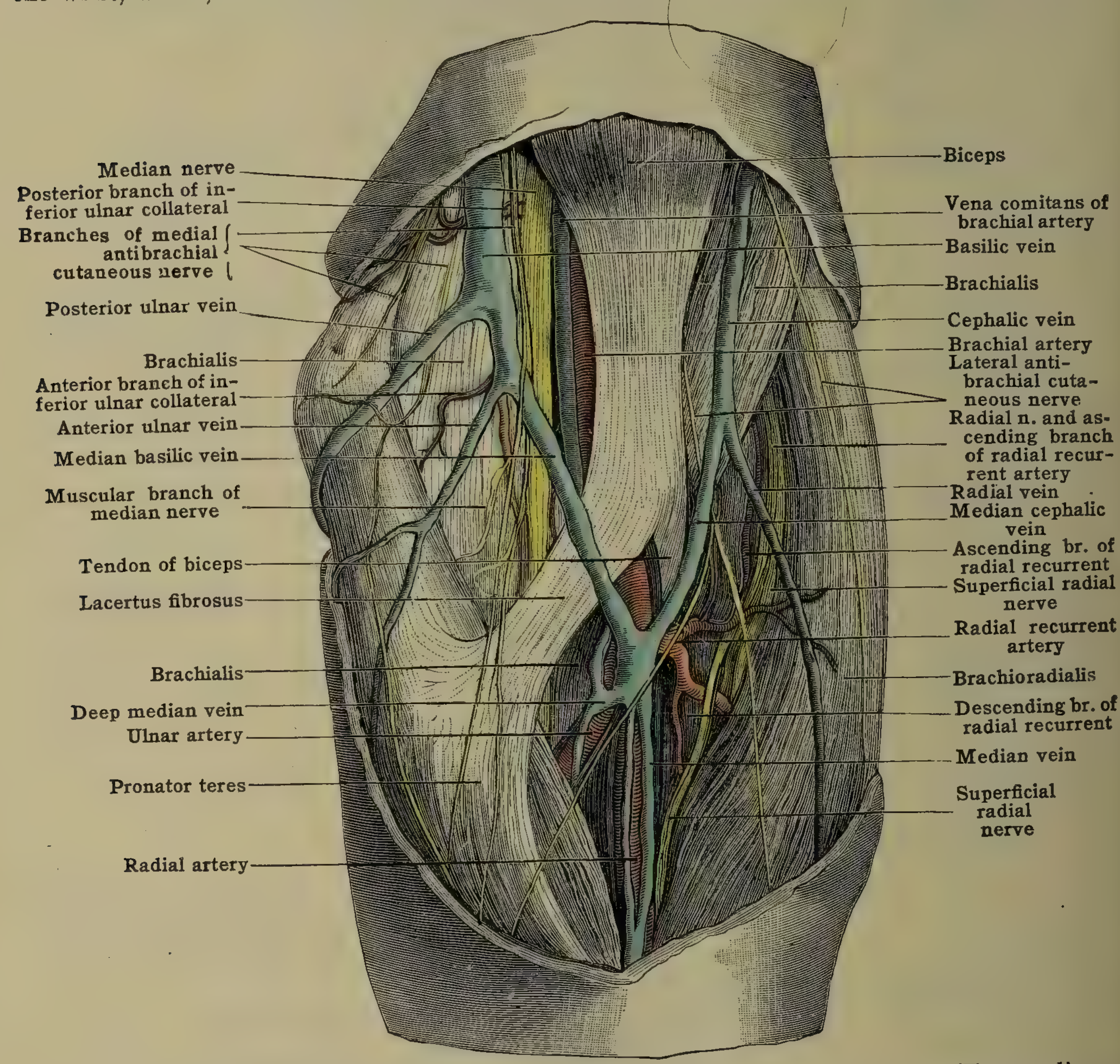


Fig. 830.—Relations of the Nerves in the Region of the Cubital Fossa. (From a dissection of Dr. Adler Smith in the Museum of St. Bartholomew's Hospital.)

deep branch (figs. 829 and 832). The latter accompanies the deep branch of the ulnar artery into the interval between the abductor digiti quinti and flexor digiti quinti brevis, and then passes through the fibers of the opponens digiti quinti to reach the deep surface of the flexor tendons and their synovial sheaths. It supplies the abductor and opponens digiti quinti, the flexor digiti quinti brevis, the third and fourth lumbricales, all the interossei, the adductors of the thumb, and the medial head, and occasionally the lateral head, of the flexor pollicis brevis. The **superficial branch** gives off a branch to supply the palmaris brevis muscle, an anastomosing branch to the median nerve, and then divides into two branches, the **proper volar digital branch**, which is distributed to the medial side of the fifth digit on its volar aspect, and the **common volar digital branch**, which passes underneath the palmar aponeurosis and divides into two branches, which supply the contiguous margins of the fourth and fifth digits. These branches usually supply also the dorsal surface of the second and third phalanges of the same digits.

Clinical aspects.—The general course of the ulnar nerve may be given as a surface line from about the middle of the axillary fossa, along the medial side of the axillary and brachial arteries, to the middle of the upper arm; thence, along the medial border of the coracobrachialis and more medially, through the medial intermuscular septum, to the interval between the medial epicondyle and the olecranon process; and thence, to and along the medial side of the ulnar artery to the terminal branches of the nerve just above the ulnar side of the wrist. Its course

must be kept in mind in operations involving the medial head of the triceps. It passes so superficially over the elbow and back of the medial condyle that it is subject to blows, giving the condyle the name 'funny bone.' Damage here to the ulnar nerve, and possibly an open elbow joint, may result from injury to the epiphysis of the medial epicondyle, an injury which occurs more often prior to the eighteenth year when the epiphyseal line is still cartilaginous. Postural effects of paralysis of the ulnar nerve are indicated in fig. 833, B and C.

The **median nerve** contains fibers of the sixth, seventh, and eighth cervical nerves and of the first thoracic, and sometimes of the fifth cervical nerve. The trunk is formed a little below the lower margin of the pectoralis minor, by the union of two components, one from the medial and one from the lateral cord of the brachial plexus. The medial component passes obliquely across the third part of the axillary artery (fig. 825), and in the upper part of the trunk the fibers of the two components are felted together. From its commencement the median nerve runs almost vertically through the lower part of the axillary fossa and through the arm and forearm to the hand (figs. 828, 830, 832).

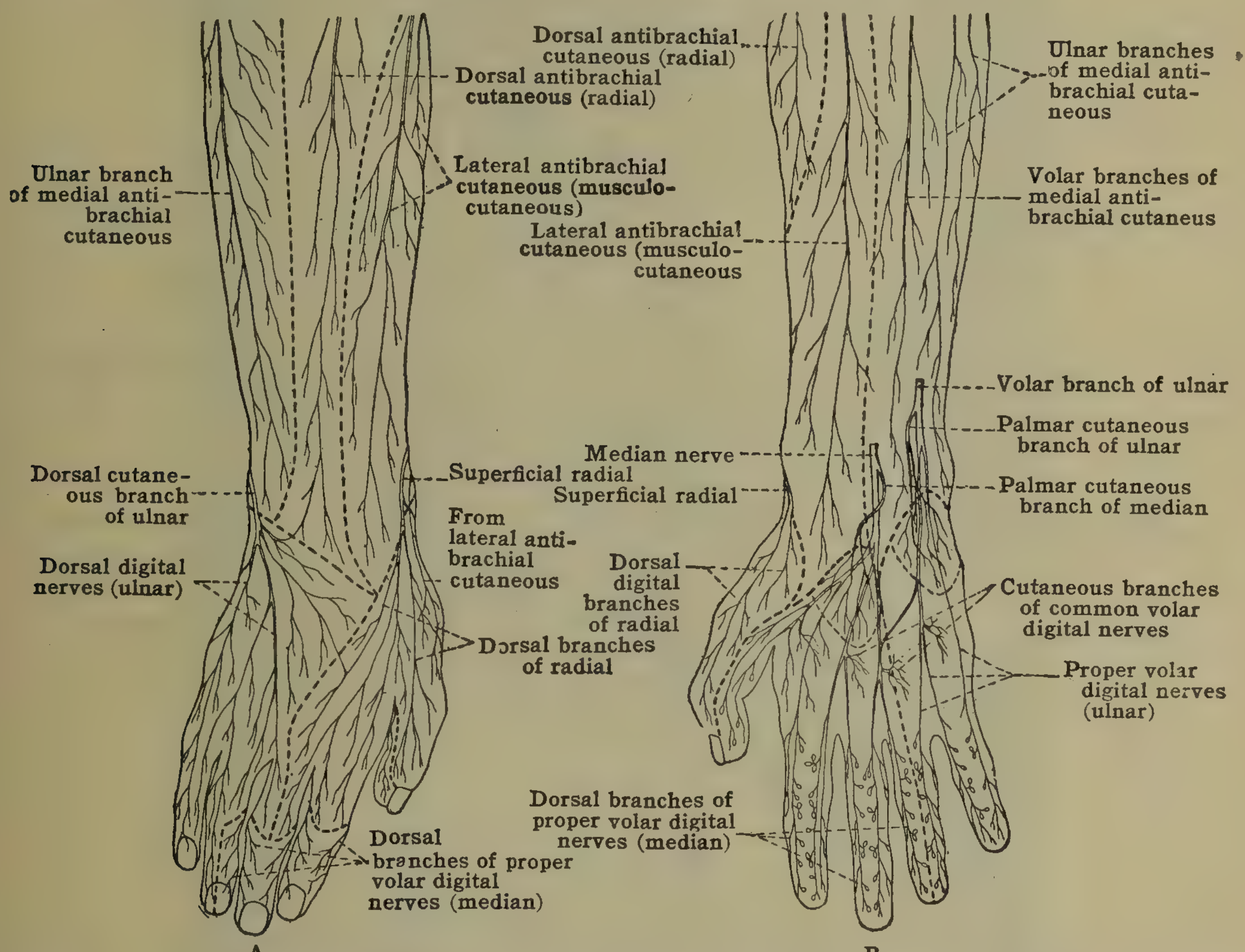


FIG. 831.—DIAGRAM ILLUSTRATING A COMMON DISTRIBUTION OF CUTANEOUS NERVES OF THE FOREARM AND HAND; A, dorsum; B, volar aspect.

In the fossa the median nerve lies lateral to the axillary artery and it is overlapped, on its lateral side, by the coracobrachialis muscle. In the upper half of the arm it lies along the lateral side of the brachial artery, and it is overlapped by the medial border of the biceps. Its position here may be indicated by a surface line drawn parallel with, and slightly lateral to, the furrow on the medial side of the prominence of the biceps; here the nerve lies deep and lateral to the basilic vein. At the middle of the arm it passes in front of the brachial artery, and it descends, on the medial side of the artery, to the elbow. In the upper part of the antecubital fossa it is still at the medial side of the brachial artery, but separated from it by a small interval, and in the lower part of the fossa it lies along the medial side of the ulnar artery (fig. 828). In case of the high division of the brachial artery, when the radial and the ulnar arteries lie together in the upper arm, the median nerve may pass between them and then one or the other of the arteries will be superficial to the nerve. As it leaves the antecubital fossa it passes between the two heads of the pronator teres, and it crosses in front of the ulnar artery (figs. 828 and 829), from which it is separated by the deep head of the pronator. In the forearm it passes vertically downward, accompanied by the median (comes nervi mediani) artery. In the upper two-thirds of this region it lies deeply, between the flexor digitorum sublimis and the flexor digitorum profundus, but in the lower third it becomes more superficial, and is placed beneath the deep fascia, between the flexor carpi radialis on the radial side and the palmaris longus and flexor digitorum sublimus tendons on the ulnar side. It crosses beneath the transverse carpal (anterior annular) ligament, in front of the flexor tendons, and in the palm at the lower border of the ligament it enlarges and divides into three branches, the **common volar digital nerves** (fig. 831).

Branches.—The median nerve does not supply any part of the upper arm. Very rarely, it may receive a small branch from the musculocutaneous nerve. In front of the elbow-joint it furnishes one or two filaments to that articulation. In the forearm it supplies all the superficial anterior muscles (with the exception of the flexor carpi ulnaris) directly from its trunk, and it supplies the deep muscles (with the exception of the ulnar half of the flexor digitorum profundus) by its volar (anterior) interosseous branch. Thus in general it supplies the pronator and flexor muscles of the forearm (radial side). In the hand it supplies the group of short muscles of the thumb, which are placed on the radial side of the tendon of the flexor pollicis longus, the two lateral lumbricales, the integument covering the central part of the palm and ulnar aspect of the thenar eminence, and the dorsal and palmar aspects of the first, second, third, and radial half of the

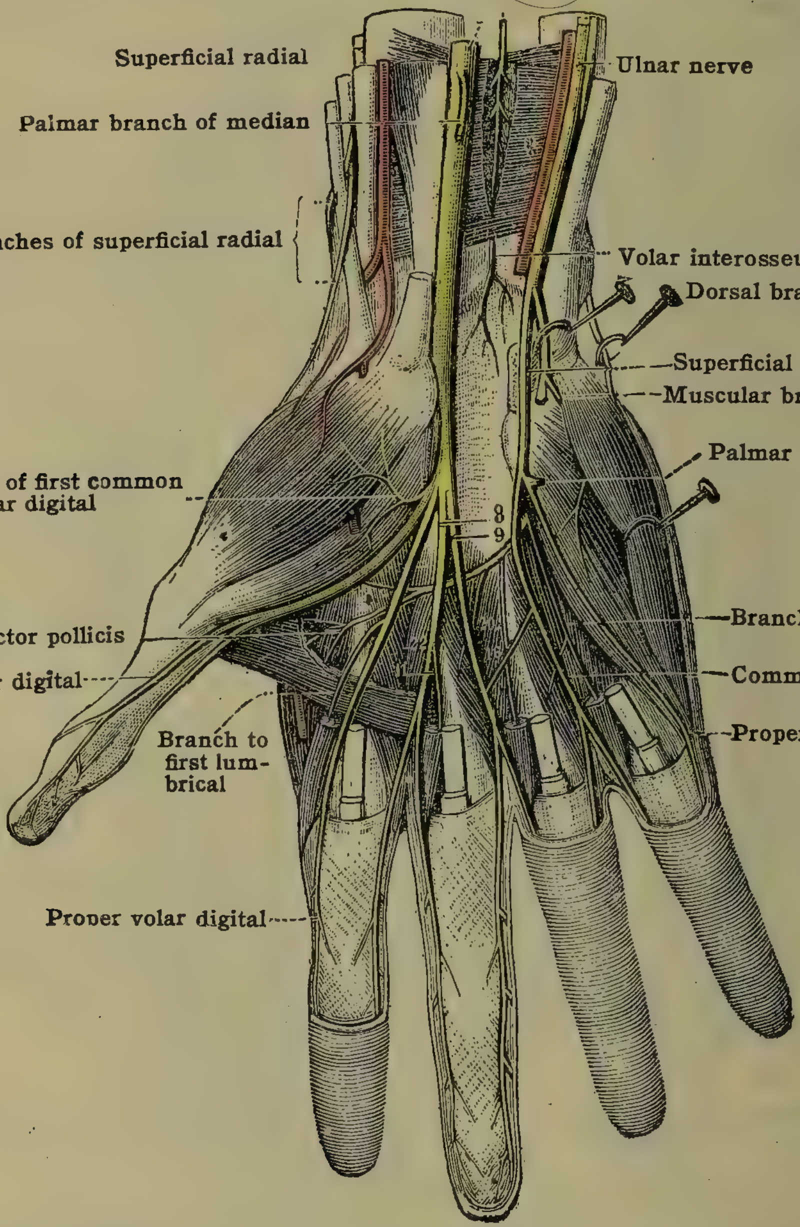


Fig. 832.—Nerves of the Palmar Surface of the Hand. (Testut.)
The transverse carpal (anterior annular) ligament, superficial volar arch, the flexor tendons of the digits, and the proximal portions of the lumbrical muscles have been removed.

fourth digits (fig. 832). The effects of paralysis of the median nerve are shown in fig. 833, A.

The **nerve to the pronator teres** usually arises a little above the bend of the elbow, and pierces the lateral border of the muscle (figs. 829, 830 and 832). It may arise in a common trunk with the following nerves:—

The **nerves to the flexor carpi radialis, palmaris longus, and flexor digitorum sublimis** arise a little lower down, and pierce the pronator-flexor mass of muscles to end in the respective members of the group for which they are destined (fig. 828).

The **volar (anterior, antibrachial) interosseous nerve** arises from the median at the level of the bicipital tubercle of the radius (fig. 829), and runs downward, on the interosseous membrane, accompanied by the volar (anterior) interosseous artery. It passes under cover of the pronator quadratus, and pierces the deep surface of that muscle, which it supplies. The volar interosseous nerve also furnishes a twig to the front of the wrist-joint, and supplies the flexor digitorum profundus and the flexor pollicis longus. The nerve to the former muscle arises from the volar interosseous near its commencement; it supplies the lateral two divisions of the

muscle, and it communicates within the substance of the muscle with twigs derived from the ulnar nerve.

It also supplies a branch to the interosseous membrane which runs downward upon, or in, the membrane, supplying it and giving branches to the volar (anterior) interosseous and nutrient arteries and to the periosteum of the radius, the ulna, and the carpus.

The **palmar cutaneous branch** [ramus palmaris] arises immediately above the transverse carpal (anterior annular) ligament and passes between the tendons of the flexor carpi radialis and the palmaris longus (fig. 829). It then crosses the superficial surface of the transverse carpal ligament, and is distributed to the integument and fascia on the central, depressed surface of the palm. It also supplies a few twigs to the medial border of the thenar eminence; these twigs communicate with the musculocutaneous and superficial radial nerves.

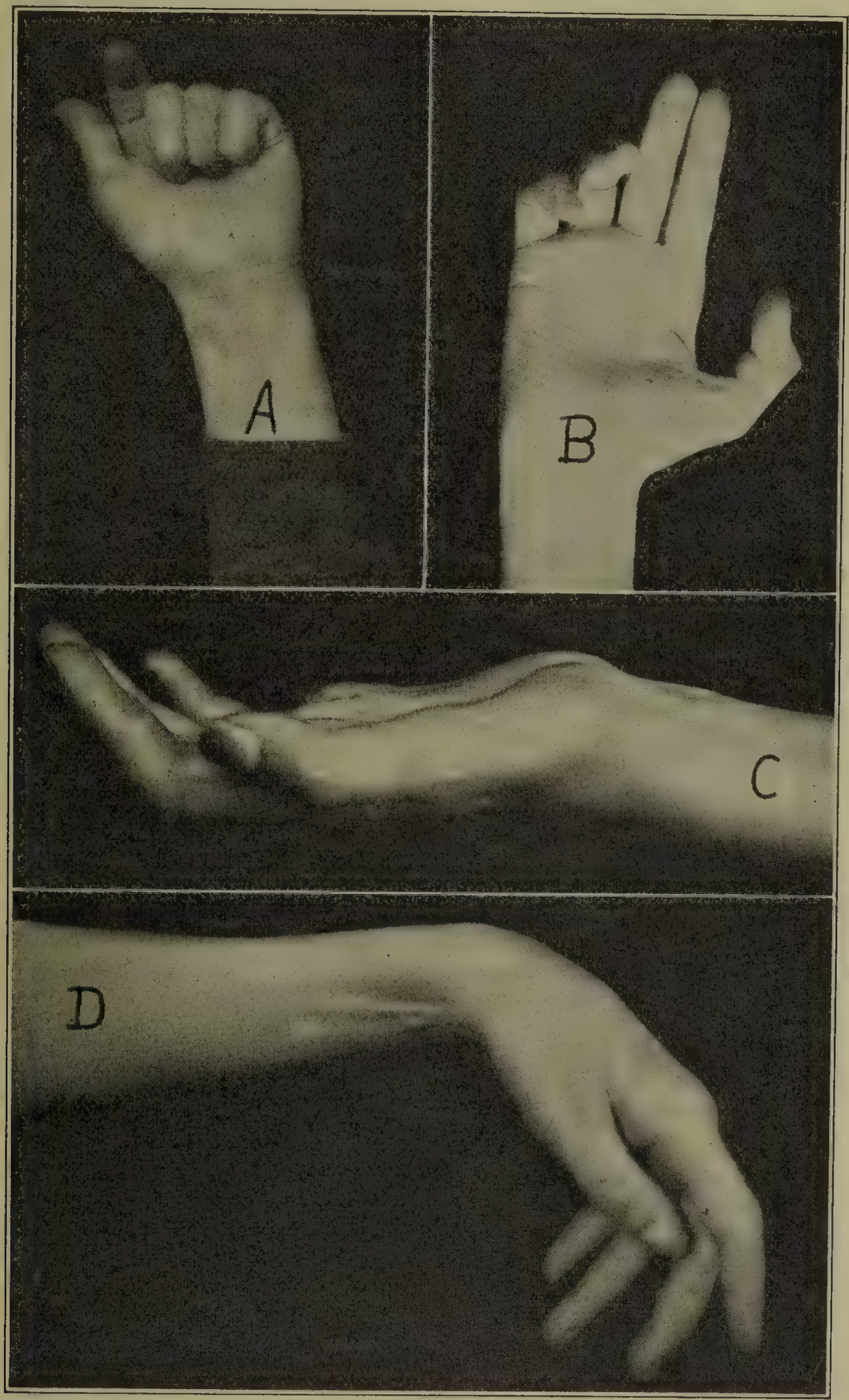


FIG. 833.—CHARACTERISTIC DEFORMITIES OF THE HAND IN PARALYSIS OF VARIOUS NERVES.

Photographs of postures resulting from the paralysis of (*A*) median, (*B*) ulnar, (*C*) combined median and ulnar, and (*D*) radial (musculospiral) nerves. (Pollock and Lewis.)

The three **common volar digital nerves** pass in the palm of the hand dorsal to the superficial volar arch and its digital branches, while the **proper volar digitals**, branches of these nerves, lie on the volar side of the digital arteries.

The **first** of the common volar digital nerves gives off a branch to supply the abductor pollicis, the opponens, and the superficial head of the flexor pollicis brevis, and joins by a delicate branch with the deep branch of the ulnar nerve. It then divides into three **proper volar digitals** (fig. 832). The lateral of these passes obliquely across the long flexor tendon of the thumb and runs along the radial border of the thumb to its extremity. It gives numerous branches to the pulp of the thumb, and a strong twig which passes to the dorsum to supply the matrix of the

nail. The second of these proper volar digitals supplies the medial side of the volar aspect of the thumb and gives off a twig to the matrix of the thumb nail. The third supplies the radial side of the second digit and gives a twig to the first lumbrical muscle.

The **second common volar digital** sends a twig to the second lumbrical muscle, and divides a little above the metacarpophalangeal articulation into two **proper volar digitals,** which respectively supply the adjacent sides of the second and third digits (fig. 831).

The **third** common volar digital communicates with the ulnar nerve, often gives a branch to the third lumbrical muscle, and divides into two **proper volar digitals** which supply the adjacent sides of the third and fourth digits.

As the proper volar digitals pass along the margins of the fingers they give off twigs for the innervation of the skin on the dorsum of the second and third phalanges and the matrix of their nails. Each of the nerves terminates in filaments to the pulp of the finger.

Clinical aspects.—Because of the frequency of wounds on the front of the wrist and in the palm, the following are some of the important locations of volar nerves which especially should be kept in mind. The median nerve passes into the hand through the mid-point of the front of the wrist, usually under the tendon of palmaris longus. The volar branch of the ulnar nerve (with the artery) comes to its superficial position between the tendons of the flexor carpi ulnaris and the superficial flexor of the fourth digit. Its palmar cutaneous branches and most of those of the median nerve pass superficial to the transverse carpal ligament. The main volar trunks of both the ulnar and median nerves break up into their volar digital branches beneath the central part of the palmar aponeurosis. The branches of the ulnar to the palmar muscles of the fourth and fifth digits course in the hypothenar eminence. Wasting of the first dorsal interosseous muscle is an indication of injury to the ulnar nerve.

Paralyses of the Forearm and Hand (Fig. 833)

Paralysis of the median nerve.—(*a*) *In forearm:* Loss of pronation. (*b*) *At wrist:* Diminished flexion and tendency toward ulnar adduction. (*c*) *In the hand:* Power of grasp is lessened especially in the thumb and index finger. Owing to the loss of flexion in the phalanges of these fingers the phalanges are liable to become overextended by the action of the extensors and interossei. The thumb remains extended, adducted, and applied to the index finger, the human characteristic being thus lost, and the 'ape's hand' of Duchenne produced. **Sensation** will be lost over the palmar aspect of the thumb and lateral two and one-half fingers and over the distal ends of the same fingers, to a varying degree, according to the sensory distribution of the median and other cutaneous nerves. The above applies to lesions of the trunk. If the nerve be injured at the wrist, flexion of the wrist and fingers is less interfered with.

Paralysis of the ulnar nerve.—(*a*) *At wrist:* Power of flexion is diminished and that of ulnar adduction lost. (*b*) *In the hand:* Power of grasp will be lessened in the ring and little fingers. The interossei will be powerless to abduct or adduct the fingers, and there will be marked wasting of the interosseous spaces and hypothenar eminence. The thumb cannot be adducted. After a time, from paralysis of the lumbricals and interossei, the hand becomes 'clawed'—the first phalanges overextended, and the second and third flexed (**main en griffe**). **Sensation** will be lessened over the area supplied by the nerve.

Paralysis of the radial (musculospiral) nerve.—(*a*) *In the forearm.* This is flexed, extension being impossible. The forearm is pronated, supination being impossible save by biceps, which acts now most strongly on a flexed elbow-joint. (*b*) *In the wrist:* This is dropped, owing to the loss of extension. (*c*) *In the hand:* The thumb is flexed and adducted. Some slight power of extension of the second and third phalanges of the fingers remains by means of the lumbricales and interossei. **Sensation** is impaired over the posterior and lateral aspect of the forearm and lost to a varying extent over the distribution of the radial on the back of the hand.

Paralysis of the deep radial (posterior interosseous) nerve.—The evidence here is somewhat similar to that just given, but with the following differences. (*a*) *In the forearm:* There is no loss of extension, and the loss of supination is less as the brachio-radialis is not paralysed. (*b*) *At the wrist:* The 'drop' and loss of extension are not so marked, as the extensor carpi radialis has escaped. **Sensation:** There is no loss.

Paralysis of the musculo-cutaneous nerve.—*Forearm:* Power of flexion is impaired, owing to complete paralysis of the biceps and partial of the brachialis (anterior). **Sensation:** This is impaired over the lateral aspect of the forearm, both back and front.

Table Showing Relation of Cervical and Thoracic Nerves to Branches of Brachial Plexus

Nerves Contributing	Nerves, Branches of Plexus
5 C	Dorsal scapular (nerve to rhomboids) Nerve to subclavius Suprascapular
5 and 6 C	Nerve to subclavius Upper subscapular Lower subscapular Axillary (circumflex)
5, 6, and 7 C	Long (posterior) thoracic Lateral anterior thoracic.
5, 6 (and 7) C	Musculocutaneous
(5), 6, 7, 8 C	Radial (musculospiral)
(5), 6, 7, 8 C and 1 T	Median
7 and 8 C	Thoracodorsal (middle or long subscapular)
8 C and 1 T	Medial anterior thoracic Ulnar Medial antibrachial (internal) cutaneous
1 T	Medial brachial (lesser internal) cutaneous

Table Showing the Relations of the Cervical Nerves to the Muscles of the Upper Extremity

Nerves Contributing	Muscles	Nerves to Muscles
Accessory, 2C	Sternomastoid	Spinal accessory
Accessory, 3, 4C	Trapezius	Spinal accessory, 3 and 4 C.
3 and 4C	Levator scapulæ	3 and 4 C.
5 and 6 C	Subclavius	Nerve to subclavius
	Supraspinatus	Suprascapular
	Infraspinatus	Suprascapular
	Subscapularis	Upper and lower subscapular
	Teres major	Lower subscapular
	Teres minor	Axillary (circumflex)
	Deltoid	Axillary (circumflex)
	Brachialis	Musculocutaneous
	Biceps	Musculocutaneous
6 C	Brachioradialis	Radial (musculospiral)
	Supinator	Deep radial (posterior interosseous)
	Pronator teres	Median
	Flexor carpi radialis	Median
	Palmaris longus	Median
6 and 7 C	Ext. carpi radialis longus	Radial (musculospiral)
	Ext. carpi radialis brevis	Deep radial (posterior interosseous)
	Abductor pollicis brevis	Median
	Opponens pollicis	Median
	Flexor pollicis brevis (superf. head)	Median
5, 6 and 7 C	Serratus anterior	Long (posterior) thoracic
7 C	Coracobrachialis	Musculocutaneous
	Ext. digitorum comm.	Deep radial (posterior interosseous)
	Ext. digiti quinti proprius	Deep radial (posterior interosseous)
	Ext. carpi ulnaris	Deep radial (posterior interosseous)
	Abductor pollicis longus	Deep radial (posterior interosseous)
	Extensor pollicis brevis	Deep radial (posterior interosseous)
	Extensor pollicis longus	Deep radial (posterior interosseous)
	Ext. indicus proprius	Deep radial (posterior interosseous)
7 and 8 C	Latissimus dorsi	Thoracodorsal (long subscapular)
	Triceps	Radial (musculospiral)
	Anconeus	Radial (musculospiral)
5, 6, 7 and 8 C	Pectoralis major	Lat. and med. ant. thoracic
8 C	Dorsal interosseus	Ulnar
	Volar interosseus	Ulnar
	Add. pollicis	Ulnar
	Add. pollicis trans.	Ulnar
	Flex. pollicis brev. (deep)	Ulnar
7, 8 C and 1 T	Pectoralis minor	Med. ant. thoracic
	Flex. digit. subl.	Median
	Lumbricalis	Median and ulnar
8 C. and 1 T	Flex. carpi ulnaris	Ulnar
	Flex. digit. prof.	Ulnar and median
	Flex. pollicis long.	Median
	Pronator quadratus	Median

2. THE THORACIC NERVES

The **anterior primary divisions of the thoracic nerves**, with the exception of the first and usually the twelfth, retain, in the simplest form, the characters of anterior primary divisions of the typical spinal nerve. They do not form plexuses, but remain distinct from each other. Each divides into an easily recognizable lateral or dorsal and anterior or ventral branch (primary division) (figs. 834 and 835), and they are not distributed to the limbs. The first, second, and last thoracic nerves, on account of their peculiarities, require separate description. The remainder are separable into two groups, an upper and a lower. The **upper group** consists of four nerves, the third to the sixth inclusive, which are distributed entirely to the thoracic wall. The **lower group** contains five nerves, the seventh to the eleventh inclusive, which are distributed partly to the thoracic and partly to the abdominal wall. The upper group is therefore purely thoracic in distribution, and the lower thoracoabdominal. All the thoracic nerves are connected with the sympathetic trunk by means of both white and gray rami communicantes.

The **first thoracic nerve** is connected with the first thoracic sympathetic ganglion, and it frequently is joined by a small branch with the second nerve (fig. 824). Its anterior primary division is distributed chiefly to the upper limb. Opposite the superior costotransverse ligament of the second rib it divides into a larger and

a smaller branch; the larger passes upward and lateralward, between the apex of the pleura and the neck of the first rib, and on the lateral side of the superior intercostal artery, to the root of the neck, where it joins the brachial plexus. The smaller branch continues along the intercostal space, below the first rib and between the intercostal muscles in which, as a rule, all its fibers terminate.

However, the smaller branch may give off a lateral cutaneous branch which connects with the medial brachial (lesser internal) cutaneous nerve and with the intercostobrachial nerve in the axillary fossa; and occasionally it terminates in an anterior cutaneous branch at the anterior extremity of the first intercostal space.

The **second thoracic nerve**, as it lies between the pleura and the superior costotransverse ligament of the third rib, gives a branch to the first nerve, then it pierces the posterior intercostal membrane and passes between the external and internal intercostal muscles in the second intercostal space. In the dorsal part of the space it sends branches backward, through the external intercostal muscle, to supply the second levator costæ and the serratus posterior superior, and then it divides into a *lateral* and an *anterior* branch (fig. 834). The two branches run forward together to the midaxillary line, where the lateral branch pierces the

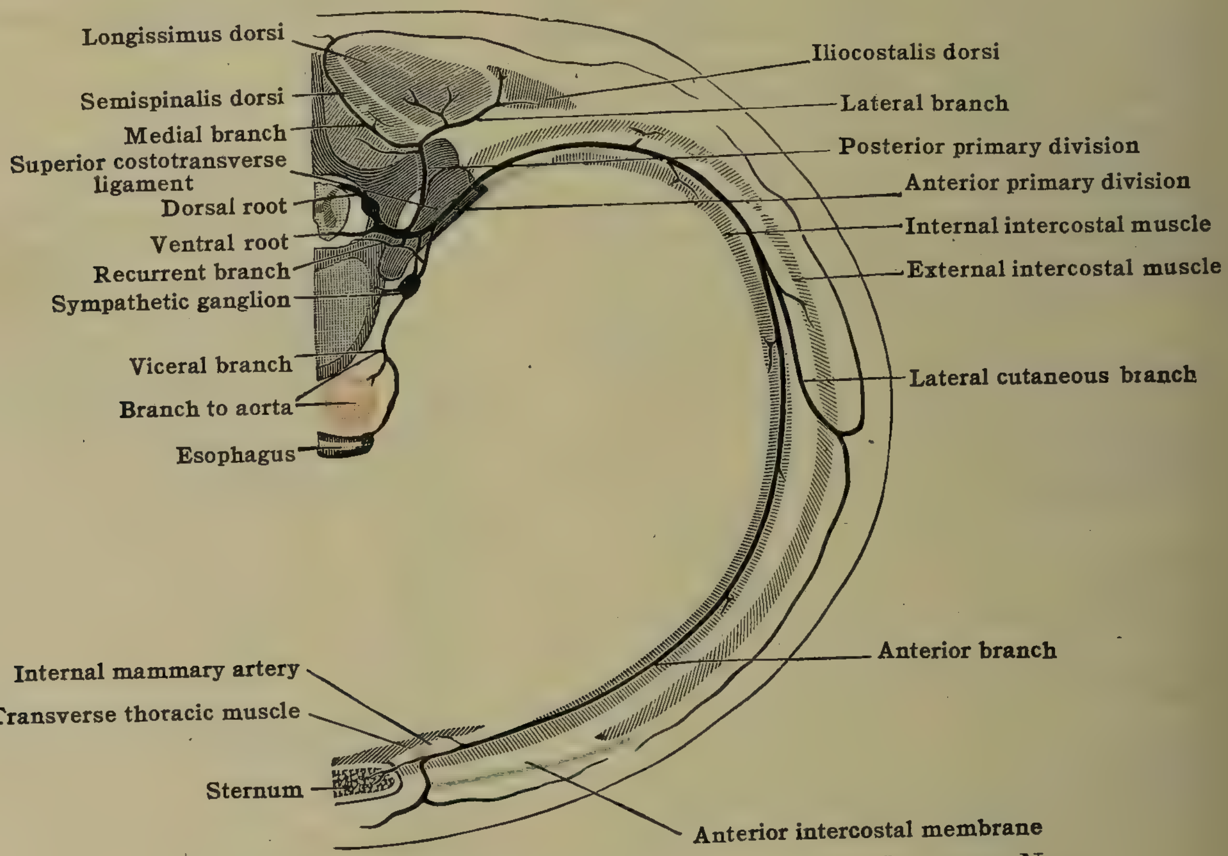


Fig. 834.—Diagram of the Distribution of a Typical Thoracic Nerve.

external intercostal muscle and passes between two digitations of the serratus anterior (magnus) into the axillary fossa. The anterior branch enters the substance of the internal intercostal muscle.

The lateral branch, the intercostobrachial (fig. 824), may divide into a small anterior and a large posterior division, or the anterior division may be absent. In either case the lateral branch anastomoses with the medial brachial cutaneous nerve, and usually with the lateral branch of the third intercostal nerve; it also anastomoses with the lateral branch of the first nerve, if the latter is present. After forming these junctions it passes out of the axillary fossa, pierces the deep fascia, and supplies the integument in the upper and posterior half of the arm. It also gives off a few filaments which terminate in the skin over the axillary border of the scapula. The size of the intercostobrachial nerve and the extent of its distribution are usually in inverse proportion to the size of the other cutaneous nerves of the upper arm, especially the middle brachial (lesser internal) cutaneous. When the latter nerve is absent, the intercostobrachial usually takes its place.

The course and distribution of the anterior branch, when it is present, being similar to the course and distribution of the anterior branches of the next four nerves, do not require a separate description.

The **thoracic intercostal nerves** (upper group).—The anterior primary divisions of the third, fourth, fifth, and sixth thoracic nerves, in the posterior parts of the intercostal spaces, give **muscular branches** to the levatores costarum, the

first to the fourth also giving branches to the serratus posterior superior. They pass forward a short distance between the external and internal intercostals, giving twigs to these muscles, and divide into two branches, lateral and anterior (figs. 834, 835).

The **lateral cutaneous branches** continue forward between the intercostal muscles, and, near the midaxillary line, pierce the external intercostals and serratus anterior and divide each into two branches, posterior and anterior. The *posterior branches* pass backward over the latissimus dorsi to supply the skin in the lower part of the scapular region. The *anterior branches,* in the four nerves, increase in size from above downward. They pass around the lateral border of the great pectoral muscle and are distributed to the integument over the front of the thorax and mamma, sending filaments, the *lateral mammary branches,* into the latter organ. The lowest two nerves also supply twigs to the upper digitations of the external oblique muscle.

The **anterior branches** run obliquely forward and medialward through the substance of the internal intercostal muscles, reaching the deep surface of these muscles at the extremity of the costal cartilages (fig. 834). They continue forward between these muscles and the pleura, pass in front of the internal mammary artery, turn abruptly ventralward a short distance from the sternum, pierce the internal intercostals, the anterior intercostal membrane, and the pectoralis major, and give off three sets of terminal branches. One set supplies the transverse thoracic muscle and the back of the sternum. A second set, cutaneous, runs mesially. The third set passes laterally over the pectoralis major, supplying the skin in that region, and, in the female, the mammary gland through the **medial mammary branches.** The anterior branches in their course supply the intercostal and subcostal muscles and give filaments that supply the ribs, the periosteum, and the pleura.

Clinical aspects.—Painful affections of the *mamma* or breast are often accompanied by troublesome *'referred pain'* in addition to the pain directly from the tissues affected. This referred pain may be apparent in the areas of the lateral (front and back) aspect of the upper thorax, over the scapula, along the medial side of the arm (via the intercostobrachial nerve) and even up on the neck. In addition to the above-mentioned mammary nerve filaments from the second to the sixth intercostal nerves, the sensory innervation of the mammary gland is shared by the middle supraclavicular nerve (fibers from the third and fourth cervical nerves).

In explanation of such identical-segment, skin-to-skin referred sensations, a natural assumption might be that the referred phenomenon results from bifurcations of the peripheral processes of spinal ganglion (sensory) neurones of the nerves concerned, the bifurcations probably occurring at the branchings of the nerves, and that one fiber from the bifurcation bears impulses from the actual source of the pain (the diseased tissue) while the other fiber terminates in the area of the referred pain. Although excesses in the number of fibers on the peripheral sides of the spinal ganglia are an established anatomical fact, yet phenomena of pain referred to specific skin areas seem to occur only in cases where the actual source of the pain includes a special abundance of vessels and muscle (usually smooth), as in the abdominal viscera and the vessels of the heart.

The nerve paths usually given for mammary referred pain are: (1) The hyperexcitation of the sensory nerve terminals in the affected skin and subcutaneous tissues of the mamma gives rise to impulses which are carried to the spinal cord by the afferent fibers of the spinal nerves above mentioned, and in the cord these fibers transfer the impulses to (2) neurones which convey the sensations from the mamma, most probably via the spinal lemniscus, to the brain where they are interpreted as painful sensations. These same afferent neurones also transfer the impulses from the affected tissues to (3) other spinal cord neurones some of which are visceral efferent to (4) sympathetic ganglion neurones whose axones terminate upon and excessively stimulate the smooth muscle of the vessels, glands and arrector pili in the areas to which the pain is referred. The excessive contractions induced in the muscle of these areas arouse impulses in (5) the sensory terminals there of neurones which distribute these impulses to (6) central neurones which convey to the cortex such impulses as are habitually interpreted as pain sensations from the areas to which the pain is referred. As stated, these referred pain sensations accompany the direct pain sensations from the actually affected tissues.

The thoracoabdominal nerves (lower group).—The relations of the posterior portions of the anterior primary divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves to the thoracic wall are similar to those of the upper thoracic intercostal nerves. Each divides in a similar manner into a *lateral* and an *anterior* branch, but these branches are distributed partly to the abdominal and partly to the thoracic wall, and the smaller muscular branches have also different distributions (fig. 835).

The **lateral cutaneous branches,** *lateral cutaneous nerves of the abdomen,* pierce the external intercostal muscles and pass through or between the digitations of the external oblique into the subcutaneous tissue, where they divide in the

typical way into anterior and posterior branches. The *posterior branches* pass backward over the latissimus dorsi. The *anterior branches* give filaments to the digitations of the external oblique and extend forward, medialward and downward to the lateral border of the sheath of the rectus.

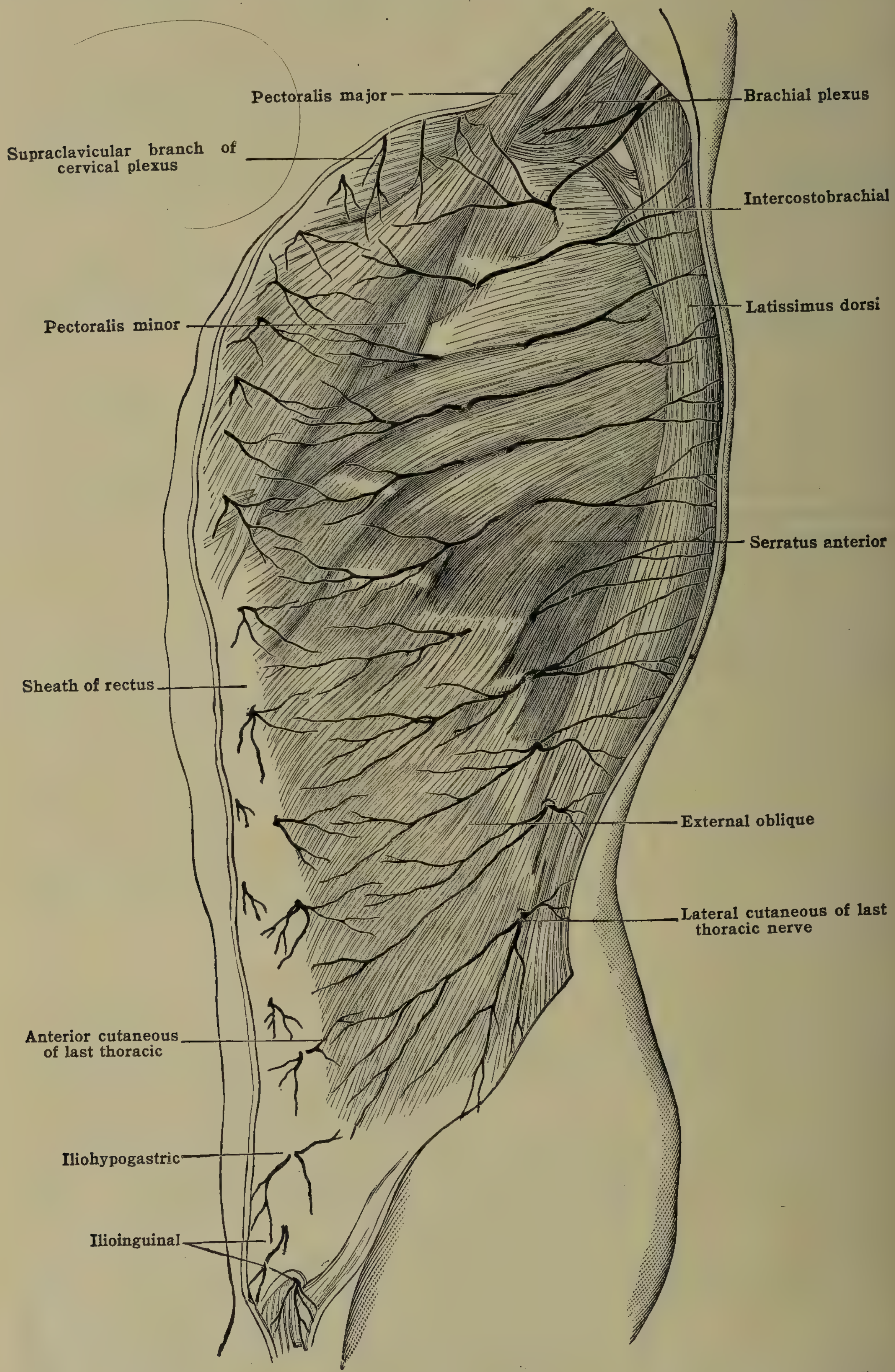


FIG. 835.—CUTANEOUS NERVES OF THE THORAX AND ABDOMEN, VIEWED FROM THE SIDE. (After Henle.)

The **anterior cutaneous branches** pass forward between the external and internal intercostal muscles, to the ends of the intercostal spaces; there they insinuate themselves between the interdigitating slips of the diaphragm and the

transversus abdominis and enter the abdominal wall. Those of the seventh, eighth, and ninth nerves, in their transit from the thoracic to the abdominal wall, pass behind the upturned ends of the eighth, ninth, and tenth costal cartilages respectively. Having entered the abdominal wall the nerves run forward between the transversus abdominis and the internal oblique muscles to the lateral border of the rectus abdominis, where they pierce the posterior lamella of the internal oblique aponeurosis and enter the sheath of the rectus. In the sheath they pass through the substance of the rectus. Finally they turn directly forward, pierce the anterior part of the sheath, and become **anterior cutaneous nerves of the abdomen.**

The muscular branches.—Muscular branches from all the thoracoabdominal nerves are distributed to the levatores costarum, the intercostal muscles, the transversus abdominis, the internal oblique, and to the rectus abdominis, and the ninth, tenth, and eleventh nerves gives branches also to the serratus posterior inferior. Branches are also distributed from a variable number of the lower nerves to the costal portions of the diaphragm.

The last thoracic nerve.—The anterior primary division of the last thoracic nerve is distributed to the wall of the abdomen and to the skin of the upper and front part of the buttock (fig. 835). It appears in the thoracic wall immediately below the last rib, where a ramus joins it with the sympathetic trunk, and gives off a communicating branch to the first lumbar nerve. It passes from the thorax into the abdomen beneath the lateral lumbocostal arch (external arcuate ligament), accompanied by the subcostal artery, and it runs across the upper part of the quadratus lumborum, dorsal to the kidney and to the ascending or the descending colon according to the side considered. At the lateral border of the quadratus lumborum it pierces the aponeurosis of attachment of the transversus abdominis muscle and divides, between the transversus and the internal oblique muscle, into a *lateral* and an *anterior* branch. It gives branches to the transversus abdominis, the quadratus lumborum, and the internal oblique muscles.

The **anterior branch** passes forward, between the internal oblique and the transversus abdominis, to which it supplies twigs. It enters the sheath of the rectus, turns forward through that muscle, and terminates in branches which become cutaneous midway between the umbilicus and the symphysis. Before it becomes cutaneous it supplies twigs to the transversus abdominis, the internal oblique, the rectus abdominis, and the pyramidalis muscles.

The **lateral branch** pierces the internal oblique; it supplies the lowest digitation of the external oblique, and then pierces the latter muscle from 2.5 to 8 cm. (1 to 3 in.) above the iliac crest, and descends in the superficial fascia of the anterior part of the gluteal region, crossing the iliac crest about 2.5 cm. (1 in.) behind its anterior extremity, reaching as far down as the level of the great trochanter. Occasionally this branch is absent and its place is taken by the iliac branch of the iliohypogastric. In such cases, however, the branch from the last thoracic to the first lumbar nerve is larger than usual. The **cutaneous distribution** of the various thoracoabdominal nerves is described later (see p. 1099).

THE LUMBOSACRAL PLEXUS

The lumbosacral plexus (fig. 836) is formed by the union of the *anterior primary divisions* of the lumbar, sacral, and coccygeal nerves. In about 50 per cent. of cases it receives a branch from the twelfth thoracic nerve. Its components are distributed to the lower extremity in a manner homologous and similar to the distribution of the parts of the brachial plexus to the upper extremity. The lumbar nerves are distributed similarly to the nerves formed from the anterior (medial and lateral) cords of the brachial plexus, and the sacral nerves are distributed in a manner similar to the distribution of the nerves from the posterior cord of the brachial plexus. For the cutaneous distribution, see also p. 1101.

Partly for convenience of description and partly on account of the differences in position and course of some of the nerves arising from it, this plexus is subdivided into four parts—the lumbar, sacral, pudendal, and coccygeal plexuses. These plexuses overlap so that there is no definite line of demarcation between them in origin and distribution. However, they will be considered separately.

3. THE LUMBAR NERVES

The anterior primary divisions of the five lumbar nerves increase in size from the first to the last. Each lumbar nerve is connected by one or two long, slender rami with a lumbar sympathetic ganglion, the rami to the last two nerves being smaller. The first three nerves and the greater part of the fourth enter into the

formation of the lumbar plexus, and the smaller part of the fourth and the fifth nerve commonly unite to form the lumbosacral trunk which takes part in the formation of the sacral plexus (figs. 836, 837). When the fourth nerve enters into the formation of both lumbar and sacral plexuses, it may be called the *furcal nerve*, but this name is also applied to any of the nerves that enter into the formation of both plexuses, so there may be one or more furcal nerves.

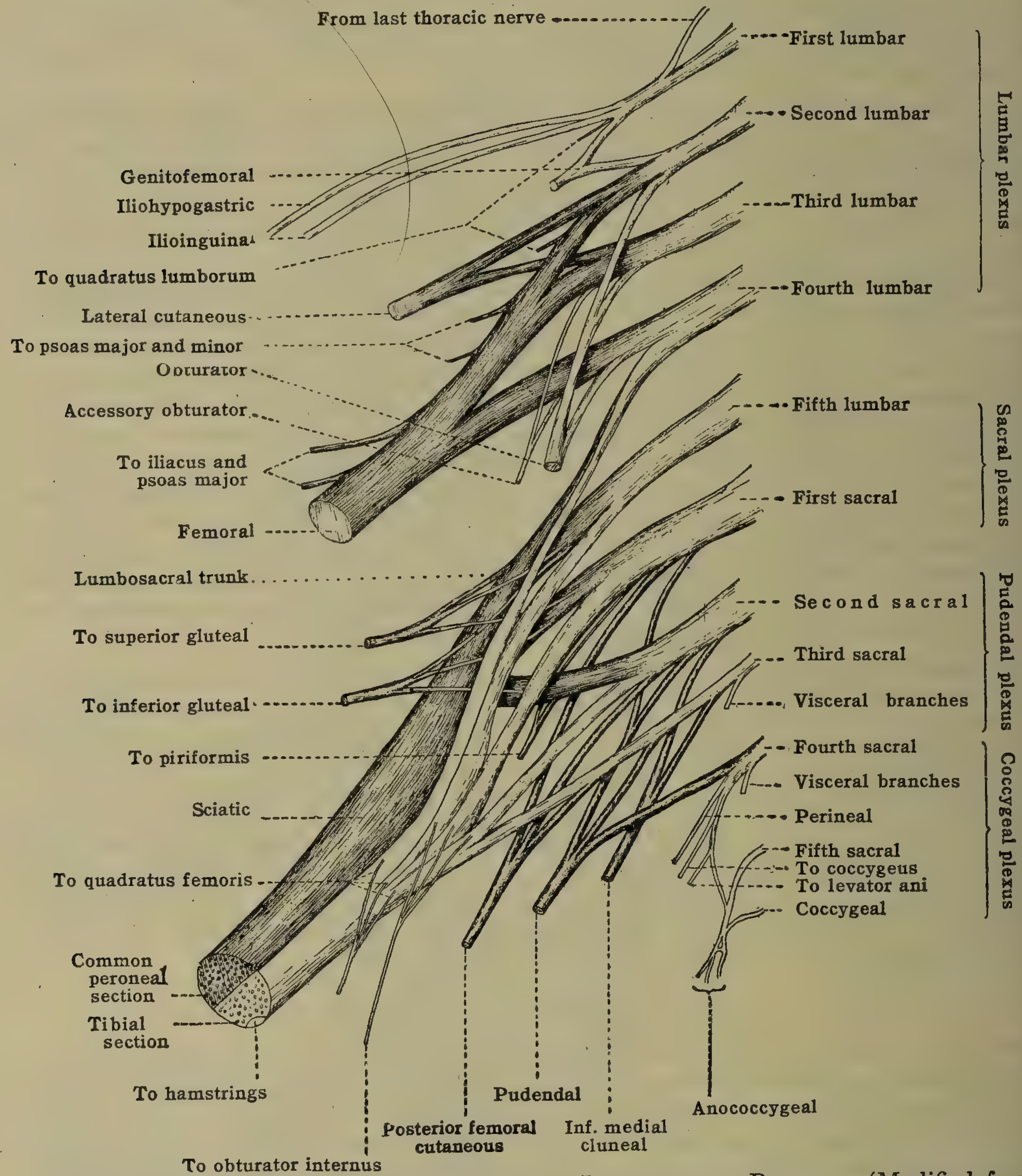


Fig. 836.—Diagram of a Common Form of Lumbosacral Plexus. (Modified from Paterson.)

THE LUMBAR PLEXUS

Although the **lumbar plexus** is ordinarily formed by the anterior primary divisions of the first three lumbar nerves and a part of the fourth, yet it is subject to considerable variation in the manner of its formation.

Owing to this variation three general classes of plexuses may be found, prefixed (proximal), ordinary, and postfixed (distal). The basis of classification is the relation of the nerves of the limb to the spinal nerves which enter into their formation. The intermediate or slighter degrees of variation may consist only of changes in the size of the portions contributed by the different spinal nerves to a given peripheral nerve, for a given nerve may receive a larger share of its fibers from a spinal nerve more anterior (cephalad) in position, and a smaller share from a more posterior nerve, or *vice versa*. However, in the more marked degrees of variation the origin of a given peripheral nerve may vary in either direction to the extent of one spinal nerve. The more extreme types of the plexuses are sometimes associated with abnormal relations of the vertebral column. It has been suggested that when the prefixed condition occurs, it indicates that the lower limb is placed a segment more cephalad than in the ordinary cases, and when the

postfixed condition is present, that the limb is arranged a segment more caudad. Three types each of the prefixed classes and one type of the ordinary class have been described by Bardeen. His statistics are made use of in the compilation of the following tables, in which are shown the common composition and the range of variation of each class of plexus:—

Common Composition of Lumbar Plexus (Range in Parenthesis)

Nerve	Prefixed	Ordinary	Postfixed
Lateral (external) cutaneous	1, 2 L (12T–3L)	1, 2, 3 L (1–4L)	2, 3 L (1–4L)
Femoral (anteror crural)....	1, 2, 3, 4 L (12T–4L)	2, 3, 4 L (1–4L)	2, 3, 4, 5 L (1–5L)
Obturator................	1, 2, 3, 4 L	2, 3, 4 L (1–4L)	2, 3, 4 L (2–5L)
Furcal..................	4 L (3–4L)	4 L	4 L (4–5L)

The lumbar plexus lies in the posterior part of the psoas muscle (figs. 836, 837, 841), in front of the transverse processes of the lumbar vertebræ and the medial border of the quadratus lumborum, and its terminal branches are distributed to the lower part of the abdominal wall, the front and medial part of the thigh, the external genital organs, the front of the knee, the medial side of the leg, and the medial side of the foot.

The first and second of the lumbar nerves give collateral *muscular branches* to the quadratus lumborum muscle, and the second and third nerves give similar branches to the psoas. The remaining branches of the plexus are *terminal branches*. The first lumbar nerve, after it has been joined by the branch from the last thoracic nerve, divides into three terminal branches, the iliohypogastric nerve, the ilioinguinal nerve, and a branch which joins the second lumbar nerve. The fibers of this latter branch pass mainly into the genitofemoral (genitocrural) nerve, but occasionally some of them enter the femoral (anterior crural) and obturator nerves. The remaining nerves divide into anterior or ventral and posterior or dorsal divisions. The **anterior divisions** form a portion of the genitofemoral (genitocrural) nerve and the obturator nerve, and the **posterior divisions** enter the lateral (external) cutaneous and femoral (anterior crural) nerves.

All the terminal branches of the plexus are formed in the substance of the psoas muscle; four of them, the iliohypogastric, the ilioinguinal, the lateral (external) cutaneous, and the femoral (anterior crural), leave the muscle at its lateral border. The genitofemoral (genitocrural) passes through its anterior surface, and the obturator through its medial border.

Terminal branches.—The **iliohypogastric nerve** springs from the first lumbar nerve, after the latter has been joined by the communicating branch from the last thoracic nerve, as it is in about 50 per cent. of all cases, and it thus contains fibers of both the last thoracic and the first lumbar nerves. It pierces the lateral border of the psoas and crosses in front of the quadratus lumborum (fig. 837), and behind the kidney and the colon. At the lateral border of the quadratus it pierces the aponeurosis of origin of the transversus abdominis and enters the areolar tissue between the transversus and the internal oblique, where it frequently communicates with the last thoracic and with the ilioinguinal nerve, and it divides into an iliac and a hypogastric branch, which correspond, respectively, with the lateral and anterior branches of a typical spinal nerve.

The **anterior cutaneous (hypogastric) branch** passes forward and downward, between the transversus abdominis and the internal oblique muscles, giving branches to both; it communicates with the ilioinguinal nerve, and, near the anterior superior spine of the ilium, it pierces the internal oblique muscle and continues forward beneath the external oblique aponeurosis toward the middle line. About 2.5 cm. above the subcutaneous inguinal ring it pierces the aponeurosis of the external oblique, becomes subcutaneous, and supplies the skin above the symphysis.

The **lateral cutaneous (iliac) branch** pierces the internal and external oblique muscles, emerging through the latter above the iliac crest at the junction of its anterior and middle thirds (fig. 841). It is distributed to the integument of the upper and lateral part of the thigh, in the neighborhood of the gluteus medius and tensor fasciæ latæ muscles (fig. 840).

The **ilioinguinal nerve** arises principally from the first lumbar nerve, but it frequently contains fibers of the last thoracic nerve. It emerges from the lateral border of the psoas, at a lower level than the iliohypogastric nerve, and passes across the quadratus lumborum (figs. 837, 838). As a rule, it is below the level of the inferior end of the kidney, but it passes dorsal to the ascending or the descending colon according to the side considered, and crosses the posterior part of the inner lip of the iliac crest; it then runs forward on the upper part of the iliacus, pierces the transversus abdominis near the anterior part of the crest, and communicates with the anterior cutaneous (hypogastric) branch of the ilio-

hypogastric nerve. A short distance below the anterior superior spine it passes through the internal oblique muscle, and then descends in the inguinal canal to the subcutaneous inguinal (external abdominal) ring, through which it emerges into the thigh on the lateral side of the spermatic cord (fig. 835). It is distributed to the skin of the upper and medial part of the thigh, in the male to the root of the penis and to the skin of the root of the scrotum through the **anterior scrotal nerves** (fig. 840), and in the female to the mons pubis and labium majus through the **anterior labial nerves.**

Not uncommonly the ilioinguinal nerve is blended with the iliohypogastric nerve and separates from the latter between the transversus abdominis and the internal oblique muscles.

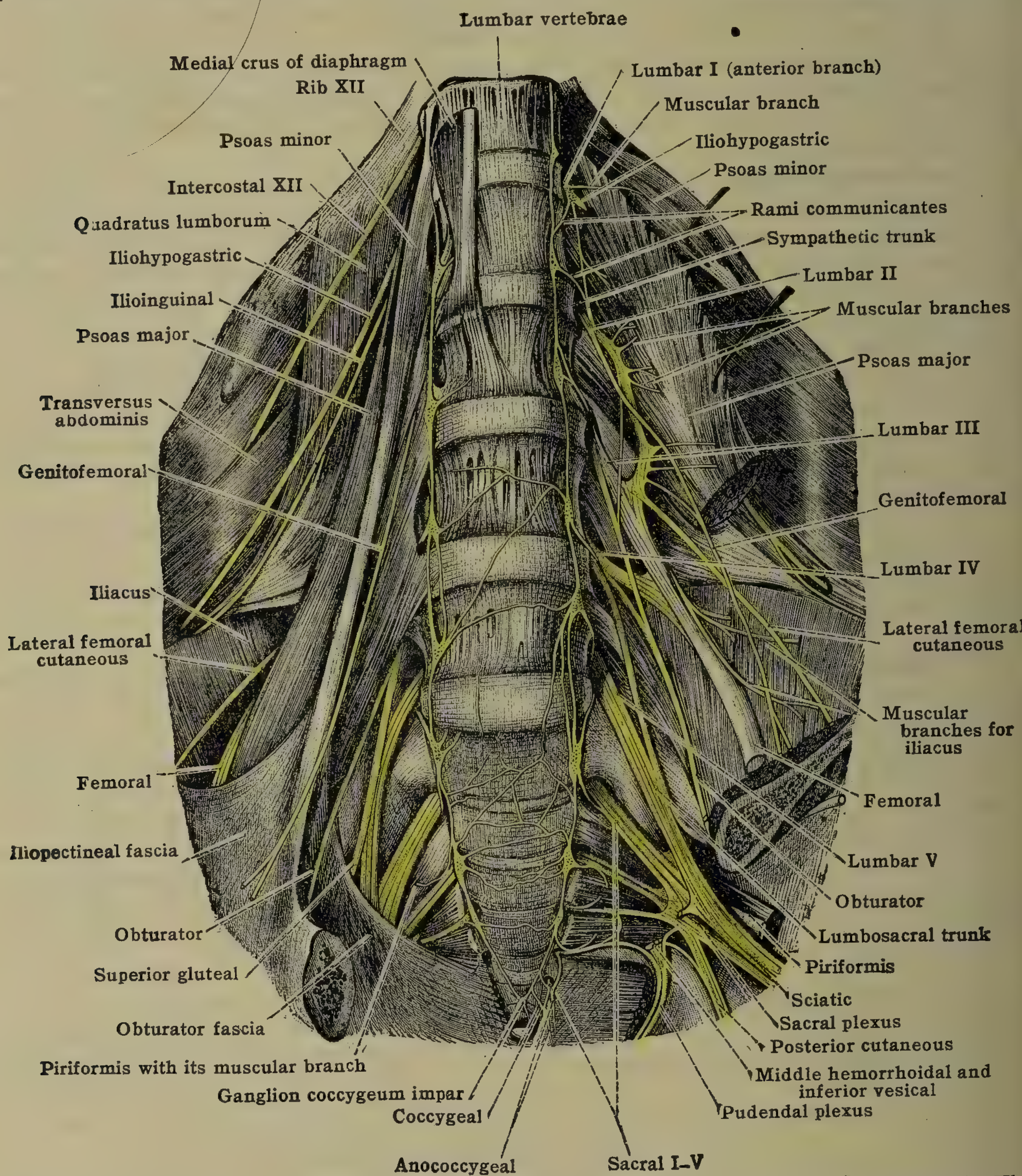


Fig. 837 —Lumbosacral Plexus. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

It may be replaced by branches of the genitofemoral (genitocrural) nerve, or it may replace that nerve or the lateral femoral cutaneous nerve.

The **genitofemoral (genitocrural) nerve** is connected with the first and second lumbar nerves, but the majority of its fibers are derived from the second nerve. It passes obliquely forward and downward through the psoas and emerges from the anterior surface of that muscle, close to its medial border, at the level of the lower border of the third lumbar vertebra. After emerging from the substance of the psoas it runs downward on the anterior surface of the muscle (fig. 837), to the lateral side of the aorta and the common iliac artery, passes behind the

ureter and divides into two branches, an external spermatic and a lumboinguinal (fig. 838). Occasionally it divides in the substance of the psoas, and then the two branches issue separately through the anterior surface of the muscle.

The **external spermatic** branch (n. spermaticus NK) runs downward on the psoas muscle, lateral to the external iliac artery; it gives a branch to the psoas, and at Poupart's ligament it turns around the inferior epigastric artery and enters the inguinal canal, accompanying the

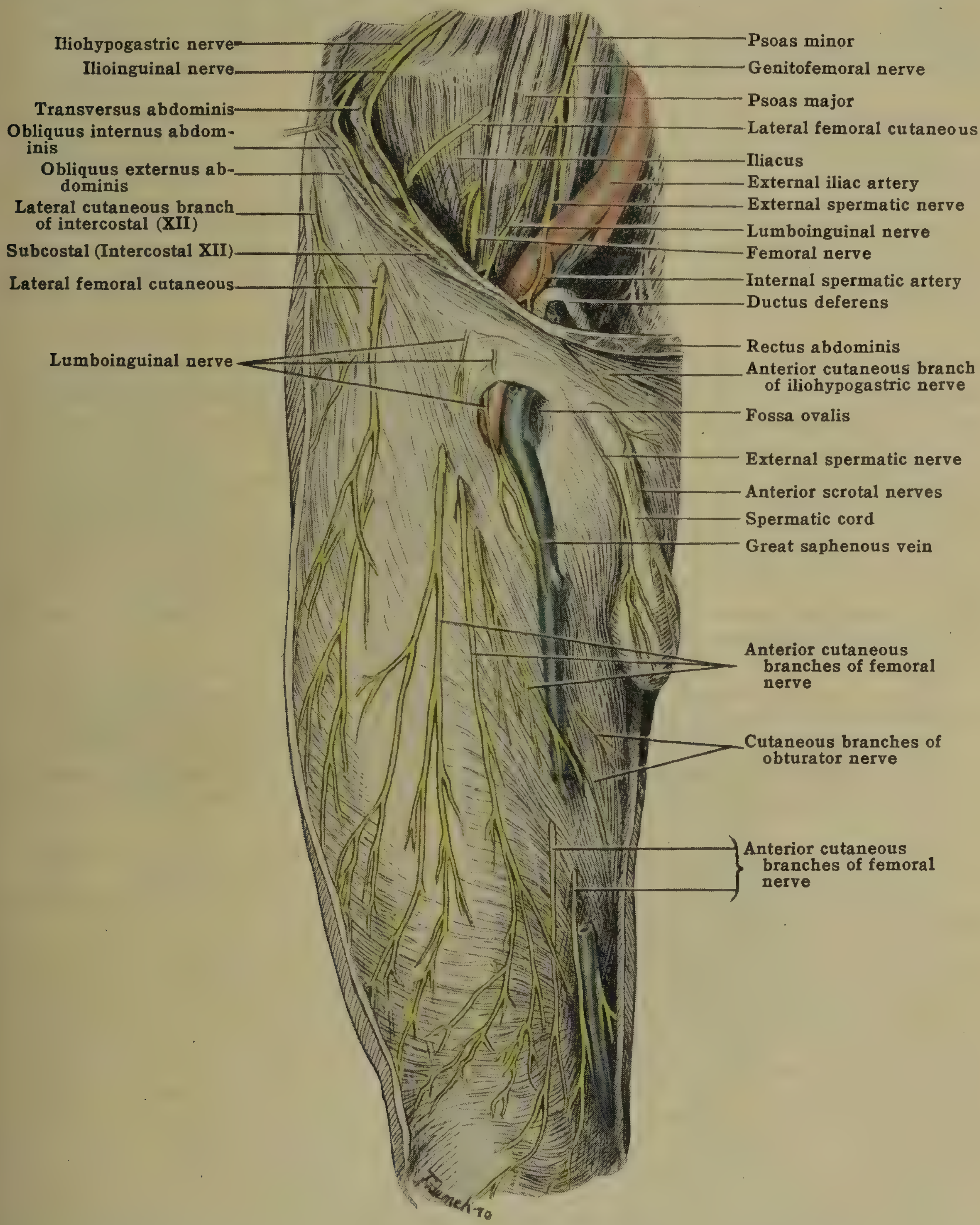


FIG. 838.—CUTANEOUS NERVES OF THE RIGHT THIGH. (After Spalteholz.)
(The iliac fascia has been removed, the fascia lata retained.)

spermatic cord in the male or the round ligament in the female. It supplies the cremaster muscle, and gives twigs to the integument of the scrotum (fig. 838) or the labium majus.

The **lumboinguinal** branch passes downward along the external iliac artery and beneath Poupart's ligament into the thigh, which it enters to the lateral side of the femoral artery. A short distance below Poupart's ligament it pierces the fascia lata or passes through the fossa ovalis (saphenous opening) and supplies the skin in the middle of the upper part of the thigh. A short distance below Poupart's ligament it sometimes sends branches to the anterior branch of the lateral cutaneous nerve, and about the middle of the thigh it often joins with the cutaneous branches of the femoral nerve.

The **lateral femoral cutaneous nerve** receives fibers from the dorsal branches of the anterior primary divisions of the second and third lumbar nerves, and frequently some fibers from the first lumbar (fig. 841). It emerges from the lateral border of the psoas and passes obliquely across the iliacus, dorsal to the iliac fascia and dorsal to the cecum on the right side and the sigmoid colon on the left side, to a point immediately below the anterior superior spine of the ilium, where it passes behind Poupart's ligament into the lateral angle of the femoral trigone (Scarpa's triangle). Leaving the trigone at once it passes through, behind, or in front of the sartorius and divides into two branches, anterior and posterior, which enter the deep fascia (figs. 838, 840).

The **posterior branch** of the lateral femoral cutaneous nerve breaks up into several secondary branches which become subcutaneous, and they supply the integument of the lateral part of the thigh, from the great trochanter to the level of the middle of the femur. The **anterior branch** runs downward in a canal in the deep fascia, for three or four inches, before it becomes subcutaneous. It usually divides into two branches, a lateral and a medial. The *lateral branch* supplies the skin of the lower half of the lateral side of the thigh, and the *medial branch* is distributed to the skin of the lateral side of the front of the thigh as far as the knee (fig. 838). Its lower filaments frequently unite with the cutaneous branches of the femoral and with the patellar branch of the saphenous nerve in front of the patella, forming with them the **patellar plexus.**

The **femoral** (anterior crural) **nerve** is the largest terminal branch of the lumbar plexus. It is formed chiefly by fibers of the dorsal branches of the anterior primary divisions of the second, third, and fourth lumbar nerves, but it sometimes receives fibers from the first nerve also (figs. 837 and 841). It emerges from the lateral border of the psoas a short distance above Poupart's ligament, and descends in the groove between the psoas and the iliacus, behind Poupart's ligament, into the femoral trigone (Scarpa's triangle), where it lies to the lateral side of the femoral artery (fig. 839), from which it is separated by some of the fibers of the psoas. In this situation it is flattened out and it divides into two series of terminal branches, the superficial and the deep. In general, they supply the muscles and skin on the anterior aspect of the thigh.

Branches.—The branches of the femoral nerve are collateral and terminal.

The **collateral branches** are twigs of supply to the iliacus, and a branch to the femoral artery; they are given off before the nerve enters the femoral trigone.

The **terminal branches** form two groups, the superficial and the deep.

The **superficial terminal branches** are two muscular branches, the nerve to the pectineus, and the nerve to the sartorius, and two anterior cutaneous branches,

The **nerve to the pectineus** passes medially and downward behind the femoral sheath and in front of the psoas to the anterior surface of the pectineus, in which it terminates.

The **nerve to the sartorius** accompanies the middle cutaneous nerve; it leaves the latter nerve above the sartorius and ends in the upper part of the muscle.

The **anterior (middle and internal) cutaneous nerves** are best described separately. The **middle cutaneous nerve** soon divides into two branches, medial and lateral. The lateral branch pierces the sartorius and both branches become cutaneous about the junction of the upper and middle thirds of the thigh (figs. 838, 840). They descend along the medial part of the front of the thigh to the knee, supplying the skin in the lower two-thirds of the medial part of the front of the thigh, and their terminal filaments take part in the formation of the patellar plexus. About the middle of the thigh the middle cutaneous is often joined by a twig with the lumboinguinal nerve (crural branch of the genitocrural nerve). The **medial (or internal) cutaneous nerve** runs downward and medialward along the lateral side of the femoral artery, to the apex of the femoral trigone (Scarpa's triangle), where it crosses in front of the artery and divides into an anterior and a posterior terminal branch. Before this division takes place, however, two or three collateral branches are given off from the trunk. The highest of these passes through the fossa ovalis (saphenous opening), or it pierces the deep fascia immediately below the opening, and supplies the skin as low as the middle of the thigh. The lowest pierces the deep fascia at the middle of the thigh and it descends in the subcutaneous tissue, supplying the skin on the medial side of the thigh from the middle of the thigh to the knee (figs. 838, 840). This nerve frequently varies in size inversely with the cutaneous branches of the obturator and saphenous nerves.

The **anterior branch** of the medial cutaneous nerve passes vertically downward to the junction of the middle and lower thirds of the thigh, where it pierces the deep fascia. It still continues downward for a short distance, then it turns lateralward and passes to the front of the knee, where it enters into the patellar plexus.

The **posterior branch** descends along the dorsal border of the sartorius, and it gives off a branch which passes beneath that muscle to unite with twigs from the saphenous and from the superficial division of the obturator nerve, forming with them the **subsartorial plexus** which lies on the roof of the adductor (Hunter's) canal. At the medial side of the knee the nerve pierces the deep fascia and it descends to the middle of the calf (figs. 838, 840).

The **deep terminal branches** of the femoral nerve are six in number, one cutaneous branch, the *saphenous*, and five *muscular branches*. The branches radiate from the termination of the trunk of the femoral nerve, and they are arranged in the following order from medial to lateral:—the saphenous nerve, the nerve to the vastus medialis, the nerve to the articularis genu (subcrureus), the nerve to the vastus intermedius (crureus), the nerve to the vastus lateralis, and the nerve to the rectus femoris.

The **saphenous nerve** passes down through Scarpa's triangle along the lateral side of the femoral artery. At the apex of the triangle it enters the adductor (Hunter's) canal and descends through it, lying first to the lateral side, then in front, and finally to the medial side of the artery

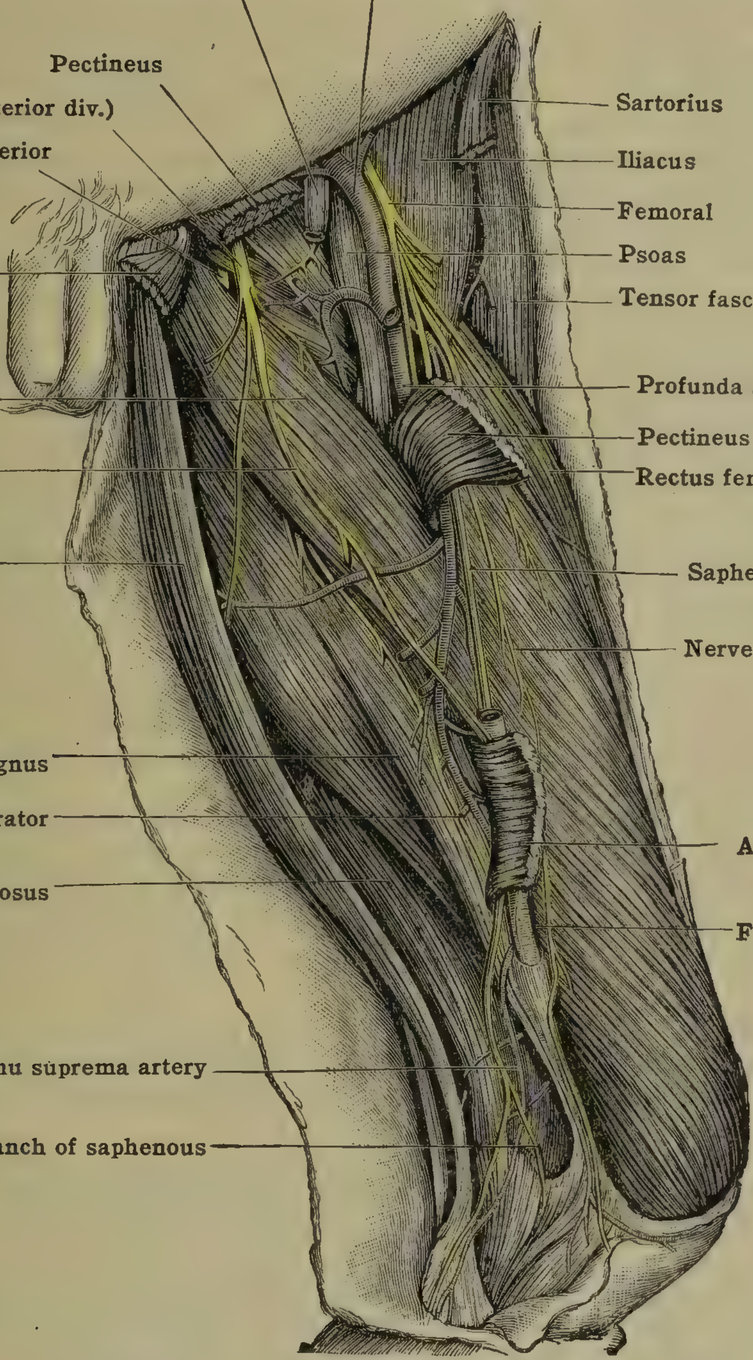


FIG. 839.—FEMORAL AND OBTURATOR NERVES. (Ellis.)

(figs. 839, 847). After emerging from the lower end of the canal, accompanied by the superficial branch of the genu suprema artery, it passes between the dorsal border of the sartorius and the anterior border of the tendon of the gracilis, and, becoming superficial, it enters into relationship with the great saphenous vein and descends with it along the inner border of the upper two-thirds of the tibia (fig. 840). It crosses the medial surface of the lower third of the tibia, passes in front of the internal malleolus, and runs forward along the medial border of the foot as far as the middle of the instep and sometimes extends to the ball of the great toe.

While it is in the adductor (Hunter's) canal it gives off a twig to the subsartorial plexus. Before it passes from under cover of the sartorius it gives off an infrapatellar branch, which pierces the sartorius just above the knee and passes outward to the patellar plexus. After it becomes superficial it supplies the integument on the medial side of the leg (rr. cutanei cruris tibiales NK) and foot, and it anastomoses, in the foot, with the medial dorsal cutaneous branch of the superficial peroneal (musculocutaneous) nerve.

The **nerve to the vastus medialis** accompanies the saphenous nerve in the femoral trigone (Scarpa's triangle), lying to its outer side. At the upper end of the adductor canal it passes

beneath the sartorius, external to the roof of the canal, and enters the medial surface of the vastus medialis. It sends a twig down to the knee-joint.

The **nerve to the articularis genu** (subcrureus), usually a terminal branch of the femoral, frequently arises from the nerve to the vastus intermedius. It passes between the vastus medialis and the vastus intermedius to the lower third of the thigh, where it supplies the articularis genu and sends a branch to the knee-joint.

The **nerve to the vastus intermedius** (crureus) is represented by two or three branches which enter the upper part of the muscle. One of them frequently sends a twig to the kneejoint.

The **nerve to the vastus lateralis** passes downward behind the rectus and along the anterior border of the vastus lateralis accompanied by the descending branch of the lateral circumflex artery. It also sends a branch to the knee-joint.

The **nerve to the rectus femoris** (fig. 839) enters the deep surface of that muscle, having previously given off a twig to the hip-joint which accompanies the ascending branch of the external circumflex artery.

The **obturator nerve** contains fibers from the anterior primary divisions of the second, third, and fourth lumbar nerves, but its largest root is derived from the third (figs. 837, 841). It sometimes receives fibers from the first lumbar nerve. It emerges from the medial border of the psoas at the dorsal part of the brim of the pelvis, where it lies in close relation with the lumbosacral trunk of the plexus, from which it is separated by the iliolumbar artery. Immediately after its exit from the psoas it pierces the pelvic fascia, crosses the lateral side of the hypogastric vessels and the ureter, and runs forward in the extraperitoneal fat, below the obliterated hypogastric artery and along the upper part of the medial surface of the obturator internus to the upper part of the obturator foramen, where it passes through the obturator canal below the so-called horizontal ramus of the pubis and above the obturator membrane, into the upper part of the thigh. It is accompanied in the pelvis and in the obturator canal by the obturator artery, which lies at a lower level than the nerve, and it divides in the obturator canal into two branches, an anterior and a posterior, which supply the adductor group of muscles, the hip and knee-joints, and the skin on the medial aspect of the leg.

The **anterior branch** (r. superficialis NK) of the obturator has a twig joining it with the accessory obturator nerve, if that nerve is present, and then descends behind the pectineus and adductor longus and in front of the obturator externus and adductor magnus muscles (fig. 839). Its branches are:—

1. A **twig** to the accessory obturator nerve if the latter is present.
2. An **articular branch** to the hip-joint.
3. **Muscular branches** to the gracilis, adductor longus, and, usually, to the adductor brevis.
4. Two **terminal branches**, of which one is distributed to the femoral artery and the other (r. cutaneus NK) communicates with the subsartorial plexus. The *subsartorial branch* is occasionally longer than usual, and it then descends, along the dorsal border of the sartorius, to the medial side of the knee, where it enters the subcutaneous tissue, and supplies the skin on the medial side of the leg as far as the middle of the calf. Twigs join it with the saphenous nerve.

The **posterior branch** (r. profundus NK) of the obturator (fig. 839) pierces the upper part of the obturator externus and passes downward between the adductor brevis and adductor magnus. Its branches are:—

1. **Muscular branches** to the obturator externus, to the oblique fibers of the adductor magnus and to the adductor brevis when the latter is not entirely supplied by the anterior branch. The branch to the obturator externus is given off in the obturator canal.
2. An **articular branch** to the knee-joint which appears in some cases to be the continuation of the trunk of the posterior branch (fig. 839). It either pierces the lower part of the adductor magnus, or it passes through the opening for the femoral artery. In the popliteal space it descends on the popliteal artery to the back of the joint, where it pierces the posterior ligament, and its terminal filaments are distributed to the crucial ligaments and the structures in their immediate neighborhood. This branch is not uncommonly absent. Occasionally the posterior branch of the obturator nerve also supplies a twig to the hip-joint.

The **accessory obturator nerve** arises from the third or fourth or from the third and fourth lumbar nerves, in the angles between the roots of the femoral (anterior crural) and obturator nerves. It is present in about 29 per cent. of all cases (Eisler). It is often closely associated with the obturator nerve to the level of the brim of the pelvis, but instead of passing through the obturator foramen, it descends along the medial border of the psoas, crosses the anterior part of the brim of the pelvis, passes beneath the pectineus, and terminates in three main branches. One of these branches joins the anterior division of the obturator nerve, another supplies the pectineus, and the third is distributed to the hip-joint.

Clinical aspects.—The obturator nerve, among the branches of the lumbosacral plexus which lie in the pelvic fascia near the peritoneum, is of surgical importance because of its course as well as its distribution. Its course from the psoas, over the sacroiliac joint, under or near the sigmoid colon, through the obturator foramen and in the canal, is important in cases of carcinoma of the large intestine and other pathological growths in the pelvis. Obturator hernia sometimes occurs. The course of the nerve over the sacroiliac joint and the branch of its anterior division through the cotyloid notch to the hip-joint are of importance in diseases

involving these joints. Suppuration in the pelvis may follow the branch of its posterior division from the obturator canal into the leg.

The Lumbosacral Trunk

The trunk of the plexus usually formed by the union of the smaller part of the fourth and the entire fifth lumbar nerves is called the **lumbosacral trunk** (figs. 837, 841). Sometimes the larger part of the fourth nerve may help to form the trunk. It may receive fibers from the third lumbar nerve or be formed entirely from the fifth. At its formation it is situated on the ala of the sacrum under cover of the psoas. It descends into the pelvis, and, as it crosses the anterior border of the ala of the sacrum, it emerges from beneath the psoas at the medial side of the obturator nerve, from which it is separated by the iliolumbar artery. It passes behind the common iliac vessels and unites with the first and second sacral nerves, forming with them the upper trunk of the sacral plexus.

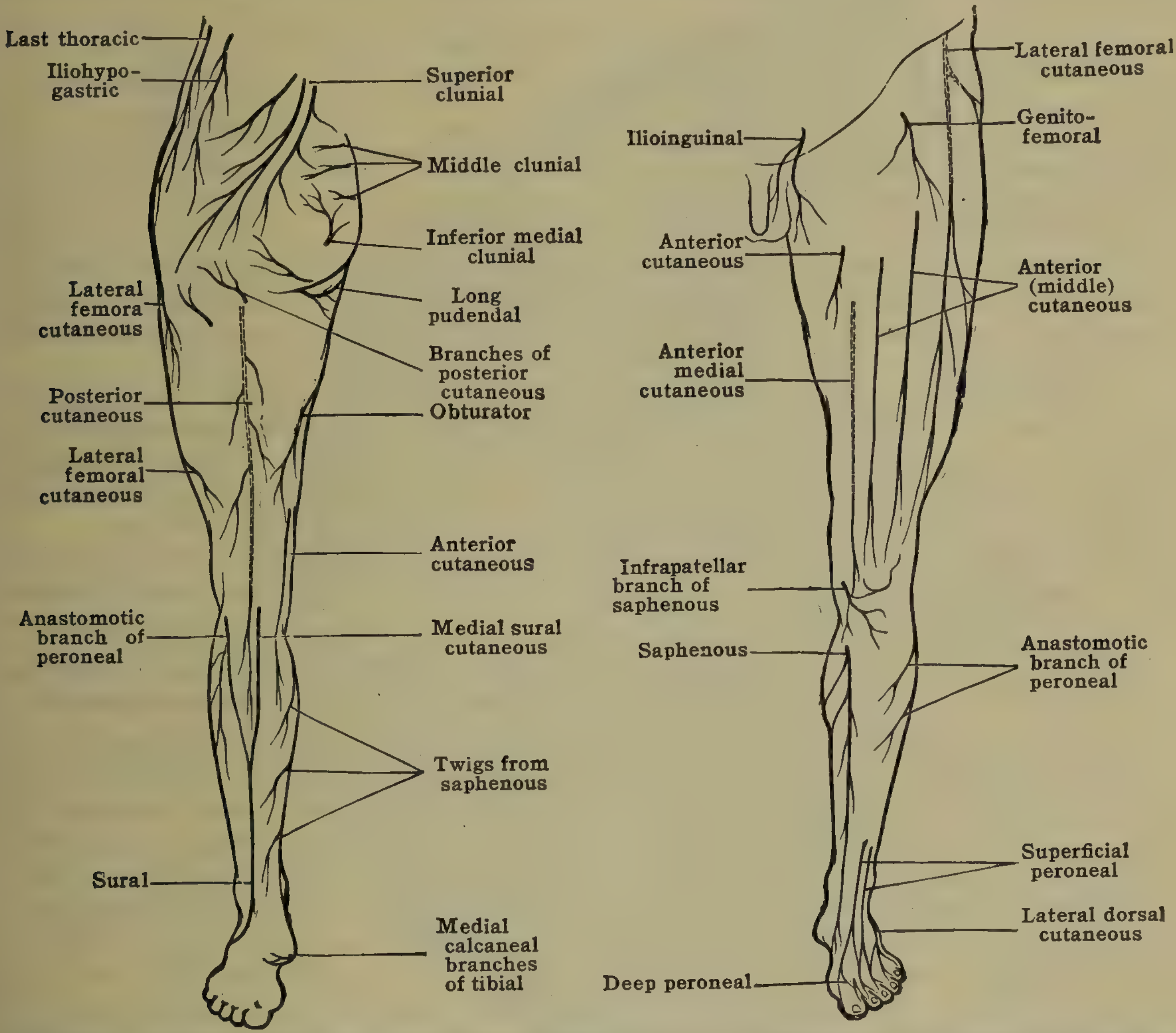


Fig. 840.—Distribution of Cutaneous Nerves on the Posterior and Anterior Aspects of the Lower Extremity.

4. SACRAL NERVES

The anterior primary divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina and they diminish in size progressively from above downward. The first sacral is the largest of the spinal nerves, the second is slightly smaller than the first, while the third and fourth are relatively small. The fifth sacral nerve is still smaller than the fourth; it enters the pelvis between the sacrum and the coccyx. The anterior divisions of these nerves enter into the formation of three parts of the lumbosacral plexus, the sacral, pudendal, and coccygeal parts (figs. 836, 837).

Sacral Plexus

The **sacral plexus** shows in its formation variations similar to those of the lumbar plexus; hence there are also seven types of this plexus, three of them

belonging to the prefixed (proximal) class, three to the postfixed (distal) class, and one to the ordinary class. The following tables show the range of variation and the common arrangement in these classes:—

Composition of the Nerves of the Sacral Plexus

Common Composition

Nerve	Prefixed	Ordinary	Postfixed
Lumbosacral trunk.......	4L.	4L.	4L.
Common peroneal.......	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S
Tibial (internal popliteal).	3,4, 5 L. 1, 2 S.	4, 5 L. 1, 2, S.	4, 5 L. 1, 2, 3, 4 S.
Posterior femoral cutaneous (small sciatic)......	1, 2, 3 S.	1, 2, 3 S.	2, 3 S.

Range of Variation

Nerve	Prefixed	Ordinary	Postfixed
Lumbosacral trunk......	3 or 3, 4 L.	4 L.	4, 5 or 5 L.
Common peroneal.......	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.
Tibial (internal popliteal)	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.	4, 5 L. 1, 2, 3, 4, S.
Posterior femoral cutaneous (small sciatic).......	5 L. 1, 2, 3 S.	5 L.1, 2, 3, 4 S.	5 L. 1, 2, 3, 4 S.

The ordinary type of sacral plexus is commonly formed by the smaller part of the anterior division of the fourth lumbar nerve and the entire anterior division of the fifth lumbar nerve, together with the first and parts of the second and third sacral nerves.

The plexus lies in the pelvis on the anterior surface of the piriformis (fig. 837) and behind the pelvic fascia and the branches of the hypogastric (internal iliac) artery. It is also dorsal to the coils of intestine, the sigmoid colon lying in front of the left plexus, and the lower part of the ileum in front of the right plexus.

The branches given off by this plexus are:—visceral, cutaneous, and muscular.

Visceral branches are given off from the second, third, and fourth sacral nerves to the pelvic viscera.

The visceral branches correspond to white rami communicantes, though not joining the sympathetic trunk. The branches from the second and fourth sacral nerves are inconstant.

Cutaneous branches.—The **posterior femoral cutaneous** (small sciatic) nerve arises partly from the anterior and partly from the posterior branches of the anterior primary divisions of the first, second, and third sacral nerves. It lies on the back of the plexus (figs. 837, 841), leaves the pelvis at the lower border of the piriformis, and descends in the buttock between the gluteus maximus and the posterior surface of the sciatic nerve (fig. 842). At the lower border of the gluteus maximus it passes behind the long head of the biceps femoris, and descends, immediately beneath the deep fascia, through the thigh and the upper part of the popliteal space. At the lower part of the popliteal region it perforates the deep fascia, and it terminates in branches which are distributed to the skin of the calf.

Branches of the posterior femoral cutaneous.—1. **Perineal branches** go in part to the skin of the upper and medial sides of the thigh on its dorsal aspect. One of the branches, known as the **long pudendal nerve** (fig. 842), runs forward and medialward in front of the tuberosity of the ischium to the lateral margin of the anterior part of the perineum, where it perforates the fascia lata and Colles' fascia and enters the anterior compartment of the perineum. In the perineum twigs join it with the superficial perineal nerves, and its terminal filaments are distributed to the skin of the scrotum in the male, and to the labium majus in the female.

2. **Inferior clunial** (gluteal) **branches**, two or three in number, are given off beneath the gluteus maximus; they turn around the lower border of this muscle and are distributed to the skin of the lower and lateral part of the gluteal region.

3. **Femoral cutaneous branches** are given off as the nerve descends through the thigh. They perforate the deep fascia and are distributed to the skin of the back of the thigh, especially toward the medial side.

In case of the separate origin of the tibial (internal popliteal) and common peroneal (external popliteal) nerves, the posterior femoral cutaneous (small sciatic) also arises from the sacral plexus in two parts. The *ventral portion* descends with the tibial nerve below the piriformis and gives off the perineal branches and medial femoral branches, while the *dorsal portion* passes through that muscle with the common peroneal nerve, and furnishes the gluteal and lateral femoral branches.

The **inferior medial clunial** (perforating cutaneous) **nerve** arises from the posterior portion of the second and third sacral nerves (figs. 836, 840, 841). It perforates the lower part of the

sacrotuberous (great sciatic) ligament, turns around the inferior border of the gluteus maximus, and is distributed to the skin over the lower and medial part of that muscle. It is sometimes associated at its origin with the pudendal nerve. It is not always present. Its place is sometimes taken by a small nerve (the *greater coccygeal perforating nerve* of Eisler), arising from the third and fourth or fourth and fifth sacral nerves, and sometimes it is represented by a branch of the posterior femoral cutaneous.

Muscular branches of the sacral plexus.—(*a*) One or two small **nerves to the piriformis** pass from the posterior branches of the first and second sacral nerves.

(*b*) The **superior gluteal nerve** receives fibers from the posterior branches of the fourth and fifth lumbar, and the first sacral nerves. It passes out of the

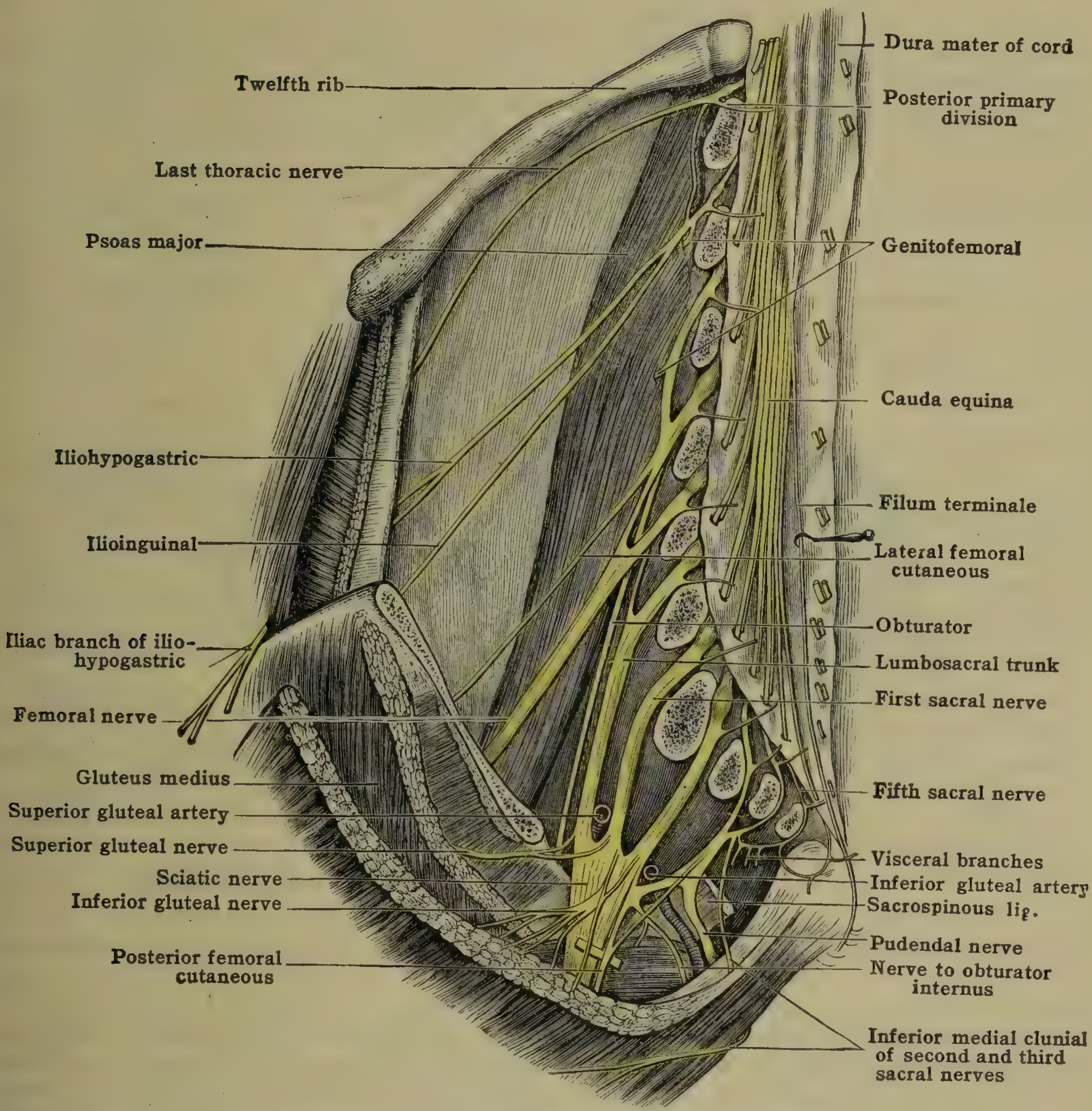


Fig. 841.—A Dissection of the Lumbar and Sacral Plexuses, from Behind.

pelvis through the great sciatic foramen, above the upper border of the piriformis, and it is accompanied by the superior gluteal artery. As soon as it enters the buttock it divides into two branches, an upper and a lower.

1. The **upper branch** is the smaller. It accompanies the upper branch of the deep division of the superior gluteal artery above the anterior curved line of the ilium, and it ends entirely in the gluteus medius (fig. 842).

2. The **lower branch**, larger than the upper, passes forward across the middle of the gluteus minimus, with the lower branch of the gluteal artery. It supplies the gluteus medius and the gluteus minimus, and it ends in the medial and posterior part of the tensor fasciæ latæ.

(*c*) The **inferior gluteal nerve** is formed by fibers from the posterior branches of the fifth lumbar, and the first and second sacral nerves. It passes through the great sciatic foramen, below the piriformis, and divides into a number of branches which end in the gluteus maximus (figs. 837, 841).

(*d*) The **nerve of the quadratus femoris** is formed by the anterior branches of the fourth and fifth lumbar and the first and second sacral nerves. It lies on the front of the plexus and issues from the pelvis below the piriformis. In the buttock it lies at first between the sciatic nerve and the back of the ischium, and, at a lower level, between the obturator internus with the gemelli and the ischium. It terminates in the anterior surface of the quadratus femoris, having previously given off a branch to the hip-joint and another to the inferior gemellus.

(*e*) The **nerve of the obturator internus** is formed by the anterior branches of the fifth lumbar, and the first and second sacral nerves (figs. 836, 841). It leaves the pelvis below the piriformis, and crosses the spine of the ischium on the lateral side of the internal pudic artery and on the medial side of the sciatic nerve. It gives a branch to the gemellus superior, and turns forward through the small sciatic foramen into the perineum, where it terminates within the inner surface of the obturator internus.

The **sciatic nerve** [n. ischiadicus].—The sciatic is not only the largest nerve of the sacral plexus, but it is also the largest nerve in the body. Its terminal

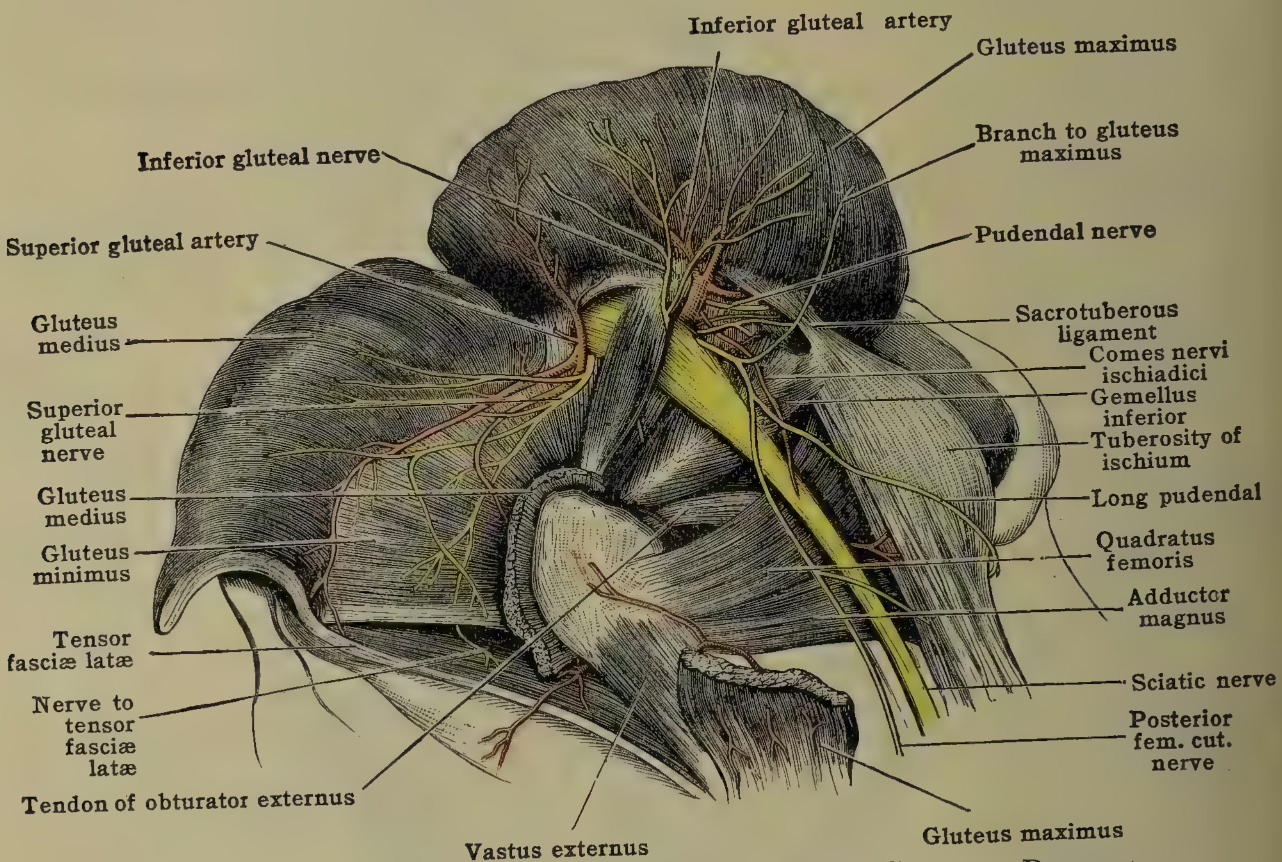


Fig. 842.—A Dissection of the Nerves in the Gluteal Region.
(The gluteus maximus and gluteus medius have been divided near their insertions, and thrown upward.)

branches are chiefly muscular, though some of its fibers are cutaneous. Although it is referred to as one trunk, it consists in reality of peroneal (lateral) and tibial (medial popliteal) portions (fig. 836), which have a common sheath of fibrous tissue as far as the upper end of the popliteal space. In about 10 per cent. of all cases the two parts remain separate, and in such cases the peroneal (lateral popliteal) part usually pierces the piriformis. The peroneal portion of the nerve consists of fibers derived from the dorsal branches of the anterior primary divisions of the fourth and fifth lumbar and the first and second sacral nerves, while the tibial part is formed by the fibers from the anterior branches of the fourth and fifth lumbar, and the first, second, and third sacral nerves (figs. 837, 841). The common trunk leaves the pelvis by passing through the great sciatic foramen, usually below the piriformis, and descends through the buttock, under the gluteus maximus and midway between the tuber ischii and the great trochanter (fig. 842). Passing down the thigh, the trunk terminates at the upper angle of the popliteal space by dividing into the common peroneal and the tibial nerves (fig. 843).

The relation of the trunk to the piriformis muscle is more or less unique. It may pass either above or below the muscle, it may split and pass around the muscle, or the muscle may be split and surround the nerve. Again, there may be a splitting of both the muscle and the nerve, in

which case any possible combination of the four parts may occur; a portion of the nerve may be above and a portion between the parts of the muscle, or a portion may be below and a portion between. The trunk of the nerve lies deeply in the thigh, and it is covered posteriorly by the skin and fascia, the gluteus maximus and the long head of the biceps femoris. Anteriorly it is in relation, from above downward, with the following structures:—the posterior surface of the ischium and the nerve to the quadratus femoris, the gemellus superior, obturator internus, gemellus inferior, quadratus femoris, and adductor magnus muscles.

Muscular branches of the sciatic are given off at the upper part of the thigh to the semitendinosus, to the long head of the biceps femoris, to the semimembranosus, and to the adductor magnus, and, about the middle of the thigh, a branch is furnished to the short head of the biceps.

The branch to the **short head of the biceps femoris** is derived from the peroneal (lateral popliteal) portion of the nerve, while all the other muscular branches are given off by the tibial (medial popliteal) part. The **semitendinosus** receives two branches, one which enters it above and another which passes into it below its tendinous intersection. The nerve to the **long head of the biceps** descends along the sciatic trunk and enters the middle of the deep surface of the muscle. The nerves to the **semimembranosus** and **adductor magnus** arise by a common trunk which divides into three or four branches. One branch ends in the adductor, and the others are distributed to the semimembranosus. The branch to the adductor magnus supplies only those fasciculi of the muscle which begin from the tuberosity of the ischium and descend vertically to the medial condyle of the femur.

The **course of the common trunk** of the sciatic in the thigh may be indicated on the surface by a line drawn from its emergence below the gluteus maximus at a point slightly medial to the middle of the space between the great trochanter and the tuber ischii, downward to a point over the upper angle of the popliteal space, where the common trunk usually divides.

At the popliteal space the two component parts of the common trunk of the sciatic are always distinct, forming (*A*) the tibial and (*B*) the common peroneal nerve.

(*A*) The **tibial nerve** (internal popliteal), formed by fibers from the anterior branches of the fourth and fifth lumbar and first, second, and third sacral nerves, passes vertically through the popliteal space, descends through the leg to a point midway between the medial malleolus and the most prominent part of the medial tubercle of the calcaneus, where it divides into its terminal branches, the *lateral plantar* and the *medial plantar* nerves.

The part of the nerve from the point of bifurcation to the lower border of the popliteus muscle was formerly called the *internal popliteal;* the part of the nerve in the dorsum of the leg being then designated the *posterior tibial nerve.*

In the upper part of the popliteal space the tibial nerve lies relatively superficially, being covered dorsally by the skin and fascia, while in the lower part of the space it is overlapped by the heads of the gastrocnemius and is crossed by the plantaris. In the upper part of the space it lies in front of the posterior femoral cutaneous (small sciatic) nerve and to the lateral side of the vein and artery; at the middle of the space it is dorsal, and in the lower part of the space it is medial to both of them.

The **branches** given off by the tibial nerve *in the popliteal space* are articular, cutaneous, and muscular.

The **articular branches** are usually three in number, a superior and an inferior internal articular and an azygos articular. They accompany the corresponding arteries, and, after piercing the ligaments, are distributed in the interior of the joint. The superior branch is often wanting.

The **medial sural cutaneous** (tibial communicating) nerve, descends between the heads of the gastrocnemius, beneath the deep fascia, to the middle of the calf, where it pierces the fascia and unites with the peroneal anastomotic branch of the lateral sural cutaneous nerve to form the **sural** (external saphenous) nerve, through which its fibers are distributed to the skin of the lower and dorsal part of the leg and the lateral side of the foot (fig. 843).

The **muscular branches** are distributed to both heads of the gastrocnemius, to the plantaris, soleus, and popliteus.

The *nerve to the soleus* is relatively large, and passes between the lateral head of the gastrocnemius and the plantaris before it reaches its termination (fig. 843). The *nerve to the popliteus* descends on the posterior surface of the muscle, turns around its lower border, and is distributed on its anterior aspect. In addition to supplying the popliteus, it gives articular branches to the knee and superior tibiofibular joints, a branch to the tibia which accompanies the medullary artery, and a long, slender twig which gives filaments to the anterior and posterior tibial arteries, and it descends as the **interosseous crural** nerve on the interosseous membrane to the inferior tibiofibular joint. It also gives branches to the interosseous membrane and to the periosteum of the lower part of the tibia.

Relations.—In the upper part of the leg the tibial nerve is placed deeply, under the gastrocnemius and soleus, but in the lower half it is merely covered by the deep fascia, which is thickened between the medial malleolus and the calcaneus to form the laciniate (internal annular)

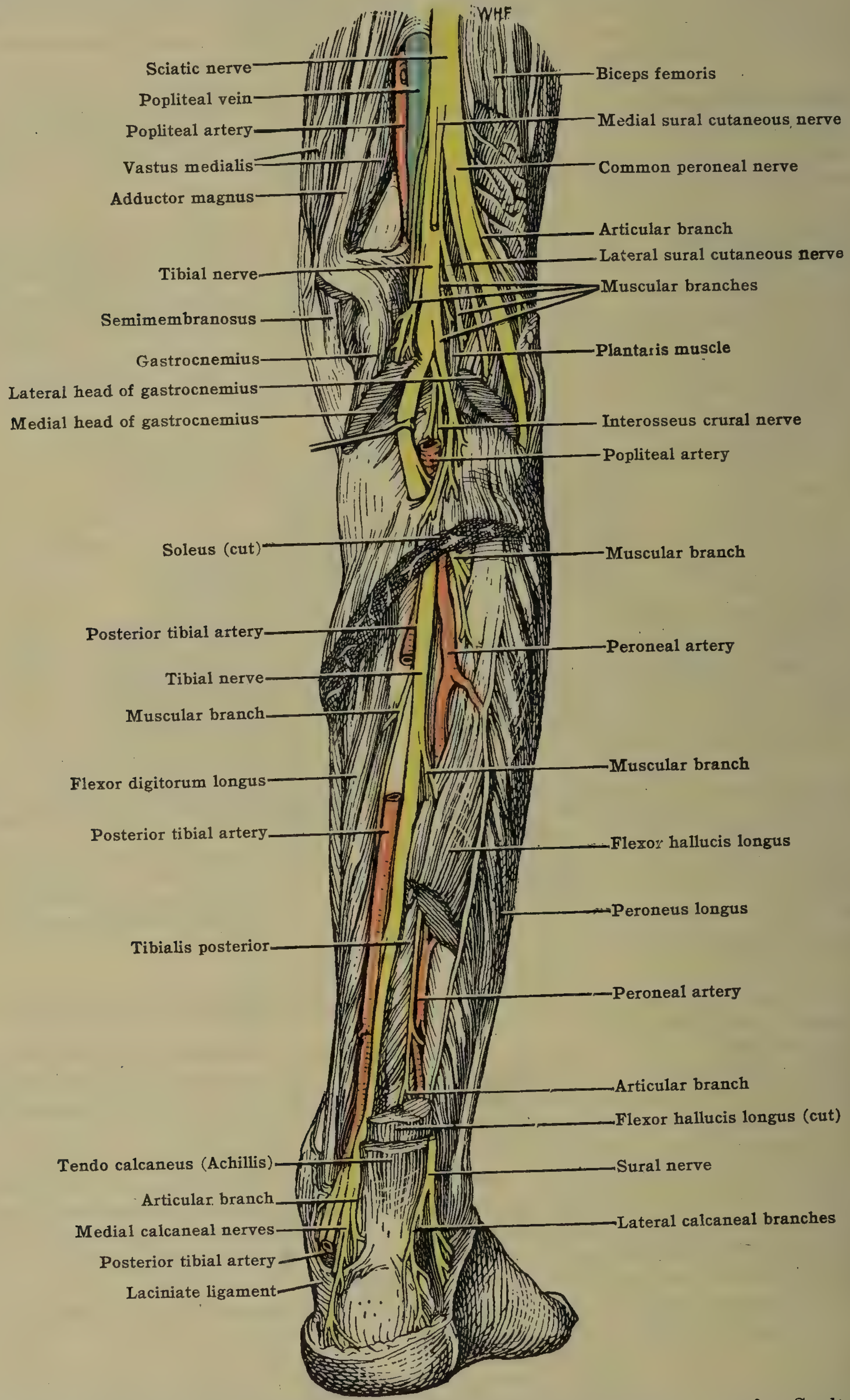


Fig. 843.—Muscle-Nerves of the Right Leg, Viewed from Behind. (After Spalteholz.) The semitendinosus, semimembranosus, biceps femoris, gastrocnemius, plantaris, soleus, and flexor hallucis longus have been wholly or in part removed.

ligament, and the termination of the nerve lies either under cover of this ligament, or under the attachment of the abductor hallucis (fig. 844). The anterior relations of the nerve are, from above downward, the tibialis posterior, the flexor digitorum longus, the lower part of the tibia,

and the posterior ligament of the ankle-joint. For a short distance after its commencement the nerve lies to the medial side of the posterior tibial artery; then it crosses behind the artery and runs downward along its lateral aspect.

The **branches of the lower part** of the tibial nerve (below the popliteal space) are likewise muscular, cutaneous, and articular. They are supplied to the deep muscles of the dorsum of the leg, to the fibula, to the skin of the heel and foot, and to the ankle-joint. Several of the terminal branches are important enough to receive special names and special treatment.

The **muscular branches** pass from the upper part of the nerve to the tibialis posterior, flexor digitorum longus, soleus, and flexor hallucis longus. The **fibular branch** arises with the nerve to the flexor hallucis longus, and accompanies the peroneal artery. It supplies the periosteum and gives filaments which accompany the medullary artery.

The **articular branches** arise from the lower part of the nerve, immediately above its terminal branches, and they pass into the ankle-joint through the deltoid ligament.

The **medial calcaneal (calcaneoplantar cutaneous) nerves** arise from the trunk of the tibial nerve in the lower part of the leg. They pierce the laciniate (internal annular) ligament and are distributed to the integument of the medial side and plantar surface of the heel and the adjoining part of the sole of the foot (figs. 843, 844, 845).

Terminal branches of tibial nerve.—Between the medial malleolus and the calcaneus the tibial nerve divides into (1) the medial plantar and (2) the lateral plantar nerve (figs. 844, 845).

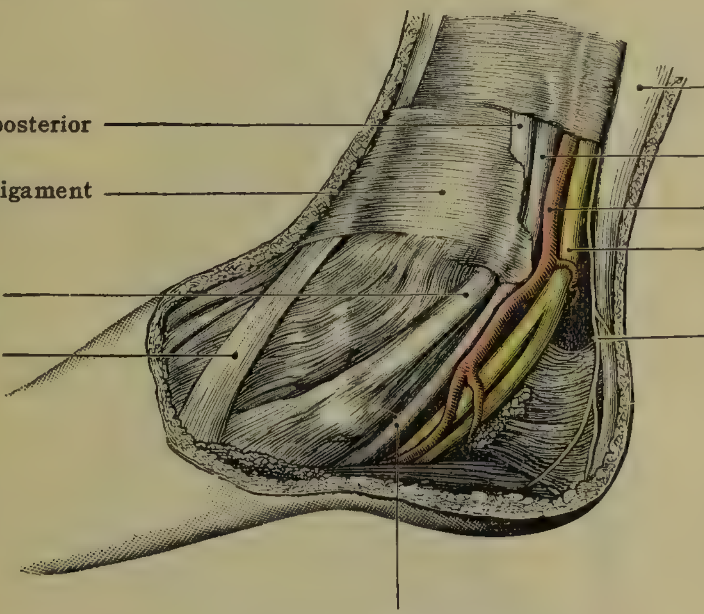


FIG. 844.—RELATIONS OF THE TIBIAL NERVE ON THE MEDIAL ASPECT OF THE ANKLE. (Heath.)

1. The **medial plantar nerve** (n. plantaris tibialis NK) is the larger of the two terminal branches of the tibial nerve. It commences under cover of the lower border of the laciniate (internal annular) ligament, or under the posterior border of the abductor hallucis, and passes forward, accompanied by the small medial plantar artery, in the intermuscular septum between the abductor hallucis and the flexor digitorum brevis. At the middle of the length of the foot it becomes superficial, in the interval between the two muscles, and divides into four sets of terminal branches (fig. 845):—

(*a*) **Muscular branches** pass from the trunk of the nerve to the abductor hallucis and the flexor digitorum brevis.

(*b*) **Articular branches** are distributed to the talonavicular and the navicular-cuneiform joints.

(*c*) **Plantar cutaneous branches** are supplied to the skin of the medial part of the sole.

(*d*) The **digital branches** are four in number, the first, a **proper plantar digital**, the second, third, and fourth, the **common plantar digitals**. Near the bases of the metatarsal bones, the second, third and fourth common plantar digitals divide into **proper plantar digital nerves**.

The first proper plantar digital nerve becomes subcutaneous farther back than the others, and, after sending a branch to the flexor hallucis brevis, passes to the medial side of the great toe. The second (common digital) nerve gives a twig to the first lumbrical and bifurcates to supply the adjacent sides of the first and second toes. The third supplies the adjacent sides

of the second and third toes, and the fourth, after connecting with the superficial branch of the lateral plantar nerve, divides to supply the adjacent sides of the third and fourth toes. All the proper digital nerves run along the sides of the toes and lie below the corresponding arteries. They supply the joints of the toes, and each give off a dorsal branch to the skin over the second and terminal phalanges and to the bed of the nail. All of them give fibers terminating in numerous Pacinian corpuscles in the plantar subcutaneous connective tissue.

2. The **lateral plantar nerve** (n. plantaris fibularis NK) is the smaller of the two terminal branches of the tibial nerve. It commences at the lower border of the laciniate (internal annular) ligament, or under cover of the origin of the abductor hallucis, and passes forward and lateralward to the base of the fifth metatarsal bone, where it divides into a superficial and a deep branch (fig. 845). As it runs

Fig. 845.—Superficial Nerves in the Sole of the Foot. (Ellis.)

forward and lateralward it is superficial to the tendon of the flexor hallucis longus and to the quadratus plantæ (flexor accessorius), and deep to the flexor digitorum brevis. At its termination it lies in the interval between the flexor digitorum brevis and abductor digiti quinti.

Branches.—From the trunk of the lateral plantar nerve muscular, superficial and deep, and articular branches are given off.

The **muscular branches** arise from the commencement of the nerve and are distributed to the abductor digiti quinti and quadratus plantæ.

The **articular branches** supply the calcaneocuboid joint.

The **superficial branch** supplies muscular filaments to the flexor digiti quinti brevis, the opponens, the third plantar and fourth dorsal interosseous muscles,

and divides into two **common plantar digital nerves**, each of which subdivides to form **proper plantar digital nerves.**

The lateral of the two common branches supplies the lateral side of the fifth digit; the medial connects with the lateral digital branch of the medial plantar nerve (fig. 845) and divides into proper plantar digital nerves for the adjacent sides of the fourth and fifth digits. The digital branches of the superficial division of the lateral plantar, like those of the medial plantar, supply the skin of the toes and the beds of the nails, and their fibers terminate in numerous Pacinian corpuscles.

The **deep branch** passes forward and medialward into the deep part of the sole with the plantar arterial arch. It runs deep to the quadratus plantæ, the long flexor tendons and the lumbricals, and the oblique adductor of the great toe. It lies, therefore, immediately beneath the bases of the metatarsal bones and it supplies the following muscular and articular branches:—

Muscular branches to the lateral three lumbricals, the interossei of the medial three intermetatarsal spaces, and the transverse and oblique adductor muscles of the great toe.

Articular branches to the intertarsal and to the tarsometatarsal joints and not uncommonly to the metatarsophalangeal joints also. Filaments from the deep branch frequently pass through the interosseous spaces and join with the interosseous branches of the deep peroneal (anterior tibial) nerve.

(B) The **common peroneal** (external popliteal) **nerve** (n. fibularis communis NK).—At the apex of the popliteal space, where the two component parts of the sciatic trunk usually become distinct, the lateral portion receives the name *common peroneal nerve.* It descends along the posterior border of the biceps femoris, which forms the upper part of the lateral boundary of the space (fig. 843). It leaves the space at the lateral angle, crosses the plantaris, the lateral head of the gastrocnemius, the popliteus, and the inferior external artery, and descends behind the upper part of the soleus, to the neck of the fibula, where it turns forward between the peroneus longus and the bone, and breaks up into its three terminal branches, the recurrent articular, the superficial peroneal (musculocutaneous), and the deep peroneal (anterior tibial) nerves (figs. 846 and 847).

Upper branches.—While it is in the popliteal space the common peroneal nerve gives off two articular branches, superior and inferior, and a cutaneous branch.

The **superior articular branch** accompanies the superior lateral articular artery. The **inferior articular branch** passes down with the trunk of the nerve, across the plantaris and the lateral head of the gastrocnemius, and it joins the inferior-lateral articular artery behind the tendon of the biceps femoris. Both the upper and lower articular branches pierce the ligaments and are distributed in the interior of the knee joint.

The **cutaneous branch**, the **lateral sural cutaneous**, is extremely variable both as to the number of its branches and as to the place of its anastomosis with the medial sural cutaneous. Leaving the common peroneal (external popliteal) in the popliteal space, it descends between the deep fascia and the lateral head of the gastrocnemius to the middle of the calf, where it pierces the fascia and unites with the medial sural cutaneous to form the sural (external saphenous) nerve. In its course it may give off no branches; or it may give off several, some of which supply the skin of the dorsum of the leg, while one of them the *peroneal anastomotic branch* (r. anastomoticus fibularis NK), unites with the medial sural cutaneous to form the sural (short saphenous) nerve. The junction of the peroneal anastomotic branch with the medial sural cutaneous may take place at any point between the popliteal space and the lower third of the leg.

The **sural** (external or short saphenous) **nerve** is formed by the union of the lateral sural cutaneous nerve either directly, or through a connecting branch, the peroneal anastomotic, with the medial sural cutaneous. It descends along the lateral border of the tendo Achillis, (figs. 840, 843), giving branches to the lower and lateral part of the leg, and **lateral calcaneal** branches to the lateral side of the heel.

It passes dorsal to the lateral malleolus, turns forward across the lateral surface of the cruciate (external annular) ligament, and becomes the **lateral dorsal cutaneous nerve.** Continuing along the lateral side of the foot it divides into two branches, the **dorsal digitals**, one of which supplies the lateral side of the fifth digit, while the other anastomoses with or takes the place of a branch of the superficial peroneal (musculocutaneous) nerve, which is distributed to the adjacent sides of the fourth and fifth digits (fig. 846).

The terminal branches of the common peroneal.—(1) The **recurrent articular nerve** (fig. 846) passes medialward, around the neck of the fibula, and through the upper part of the attachment of the extensor digitorum longus. At the medial border of the fibula it becomes associated with the anterior tibial recurrent

artery, with which it ascends through the upper part of the tibialis anterior to the head of the tibia and the knee-joint. It supplies the tibialis anterior, the superior tibiofibular joint, and the knee-joint.

(2) The **superficial peroneal nerve** (n. fibularis superficialis NK) (fig. 846) arises from the common peroneal between the peroneus longus and the neck of the

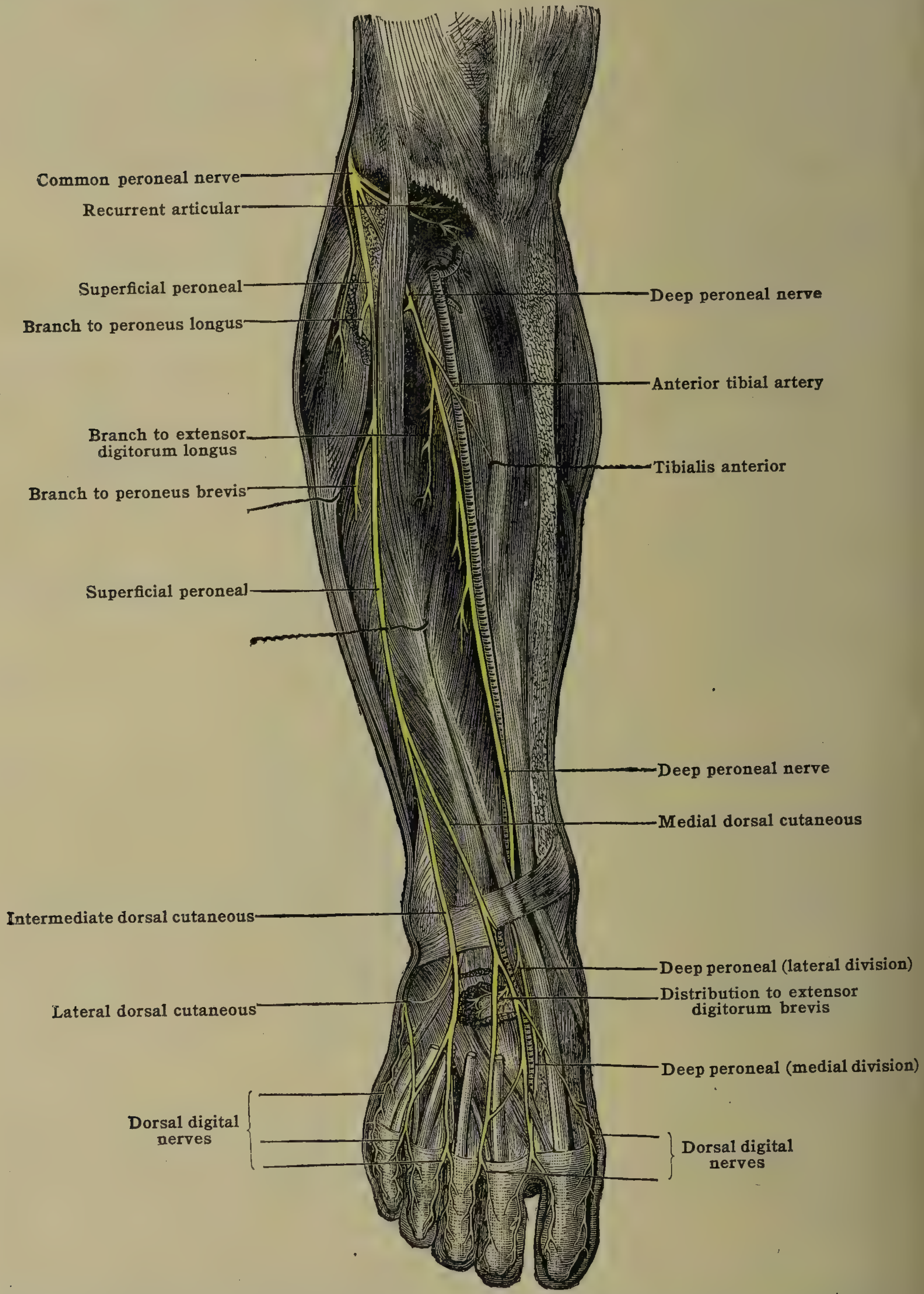


Fig. 846.—Distribution of Superficial and Deep Peroneal Nerves on the Anterior Aspect of the Leg and on the Dorsum of the Foot. (Hirschfeld and Leveillé.)

fibula and descends in the intermuscular septum between the long and short peronei on the *lateral* side, and the extensor digitorum longus on the medial side (fig. 847). It gives off muscular and cutaneous branches in its descent, and at the junction of the middle and lower thirds of the leg it pierces the deep fascia and divides into a *medial dorsal* and a *lateral branch* (fig. 846).

Muscular branches are given off from the superficial peroneal to the peroneus longus and peroneus brevis before the nerve pierces the deep fascia.

Cutaneous branches pass from the trunk of the superficial peroneal to the skin of the lower part of the front of the leg.

The **medial dorsal cutaneous nerve** (n. cutaneus dorsi pedis tibialis NK) passes downward and medialward across the transverse and the cruciate (anterior annular) ligament of the ankle and subdivides into two branches. The *medial branch* passes to the medial side of the great toe; it also supplies twigs to the skin of the medial side of the foot, and it anastomoses with the saphenous nerve and with the medial terminal branch of the deep peroneal (anterior tibial) nerve. The *lateral branch* passes to the base of the cleft between the second and third toes and divides into two dorsal digital branches which supply the adjacent sides of the cleft.

The **lateral branch (intermediate dorsal cutaneous)** of the superficial peroneal, in separating from the medial, crosses in front of the cruciate ligament and divides into two dorsal digital branches, which pass beneath the dorsal venous arch. The medial of these branches supplies the adjacent sides of the third and fourth toes (fig. 846). The lateral branch communicates with the sural (external saphenous) nerve and is distributed to the adjacent sides of the fourth and fifth toes. This latter branch is frequently replaced by the sural nerve.

(3) The **deep peroneal (anterior tibial) nerve** (n. fibularis profundus NK) springs from the end of the common peroneal (external popliteal) nerve between the peroneus longus muscle and the neck of the fibula. It passes forward and medialward through the upper part of the origin of the extensor digitorum longus, to the interval between that muscle and the tibialis anterior (fig. 847), then it descends, in the anterior compartment of the leg, to the ankle, where it divides into a medial and a lateral terminal branch (fig. 846).

In the upper part of the leg the deep peroneal nerve lies between the extensor digitorum longus and tibialis anterior and lateral to the anterior tibial artery (fig. 847). In the middle of the leg it is in front of the artery and between the extensor hallucis longus and tibialis anterior; then it crosses beneath the extensor hallucis, and in the lower third of the leg it is again to the lateral side of the artery, but between the extensor hallucis longus and the extensor digitorum longus.

Branches furnished from the trunk of the deep peroneal are muscular, articular, and terminal.

The **muscular branches** supply the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius.

Articular filaments are given to the ankle-joint and the inferior tibiofibular articulation.

Terminal branches.—The **medial terminal branch** of the deep peroneal nerve passes downward along the side of the dorsalis pedis artery and divides into two dorsal digital branches which supply the adjacent sides of the first and second toes. It also gives filaments to the periosteum of the adjacent bones, to the metatarsophalangeal and interphalangeal articulations, a twig to the dorsal interosseous muscle of the first space, and a perforating twig which connects with the lateral plantar nerve. The **lateral terminal branch** passes lateralward, beneath the extensor digitorum brevis, and it ends in a gangliform enlargement from which branches are distributed to the extensor digitorum brevis, the tarsal joints, and to the three lateral intermetatarsal spaces. The latter branches supply the neighboring bones, periosteum, and joints. They give off perforating twigs, which pass through the spaces and anastomose with branches of the lateral plantar nerve, and the most medial also gives a twig to the second dorsal interosseous muscle.

Topography.—A transverse section of the leg 3 cm. below the head of the fibula (cf. fig. 847) will pass just below the division of the common peroneal nerve and will show its superficial and deep branches cut in the peroneal compartment, lateral to the fibula and under cover of the peroneus longus. The trunk of the tibial nerve lies near the middle of the section, behind the popliteus muscle and accompanied by the popliteal veins and artery, the only main artery in this section. The medial sural cutaneous nerve will be found in the middorsum of the section, superficial to the gastrocnemius and accompanied by the small saphenous vein, while the lateral sural cutaneous lies lateral to the medial one but superficial to the common perimysium of the gastrocnemius. The saphenous nerve is cut in the medial surface of the section, near but not yet with the great saphenous vein.

Clinical aspects.—Because of the comparative ease with which the weight of the body can be carried on the prominences about the knee joint, especially the tuberosity of the tibia, when

the knee is flexed upon a bucket artificial limb, a section of the leg about 10 cm. below the knee joint (fig. 847) is called the seat of election for amputation. Such a section shows the superficial peroneal nerve, having passed through the peroneus longus, now lying anterolateral to the fibula and beginning to approach the lateral surface of the leg between the combined peroneus longus and brevis and the extensores longi digitorum. The deep peroneal nerve is found anterior to the fibula, accompanied by the anterior tibial artery and vein, in the compartment between the tibialis posterior and the above long extensors. There are three arterial trunks in this section, the anterior and posterior tibial and the peroneal artery, the tibial nerve lying between the latter two and among their veins. The saphenous nerve lies here in the tela subcutanea beside the great saphenous vein. The lateral sural cutaneous nerve is beginning to approach the medial position in the dorsal surface of the leg, the medial one being still in the septum or raphe between the two parts of the gastrocnemius and with the small saphenous vein, which is now outside the common epimysium of the gastrocnemius. Therefore, the section passes above the level at which the sural nerve is formed by junction of the lateral and medial sural cutaneous nerves.

For ligation of the posterior tibial artery anywhere in the middle part of the leg, the incision should be made about 1 cm. behind the medial border of the tibia to avoid injury to the saphenous nerve.

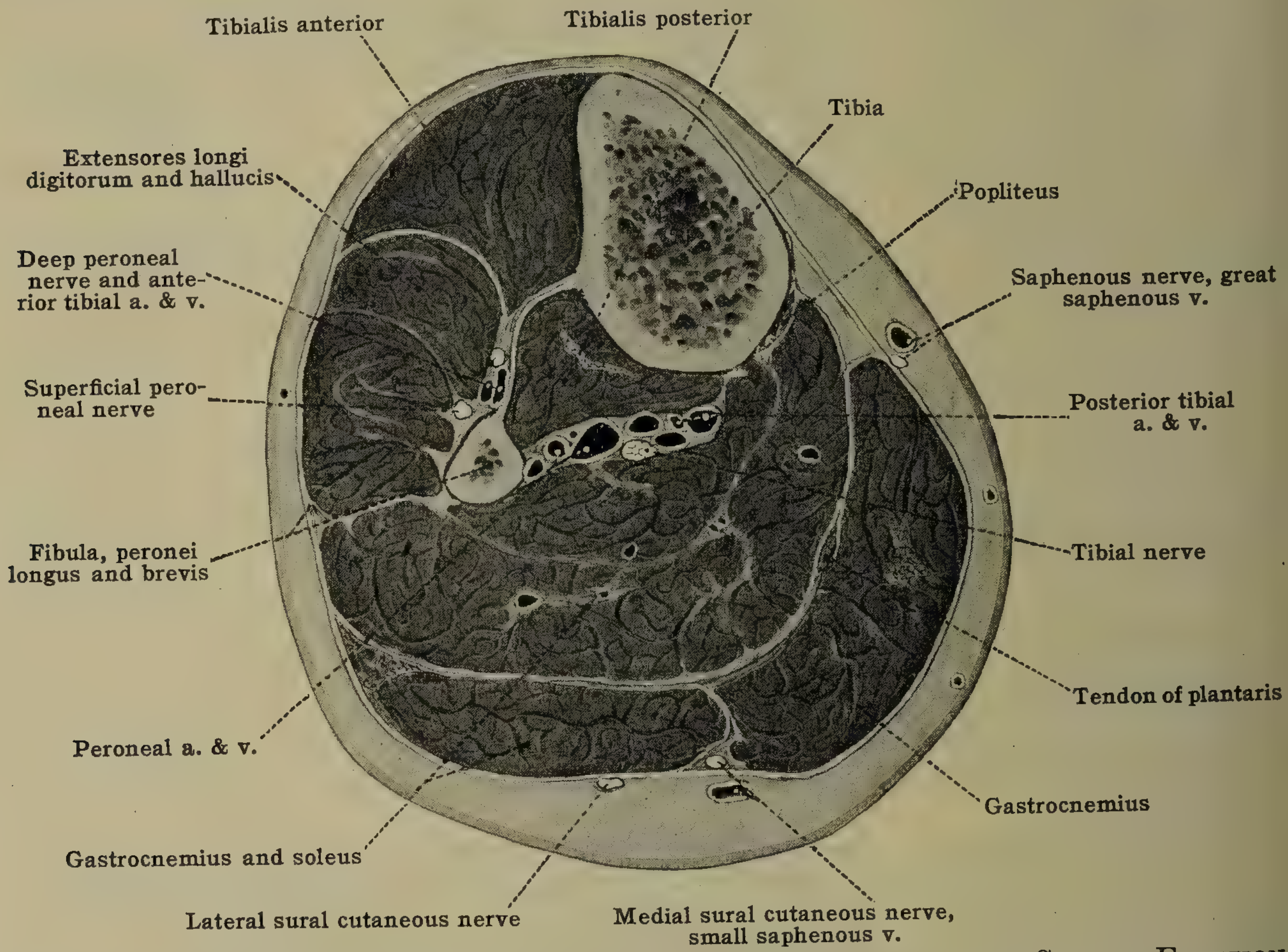


Fig. 847.—Transverse Section of Left Leg at About the Level of the Seat of Election for Amputation. (From Eycleshymer and Schoemaker's 'Cross Section Anatomy'; D. Appleton & Co.)

Table Showing Ordinary Relations of Lumbar and Sacral Nerves to Branches of the Lumbar and Sacral Plexuses and to the Pudendal Nerve

Nerves Contributing	Nerves
1 L.	Iliohypogastric Ilioinguinal
1 and 2 L.	Genitofemoral
1, 2, and 3 L.	Lateral cutaneous
2, 3, and 4 L.	Femoral Obturator
4, 5 L., and 1 S.	Superior gluteal Nerve to quadratus femoris
4, 5 L., 1 and 2 S.	Sciatic (peroneal part)
4, 5 L., 1, 2, and 3 S.	Sciatic (tibial part)
5 L., 1 and 2 S.	Inferior gluteal Nerve to obturator internus
1 and 2 S.	Nerve to piriformis
2 and 3 S.	Medial inferior clunial
1, 2, and 3 S.	Posterior femoral cutaneous
2, 3, and 4 S.	Pudendal (pudic)

Paralysis of the nerves of the lower extremity.—The student should consider from the viewpoint of surgical anatomy the results of paralysis of the nerve chiefly affected, viz., the great sciatic and its branches. *Sciatic:* The limb hangs flail-like, much in the position of one affected with advanced infantile paralysis. In addition to the results of paralysis of its two divisions, flexion at the knee will be lost, owing to paralysis of the flexor muscles. *Peroneal* (*external popliteal*) *nerve:* The extensors and peronei being paralysed the foot drops; it cannot be dorsiflexed at the ankle nor abducted at the medio-tarsal joint. Adduction at the latter joint is impaired owing to paralysis of the tibialis anterior. The arch of the foot is largely lost owing to paralysis of the peroneus longus. Slight extension of the two distal phalanges of the four lateral toes is still possible by means of the interossei. Sensation is impaired over the distribution of the medial sural cutaneous and the deep and superficial peroneal nerves. *Tibial* (*internal popliteal*) *nerve:* Here the calf muscles, the flexors, and the muscles of the sole of the foot are paralysed. The ankle cannot be plantar-flexed.

Table Showing Relations of Muscles of Lower Extremity to Nerves of Lumbar and Sacral Plexuses

Nerves Contributing	Muscles	Nerves
2 and 3 L.	Iliopsoas	Femoral
	Sartorius	Femoral
	Pectineus	Femoral
	Adductor longus	Obturator
2, 3, and 4 L.	Gracilis	Obturator
	Adductor brevis	Obturator
3 and 4 L.	Quadriceps femoris	Femoral
	Obturator externus	Obturator
3, 4, and 5 L.	Adductor magnus	Obturator and sciatic
4, 5 L., and 1 S.	Gluteus medius	Superior gluteal
	Gluteus minimus	Superior gluteal
	Tensor fasc. latæ	Superior gluteal
	Semimembranosus	Sciatic
	Plantaris	Tibial
	Popliteus	Tibial
	Quadratus femoris	Nerve to quad. fem
	Inferior gemellus	Nerve to quad. fem
5 L., and 1 S.	Flex. digit. long.	Tibial
	Tibialis posterior	Posterior tibial
	Flexor digit. brev.	Plantar
	Flexor hallucis brev.	Plantar
	Abductor hallucis	Plantar
	First lumbrical	Plantar
5 L., 1 and 2 S.	Superior gemellus	Nerve to obt. int.
	Obturator internus	Nerve to obt. int.
	Gluteus maximus	Inferior gluteal
	Semitendinosus	Sciatic
	Soleus	Tibial
	Flex. hallucis long.	Tibial
1 and 2 S.	Piriformis	
	Gastrocnemius	Tibial
	Quadratus plantæ	Lateral plantar
	Abd. digiti quinti	Lateral plantar
	Plantar interossei	Lateral plantar
	Dorsal interossei	Lateral plantar
	Add. hallucis trans.	Lateral plantar
	Add. hallucis obliq.	Lateral plantar
1, 2, and 3 S.	Long head of biceps femoris	Sciatic
4, 5 L., and 1 S.	Ext. hall. long.	Deep peroneal
	Ext. digit. long.	Deep peroneal
	Ext. digit. brev.	Deep peroneal
	Tibialis anterior	Deep peroneal
	Peroneus tertius	Deep peroneal
	Peroneus longus	Superficial peroneal
	Peroneus brevis	Superficial peroneal

THE PUDENDAL PLEXUS

The **pudendal plexus,** like the parts of the lumbosacral plexus already described, varies in its formation. The following table shows the extreme range of variation and the common method of formation of the largest nerve (pudendal or pudic) of this plexus in each of the three classes previously referred to.

Common Composition

Nerve	Prefixed	Ordinary	Postfixed
Pudendal nerve	2, 3 S.	2, 3, 4 S.	3, 4 S.

RANGE OF VARIATION

NERVE	PREFIXED	ORDINARY	POSTFIXED
Pudendal nerve	1, 2, 3, 4, 5 S.	1, 2, 3, 4 S.	2, 3, 4, 5 S.

The pudendal plexus is commonly formed by parts of the anterior divisions of the second, third, and fourth sacral nerves (fig. 836). It lies in the lower part of the back of the pelvis, and gives off visceral, muscular, and terminal branches.

Visceral branches (pelvic splanchnics) arise from the third and fourth sacral nerves especially, and enter branches of the sympathetic plexus. They are distributed both directly by their afferent or sensory fibers terminating in the pelvic viscera and indirectly by their visceral efferent fibers terminating in the ganglia of the sympathetic plexus or upon ganglion cells in the walls of the pelvic

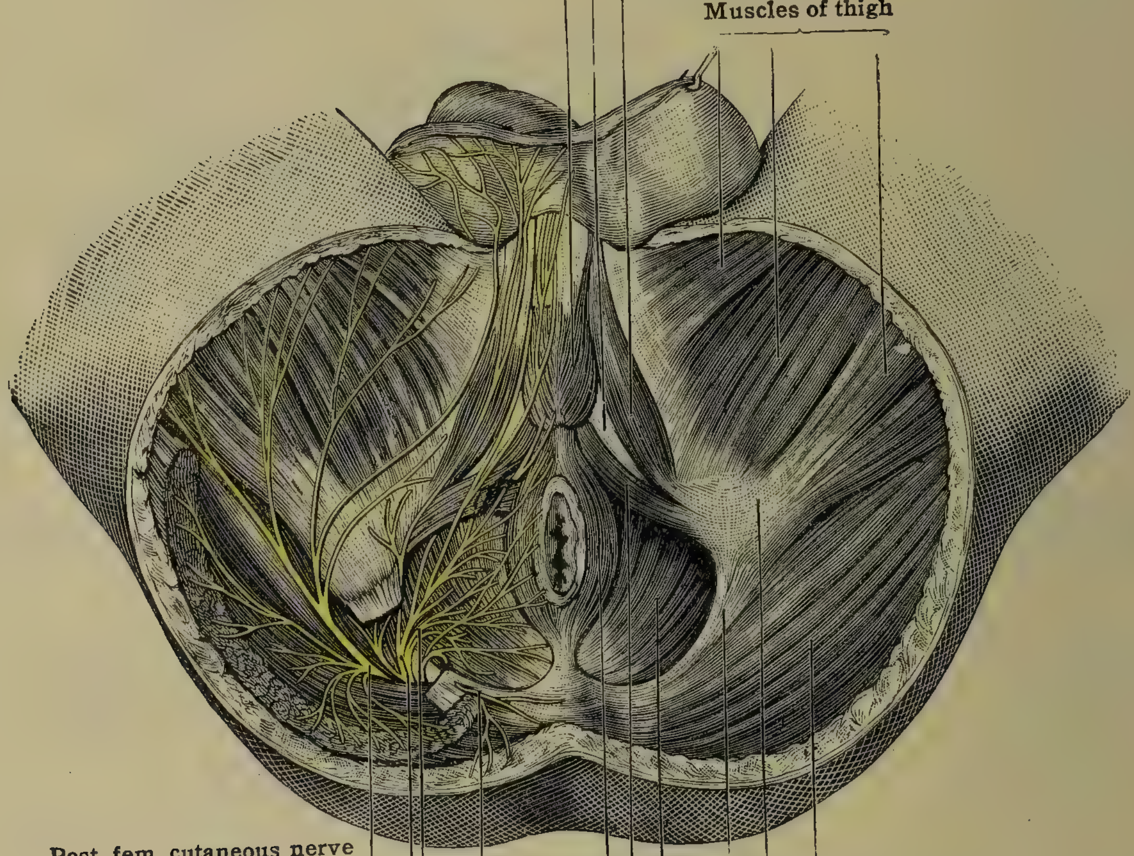


FIG. 848.—THE NERVES OF THE MALE PERINEUM. (Modified from Hirschfeld and Leveillé.)

viscera (figs. 836, 863). The **middle hemorrhoidal nerves** (nn. rectales caudales NK) pass to the rectum, the **inferior vesical nerves** to the bladder, and, in the female, the **vaginal nerves** to the vagina (see SYMPATHETIC SYSTEM).

Muscular branches are given by the fourth sacral nerve to the coccygeus, levator ani, and sphincter ani externus (fig. 836).

The nerves to the two former muscles pass into the pelvic surfaces of the muscles, but that to the last-named muscle, called the **perineal branch**, passes backward between the levator ani and the coccygeus, or through the posterior fibers of the latter muscle, into the posterior part of the ischiorectal fossa, and, in addition to supplying the sphincter ani externus, it gives cutaneous filaments to the skin between the anus and the coccyx.

Terminal branches.—The **pudendal (pudic) nerve** [n. pudendus] rises usually from the anterior primary divisions of the second, third, and fourth sacral nerves (figs. 836, 837). It emerges from the pelvis below the piriformis, crosses the spine of the ischium, lying to the medial side of the internal pudic artery (figs. 841, 842), and accompanies the artery, through the small sciatic foramen, into Alcock's canal

in the obturator fascia on the lateral wall of the ischiorectal fossa, where it terminates by dividing into three branches, the inferior hemorrhoidal, the perineal, and the dorsal nerve of the penis.

The **inferior hemorrhoidal nerves** (nn. anales NK) frequently arise independently from the third and fourth sacral nerves, pierce the medial wall of Alcock's canal, and pass forward and medialward through the ischiorectal fat to supply the sphincter ani externus and adjacent skin. They anastomose with branches of the perineal nerve.

The **perineal nerve** (fig. 848) runs forward for a short distance in Alcock's canal and divides into a deep and a superficial branch. The *deep branch* breaks up into filaments, one or two of which pierce the medial wall of the canal and pass medialward to the anterior fibers of the sphincter and levator ani. The remaining part of the nerve pierces the base of the urogenital diaphragm, and enters the superficial pouch of the urethral triangle, where it is distributed to the bulb of the urethra, and to the transversus perinei, bulbocavernosus, and ischiocavernosus. It also sends some sensory filaments to the mucous membrane of the urethra. The *superficial branch* almost at once divides into medial and lateral branches, the *posterior scrotal* (or *labial*) nerves.

Both branches pass through the wall of Alcock's canal into the anterior part of the ischiorectal fossa, then they pierce the base of the urogenital diaphragm, and enter the superficial pouch of the urethral triangle. The lateral branch usually passes below the transversus perinei, and the medial branch above the muscle or through its fibers. The lateral branch connects with the long pudendal nerve, and with the inferior hemorrhoidal nerve, and both branches end in terminal filaments which anastomose and which are distributed to the skin of the scrotum and the anterior part of the perineum in the male, and to the labium majus in the female.

The **dorsal nerve of the penis** runs forward in Alcock's canal above the internal pudic artery. It pierces the base of the urogenital diaphragm, continues forward between its layers, embedded in the fibers of the constrictor urethræ, and it gradually passes to the lateral side of the internal pudic artery. A short distance below and behind the pubic arch it pierces the anterior layer of the urogenital diaphragm, gives a branch to the corpus cavernosum penis, passes forward between that structure and the bone, and turns downward on the dorsum of the penis, passing between the layers of the suspensory ligament and along the outer side of the dorsal artery of the penis. It supplies the skin of the dorsum of the penis, and, having given branches to the prepuce, it breaks up into terminal filaments which are distributed to the glans penis.

The **dorsal nerve of the clitoris** is much smaller than the dorsal nerve of the penis to which it corresponds. It is distributed to the clitoris.

THE COCCYGEAL PLEXUS

This plexus (ansa sacrococcygea NK) is frequently, and with reason, considered as a subdivision of the pudendal plexus, and sometimes it is described with the coccygeal nerves. It is formed chiefly by the anterior division of the fifth sacral nerve and the coccygeal nerve, but it receives a small filament from the anterior division of the fourth sacral nerve (figs. 836, 837, 841). These constituents unite to form plexiform cords lying on either side of the coccyx. From these cords arise the **anococcygeal nerves,** which pierce the sacrotuberous (great sacro-sciatic) ligament and supply the skin in the neighborhood of the coccyx.

III. THE DISTRIBUTION OF THE CUTANEOUS BRANCHES OF THE SENSORY AND MIXED CRANIAL AND SPINAL NERVES.

The cutaneous filaments of the sensory and mixed nerves are distributed to definite regions of the surface of the body which are known as 'cutaneous areas.' Each cutaneous area has one special nerve of supply and the central part of the area receives that nerve alone, but wherever the borders of two areas meet they reciprocally overlap, therefore each margin of every cutaneous area has two nerves of supply, its own nerve and that of an adjacent area, and of these, sometimes one and sometimes the other preponderates.

The area of skin supplied by a given nerve is a matter of considerable clinical importance in neuropathological diagnosis. Because of this importance, various investigators have given

much time to the problem and some of the results obtained are summarized in the following pages.

The Cutaneous Areas of the Scalp

The limits of the cutaneous areas in the scalp region are indicated in figs. 849, 852, but in general terms it may be said that the skin of the scalp in front of the auricle is supplied by four cutaneous nerves, viz., the medial part by the supratrochlear and the supraorbital branches of the ophthalmic division of the trigeminus, and the lateral part by the zygomatico-temporal branch of the maxillary division, and the auriculotemporal branch of the mandibular division of the same nerve.

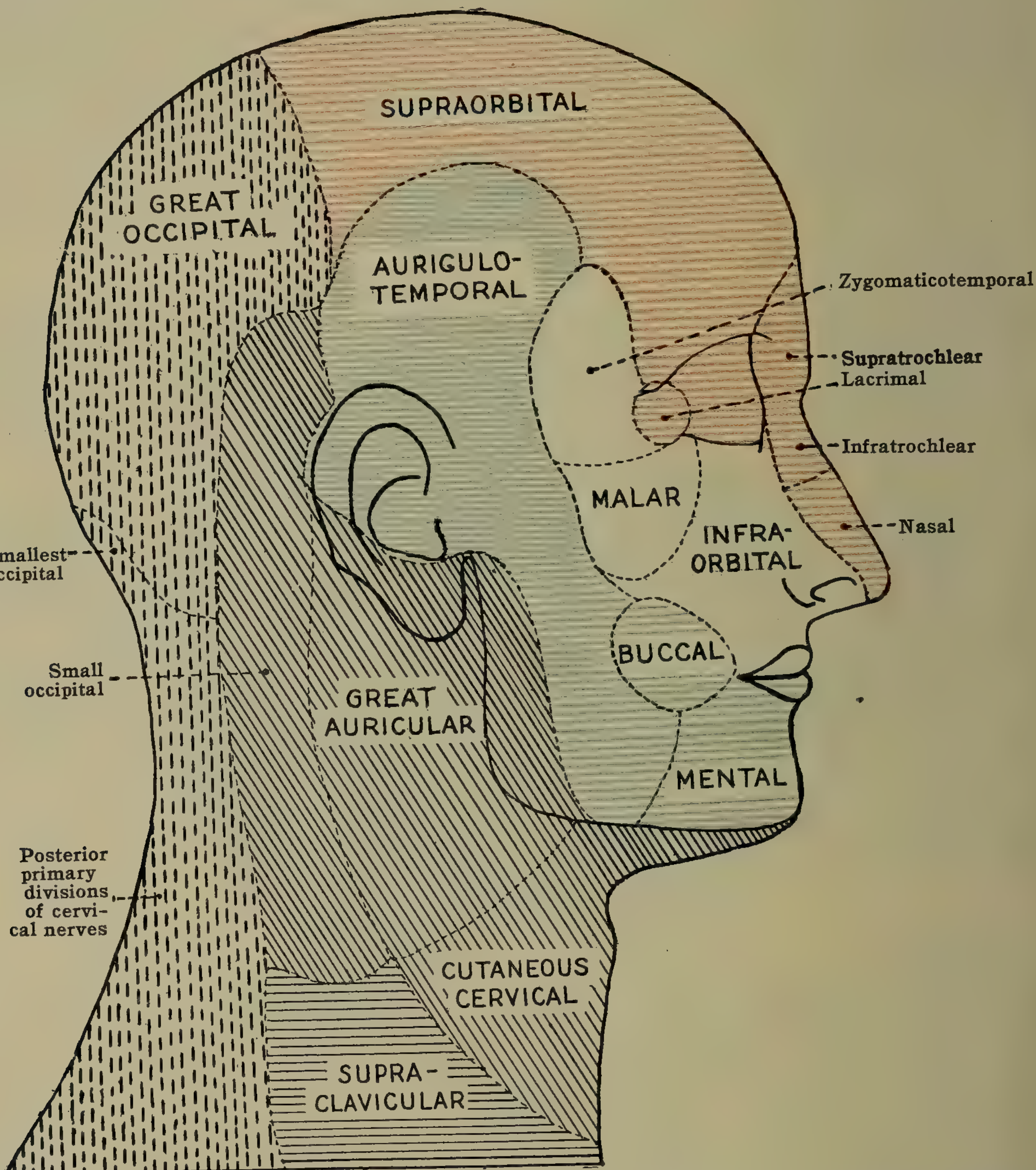


Fig. 849.—Diagram of the Cutaneous Nerve-areas of the Head and Neck.
Red—ophthalmic division of trigeminus. White—maxillary division of trigeminus. Blue—mandibular division of trigeminus.

Vertical broken line shading—Posterior primary divisions of cervical nerves.
Oblique shading—Ascending and transverse superficial branches of cervical plexus.
Transverse shading—Descending superficial branches of cervical plexus.
It must be remembered that the boundaries of each area are not distinct; wherever two areas meet they overlap.

The portion of the scalp behind the auricle also receives four cutaneous nerves; laterally it is supplied by the great auricular and small occipital branches of the cervical plexus which contain filaments from the second and third cervical nerves, and medially it receives the great and smallest occipital nerves which are derived from the medial branches of the posterior primary divisions of the second and third cervical nerves respectively.

The Cutaneous Areas of the Face

With the exception of the skin over the posterior part of the masseter muscle, the whole of the skin of the face is supplied by the branches of the trigeminus (figs. 849, 852). The nose is

supplied medially by the supratrochlear, the infratrochlear, and the nasal branches of the ophthalmic division, and laterally by the infraorbital branch of the maxillary division. The upper eyelid is supplied by the supratrochlear, the supraorbital, and the lacrimal branches of the ophthalmic division; the lower eyelid by the infratrochlear branch of the ophthalmic division and by the infraorbital and the zygomaticofacial (malar) branches of the maxillary division. The skin over the upper jaw and the zygomatic (malar) bone is supplied by infraorbital and zygomaticofacial branches of the maxillary division, that over the buccinator by the buccal branch of the mandibular division, and that over the lower jaw, from in front backward, by the mental, buccal, and auriculotemporal branches of the mandibular division, except a small part near the posterior border which receives its supply from the great auricular nerve.

The Cutaneous Areas of the Auricle

The upper two-thirds of the outer surface of the auricle (pinna) are supplied by the auriculotemporal branch of the mandibular division of the trigeminus, and the lower third by twigs of

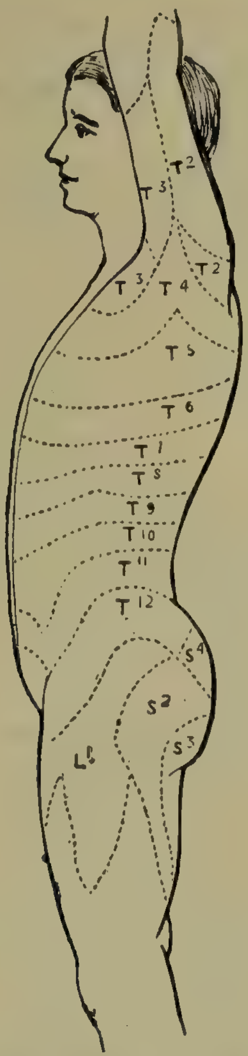


Fig. 850.—Diagram of the Cutaneous Areas of the Side of the Body and Part of the Limb. (After Head.)

the great auricular nerve (fig. 849). The lower three-fourths of the cranial surface of the auricle are supplied by the great auricular nerve, and the upper fourth by the small occipital nerve. The posterior surface of the external auditory meatus receives filaments from the auricular branch of the vagus.

The Cutaneous Areas of the Neck

The skin over the anterior part of the neck (figs. 849, 852) is supplied by the superficial cervical branch of the cervical plexus, which contains fibers from the second and third cervical nerves, and in the lower part of its extent, by the anterior supraclavicular nerves (suprasternal branches), which convey twigs of the third and fourth cervical nerves. The lateral part of the neck receives filaments from the second, third, and fourth cervical nerves by way of the great auricular, small occipital, and middle supraclavicular (supraclavicular) branches of the cervical plexus, and posteriorly the skin of the neck is supplied by the smallest occipital nerve and by the medial branches of the posterior primary divisions of the cervical nerves from the second to the sixth inclusive.

The Cutaneous Areas of the Trunk

The skin over the ventral aspect of the trunk as far down as the third rib is supplied by the anterior supraclavicular (suprasternal) and middle supraclavicular (supraclavicular)

branches of the cervical plexus, which contain filaments from the third and fourth cervical nerves (fig. 852). From the third rib to the lower part of the abdominal wall the skin receives the anterior cutaneous branches, and the anterior divisions of the lateral cutaneous branches of the thoracic nerves except the first, second, and twelfth. The skin over the lower and anterior part of the abdominal wall is supplied by the ilio-hypogastric branch of the first lumbar nerve

The cutaneous supply of the lateral aspects of the body (fig. 850) is derived from the lateral branches of the anterior primary divisions of the thoracic nerves from the second to the eleventh, and the skin over the dorsal aspect of the body is supplied laterally by the posterior divisions of the lateral branches of the thoracic nerves from the third to the eleventh, and medially by the posterior primary divisions of the thoracic nerves, in the upper half by their medial branches and in the lower half principally by their lateral branches.

THE CUTANEOUS AREAS OF THE LIMBS

The areas of skin of the upper and lower limbs which are supplied by the branches of the brachial, lumbar, and sacral plexuses are indicated in fig. 852, and the spinal nerves which contribute to each nerve area are noted. The question of the skin areas supplied by any given spinal nerve is one of great clinical importance, in connection with the diagnosis of injuries of nerves and of pathological conditions affecting them. Therefore, considerable attention has been directed to the matter and it has been found that the areas which become hypersensitive when certain spinal nerve-roots are irritated, or anesthetic when the roots are destroyed, do not correspond exactly with the regions to which the fibers of the roots can apparently be traced by dissection.

Moreover, it has been discovered, partly by clinical observations on the human subject and partly by experiment on monkeys, that the spinal nerves of the limbs have a more or less definite *segmental distribution.* To understand clearly this segmental arrangement the reader must remember that in the embryonic stage when no limbs are present the body is formed of a series

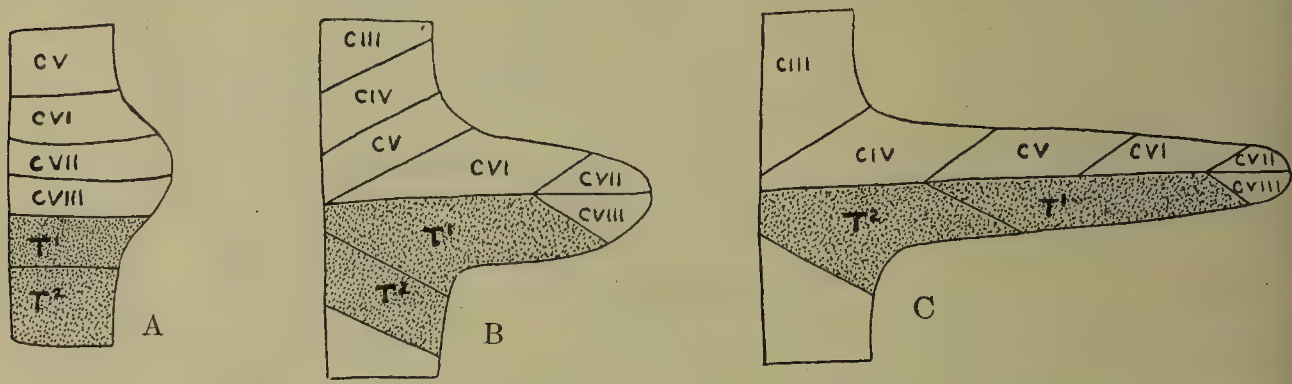


Fig. 851.—Diagrams A, B, and C, Illustrating stages in the projection of the Limb-buds for the upper extremity, and the drawing out of the Nerves of the Corresponding Body Segments for the Cutaneous Areas of the preaxial and postaxial Border of the Limb. Postaxial border shaded.

of similar segments, each of which is provided with its own nerve. At a later stage when the limbs grow outward, each limb is formed by portions of a definite number of segments which fuse together into a common mass of somewhat wedge-like outline. Each rudimentary limb possesses a dorsal and a ventral surface. The dorsal surfaces of both the upper and the lower limbs are originally the extensor surfaces, and the ventral surfaces the flexor surfaces, but, as the upper limb rotates lateralward and the lower limb rotates medianward as development proceeds, in the adult, the extensor surface of the upper limb becomes the posterior surface, and the extensor surface of the lower limb, the anterior surface. The preaxial border of the upper limb is the radial or thumb border, and the postaxial border, the ulnar or little finger border. The preaxial border of the lower limb is the tibial or great toe border, and the postaxial border, the fibular or little toe border. As projections of the segments of the body grow out to form the limb-buds and limbs, each projection carries with it the whole or part of the nerve of the segment to which it belongs, and therefore the number of body segments which take part in a limb is indicated by the number of spinal nerves which pass into it. If these facts are remembered it will naturally be expected (1) that the highest spinal nerves passing into a limb will be associated with its preaxial portion and the lowest with its post-axial portion; (2) that only the nerves of those segments forming middle or central portions of the limbs will extend to the tips of the limbs; (3) that the highest and lowest segments in each limb area will take a smaller part in the formation of the limb than the middle segments; and (4) that, consequently, the highest and lowest nerves will pass outward into the limb for a shorter distance than the middle nerves. Observers are not yet in perfect agreement as to the exact distribution of each nerve, but the diagrams in figs. 850 to 856 show the embryonic derivation of the cutaneous areas and the adult dorsoventral segmental arrangement in the projected portions of both the upper and lower limbs as assumed from clinical observations. In the upper parts of the lower limbs, the original segmental distribution appears to be masked. This may be due (1) partly to the fact that the areas recognizable by clinical phenomena do not correspond exactly with the areas to which definite dorsal root-fibers are distributed, but rather to definite segments of the gray substance of the spinal cord with which the root-fibers are connected; (2) partly to the overlapping of segments and the acquired preponderance of one nerve over another in the overlapping areas, and (3) partly to the fact that in the lower limb there has been a greater amount of shifting of parts to result in the fixed flat position of the sole of the foot; (4) and partly to the incompleteness of the data which are at our disposal in the case of the human subject. Sherrington has

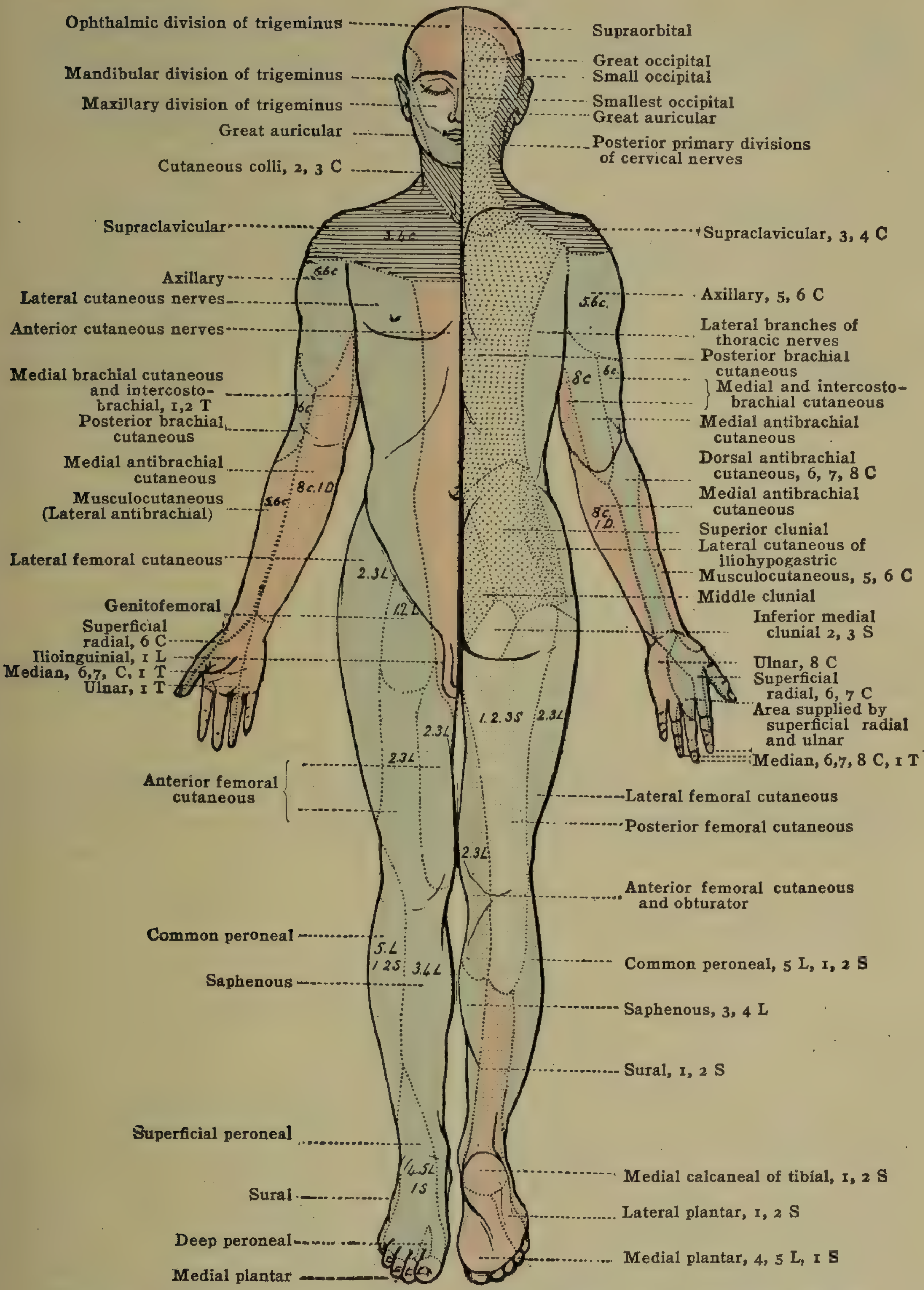


FIG. 852.—DIAGRAM SHOWING AREAS OF DISTRIBUTION OF CUTANEOUS NERVES.

HEAD:—RED—Ophthalmic division of trigeminus. White—maxillary division of trigeminus. Blue—mandibular division of trigeminus. Dotted area—Posterior primary division of cervical nerves. Oblique and transverse shading—Branches of cervical plexus.

BODY AND LIMBS:—RED—Anterior branches of anterior primary divisions. Blue—Posterior branches of anterior primary divisions. Two colors in one area indicate that the area is supplied by two sets of nerves, and it should be remembered that wherever two nerve areas approach each other they overlap. The dotted blue area of the posterior femoral cutaneous (small sciatic) indicates that the nerve comes from the posterior as well as from the anterior parts of the anterior primary divisions of the sacral nerves, but it supplies a flexor area. The area of the inferior medial cluneal nerve is left uncolored, because its true nature is uncertain. Dotted shading—posterior primary divisions. The numbers and initial letters refer to the respective spinal nerves from which the nerve-supplies are derived.

proved that in the monkey the sensory areas of the limbs are arranged in serial correspondence with the spinal nerves, the middle nerves of each limb series passing to the distal parts of the extremity while the higher and lower nerves are limited to the proximal regions. Thorburn's observations, which differ from Head's, are, especially as regards the upper limb, in close conformity with the results obtained by Sherrington's experiments on monkeys.

Each limb may be divided into its preaxial and postaxial borders by a line drawn longitudinally along the middle of both its anterior and posterior surfaces (compare figs. 851 and 854).

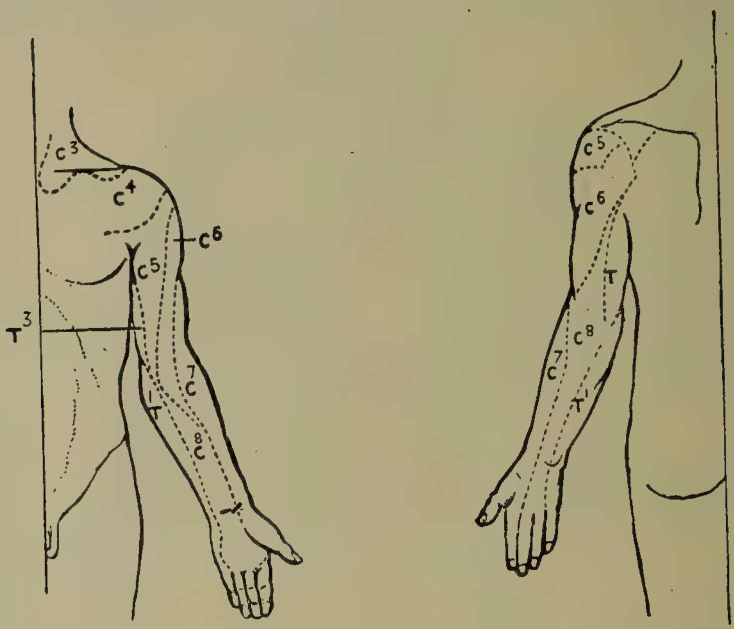


Fig. 853.—Diagram of the Cutaneous Areas of the Upper Extremity. (Modified from Head.)

The cutaneous nerves to the preaxial border are from the cephalic portion of the limb plexus and those to the postaxial are from the caudal components of the plexus. Thus the thumb and index finger are cephalad.

The Cutaneous Areas of the Upper Limb

A line passing along the middle of both the anterior and posterior surfaces of the upper extremity to the tip of the middle finger (fig. 854) separates the preaxial from the postaxial border and passes longitudinally along the area of the cutaneous fibers derived from the seventh cervical nerve.

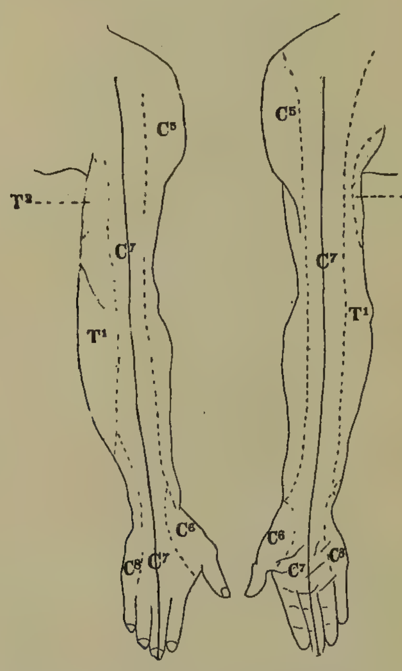


Fig. 854.—Diagram of the Cutaneous Areas of the Upper Extremity. The solid middle lines are drawn to separate preaxial (radial) borders from postaxial borders. (After Thorburn, modified.)

The skin over the upper third of the deltoid muscle is supplied by the posterior supraclavicular (supra-acromial) and middle supraclavicular (supraclavicular) nerves, which are branches of the cervical plexus containing fibers of the third and fourth cervical nerves, and that over the lower two-thirds by the axillary (circumflex) nerve which conveys fibers of the fifth and sixth cervical nerves (fig. 852).

The skin over the lateral surface of the upper arm is supplied externally by the axillary (circumflex) nerve above, and below by the superior branch of the dorsal antibrachial cutaneous, the external cutaneous branch of the radial (musculospiral) nerve. The former contains

filaments of both the fifth and sixth cervical nerves, and the latter filaments of the sixth alone. The skin of the medial side of the upper arm is supplied by the medial antibrachial cutaneous (internal cutaneous) nerve with fibers of the eighth cervical and first thoracic nerves, and by the medial brachial cutaneous (lesser internal cutaneous) and intercostobrachial (intercostohumeral) nerves which are derived from the first and second thoracic nerves. The dorsal side of the upper arm is supplied, laterally, by the fifth and sixth cervical nerves through the axillary (circumflex) nerve and by the dorsal antibrachial cutaneous; the middle portion, by the seventh cervical nerve through the posterior brachial cutaneous, the internal cutaneous branch of the radial (musculospiral) nerve; and the medial portion by the first and second thoracic nerves through the medial brachial cutaneous (lesser internal cutaneous) nerve, and the intercostobrachial (intercostohumeral) nerve (fig. 851).

The front of the forearm is divided into three areas, a lateral which is supplied by the fifth, sixth, and possibly the seventh cervical nerves, through the musculocutaneous branch of the brachial plexus; a middle which is supplied by the seventh cervical nerve as above, and a medial area supplied by the eighth cervical and first thoracic nerve through the medial antibrachial cutaneous (internal cutaneous) nerve. On the dorsal side of the forearm there are three areas:—(1) a lateral supplied by fibers of the fifth and sixth cervical nerves through the musculocutaneous nerve; (2) a middle, which receives fibers of the seventh, and probably some from the sixth and eighth cervical nerves through the lower branch of the dorsal antibrachial cutaneous branch of the radial (inferior external cutaneous branch of the musculospiral nerve), and (3) a

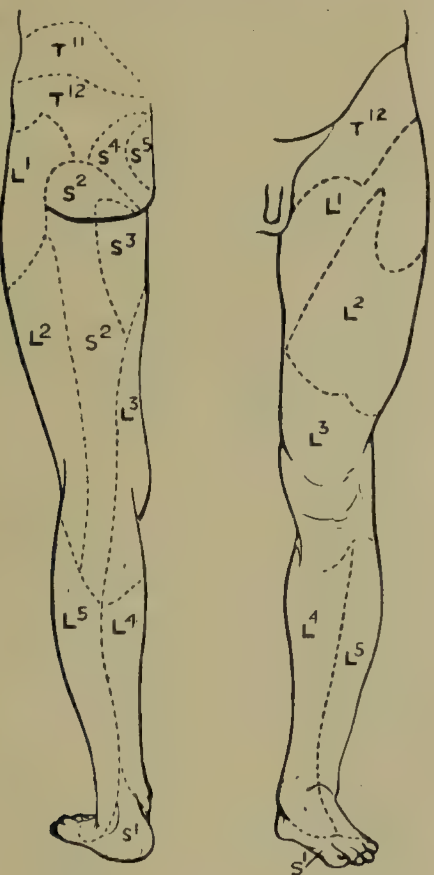


Fig. 855.—Diagram of the Cutaneous Areas of the Lower Extremity. (After Head.)

medial which receives fibers from the eighth cervical and first thoracic nerves through the medial antibrachial cutaneous (figs 852, 854).

The palm of the hand is supplied by the sixth, seventh, and eighth cervical nerves through the superficial radial (radial) nerve, and through the median and ulnar nerves. The superficial radial supplies the radial side of the thumb by its palmar cutaneous branch. The remainder of the palm and the palmar aspects of the fingers are supplied by the median and ulnar nerves through their palmar cutaneous and digital branches, the median supplying three and a half digits and the ulnar the remaining one and a half (figs. 831, 852 and 854).

The dorsal aspect of the hand is supplied by the sixth, seventh, and eighth cervical nerves, which reach it through the superficial radial (radial) and through the median and ulnar nerves. The superficial radial supplies the lateral part of the dorsum and the lateral three and a half digits, except the lower portions of the second, third, and half of the fourth digits, which receive twigs from the median nerve; the ulnar nerve supplies the ulnar half of the dorsum of the hand, including the medial one and a half digits. The areas supplied by definite spinal nerves according to the observations of Head and Thorburn, are shown in figures 853 and 854 respectively.

The Cutaneous Areas of the Lower Extremity

The segmental arrangement of the cutaneous areas of the lower extremity is not so well retained as in the upper, due largely to a greater amount of developmental shifting of the parts. Both of the lines separating the areas of the lumbar (cephalic) and the sacral (caudal) parts of the lumbosacral plexus lie on the dorsal aspect of the limb. The nerves from the lumbar part of the plexus are distributed to the entire anterior and the medial and lateral surfaces of the limb and to the muscles of the anterior and medial portions of the thigh and the anterior

portion of the leg, whereas the cutaneous nerves from the sacral part of the plexus are confined to a narrow strip along the dorsal aspect of the limb (fig. 856). However, the muscular distribution of the sacral part is as much expanded as its cutaneous area is contracted; it supplies the muscles in the dorsal portions of the hip, thigh and knee, the whole of the dorsal part of the leg and ankle and the plantar muscles of the foot.

Areas of the buttock.—There are six cutaneous areas comprising the region of the buttock, three upper and three lower (figs. 852 and 855). Of the three lower areas the lateral is a strip supplied by lateral twigs of the lateral femoral cutaneous nerve (fibers from the first, second and third lumbar nerves), and extending downward from the dorsal side of the great trochanter. The middle of the lower areas is supplied by fibers from the first, second and third sacral nerves via twigs from the posterior femoral cutaneous (small sciatic) nerve which pass over the inferior border of the gluteus maximus and turn to this area. The medial of the lower three areas is supplied by fibers from the second and third sacral nerves through the medial inferior cluneal nerves of the sacral plexus. Of the upper three areas of the buttock, the lateral is supplied by fibers from the anterior primary divisions of the last thoracic and first lumbar nerves via the iliac branches of the last thoracic and the iliohypogastric nerves; the middle upper area by fibers from the lateral branches of the posterior primary divisions of the upper three lumbar nerves which, as branches of the superior cluneal nerves, cross the dorsal part of the iliac crest at the lateral margin of the sacrospinalis. The medial of the upper areas is supplied by twigs from the lateral branches of the posterior primary divisions of the upper two or three sacral

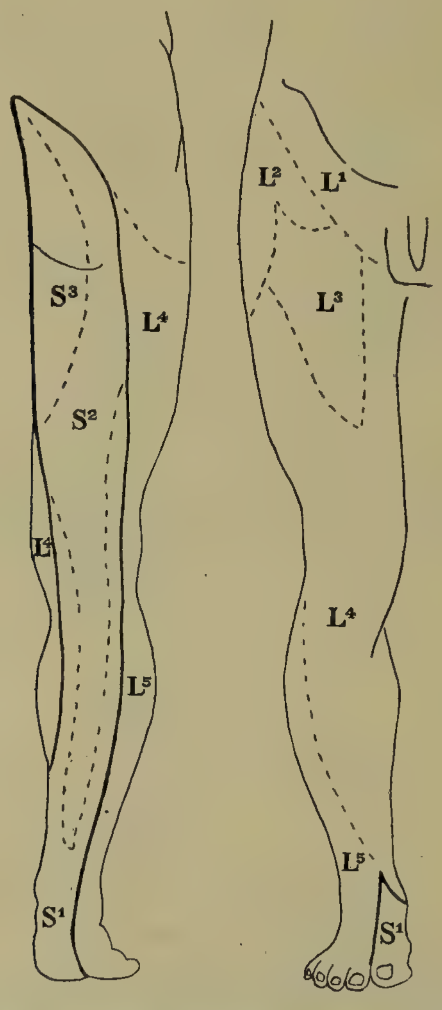


FIG. 856.—DIAGRAM OF THE CUTANEOUS AREAS OF THE LOWER EXTREMITY. (After Thorburn, modified.)

nerves, reaching it as the middle cluneal nerves (fig. 852). The skin of the buttocks is not so delicately sensitive as most other surfaces of the body.

On the back of the thigh there are three areas. According to Head, the medial and lateral areas are supplied by the second and third lumbar nerves, the latter through the lateral femoral cutaneous (external cutaneous) branch of the lumbar plexus, and the former through the anterior cutaneous branches of the femoral (internal cutaneous branch of the anterior crural) nerve. The middle area receives twigs from the first, second, and third sacral nerves through the posterior femoral cutaneous (small sciatic), a branch of the sacral plexus.

The front of the thigh is supplied by the first, second, and third lumbar nerves, and, according to Head, there are five cutaneous areas. The lateral area receives twigs of the second and third lumbar nerves through the lateral (external) cutaneous nerves. There are two medial areas, an upper and a lower. The former is supplied by the lumboinguinal (crural) branch of the genitofemoral (genitocrural), which conveys twigs of the first and second lumbar nerves; the latter receives fibers of the second and third lumbar nerves through one of the anterior (middle) cutaneous branches of the femoral (anterior crural) nerve. The small upper and medial area is supplied by the first lumbar nerve through the ilioinguinal, and the lower medial area receives twigs of the second and third lumbar nerves through one of the anterior cutaneous branches (internal cutaneous) of the femoral (anterior crural) nerve (fig. 852).

The front of the knee is supplied by the second, third, and fourth lumbar nerves through the anterior (middle and internal) cutaneous and saphenous (long saphenous) branches of the femoral (fig. 852).

Of the skin over the region of the popliteal space, the medial portion receives fibers from the second, third, and fourth lumbar nerves through the anterior (internal) cutaneous branch of the femoral (anterior crural) nerve and through the superficial division of the obturator nerve; the middle and lateral portion receives twigs of the first three sacral nerves through the posterior cutaneous (small sciatic) nerve (fig. 852).

The skin over the front and medial side of the leg is supplied by the fourth lumbar nerve through the saphenous nerve, and the skin of the front and lateral side receives nerve-fibers from the fifth lumbar nerve through the sural cutaneous (fibular communicating) branch of the common peroneal (external popliteal) nerve.

In the skin of the back of the leg four areas can be distinguished, a medial, two middle, upper and lower, and a lateral area. The medial area is supplied by the fourth and fifth lumbar nerves through an anterior cutaneous branch (internal cutaneous) of the femoral (anterior crural) nerve and the superficial branch of the obturator nerve. The upper middle area is supplied by the second and third sacral nerves through the posterior femoral cutaneous (small sciatic) nerve, and the lower middle area by the first sacral nerve through the sural (external saphenous) nerve. The lateral area is supplied by the fifth lumbar nerve through the lateral sural cutaneous (fibular communicating) branch of the common peroneal (external popliteal) nerve (figs. 852, 855, 856).

The skin of the dorsum of the foot is supplied principally by the fifth lumbar and by the first sacral nerves; the majority of the nerve-fibers travel by the superficial peroneal (musculocutaneous) nerve, but the adjacent sides of the first and second toes are supplied by the femoral (anterior crural) nerve and the side of the dorsum of the little toe is supplied through the sural (external saphenous).

The skin of the region of the heel is supplied by the first sacral nerve, the medial surface and medial part of the under surface by the medial calcaneal branches of the tibial (calcaneoplantar) nerve and the posterior, external, and lower aspects by the sural (external saphenous) nerve (fig. 852).

The sole of the foot in front of the heel receives cutaneous fibers from the fifth lumbar and the first sacral nerves; the medial area, which includes the medial three and a half digits, being supplied by the medial plantar nerve which conveys fibers of the fifth lumbar and the first sacral nerves; and the lateral area by the fifth lumbar nerve through the lateral plantar nerve.

The medial side of the foot is supplied by the first sacral and fourth lumbar nerves through the saphenous nerve and the lateral side by the fifth lumbar nerve through the sural (external saphenous) nerve.

The skin of the scrotum and penis is supplied by the first lumbar nerve through the ilio-inguinal nerves, and by the second and third sacral nerves through the perineal and dorsal penile branches of the pudendal (pudic) nerve.

The cutaneous areas of the lower extremity which have been demarcated by Head and Thorburn are shown in fig. 855. These do not conform wholly with each other nor with the areas given in more detail in fig. 852, due probably to individual differences in subject and observer and to the difficulties coincident with the overlapping of the areas. Fig. 856 is more general in character but is considered more approximately correct.

The **homology of the parts of the plexuses** of the upper and lower extremities is not well carried out in the distribution of the nerves. The radial and great sciatic nerves are similar to the extent that the one arises from the posterior cord of the brachial plexus and the other from the sacral plexus, and that the one is distributed to the dorsal aspect of the arm and the other to the dorsal surface of the lower extremity, but the great sciatic supplies the sole of the foot, and the plantar muscles, whereas the radial does not supply the palm of the hand and the palmar muscles.

THE SYMPATHETIC SYSTEM

The so-called sympathetic system is that collateral division of the peripheral nervous system which is especially concerned in the distribution of impulses to all glands, to the muscle of the heart, and to the smooth muscular tissue of the body (including that of blood- and lymph-vessels, of the digestive, respiratory and urogenital apparatuses, integument, etc.). Since these tissues are most abundant in and largely comprise the viscera or splanchnic organs of the body, the largest and most evident of the structures comprising the sympathetic system proper are found either in or near the cavities containing the viscera. However, the finer divisions of the system ramify throughout the whole body, supplying vasomotor fibers to the blood-vessels throughout their course, controlling the glands of the skin, supplying pilomotor fibers for the hairs, secretory fibers to all glands and forming intrinsic plexuses within the walls of the viscera. Though it seems probable that certain of the simpler reflexes of the splanchnic organs may be mediated by the sympathetic system alone, yet the sympathetic is by no means independent of the craniospinal system, but is rather, both anatomically and functionally merely a part of one continuous whole. Throughout, it shares its domain of termination with craniospinal fibers, chiefly of the sensory variety, and most of its rami and terminal branches carry a few craniospinal fibers toward their respec-

tive areas of distribution. Likewise the craniospinal nerves carry numerous sympathetic fibers gained by way of rami connecting the two systems.

The term 'sympathetic system' was first suggested almost entirely on the basis of observations made in gross dissections and it implied all those parts of the peripheral system not included as the cranial and spinal nerves and their dissectible branches. With advances in physiology and microscopic anatomy, the term, never accurately expressive, became a cause of confusion. Substitute names were offered, such as vegetative nervous system, sympathetic system proper, autonomic system, etc. Sympathetic system proper implies all neurones whose cell bodies are situated in the sympathetic ganglia, any ganglia outside the central system other than those involved in the sensory roots of the spinal and cranial nerves. Autonomic nervous system is defined below.

Like the craniospinal system, the sympathetic system proper consists of cell-bodies, each of which gives off one axone. In addition, the cell-bodies give off numerous dichotomously branched dendrites by which their receptive surfaces are increased, and they are accumulated into ganglia, large and small. The larger ganglia have more or less constant positions, shapes, and arrangements, while the smaller, some of which are microscopic, are scattered throughout the body in a seemingly more indefinite manner. The axones or fibers arising in these sympathetic ganglia are given off in trunks and rami which associate the ganglia with each other or with the craniospinal system, or which pass from the ganglia to be distributed directly upon their alotted elements.

The **sympathetic fibers** arising from the ganglia are, for the most part, either totally non-medullated or partially medullated. Some fibers are completely medullated near their cells of origin, but lose their medullary sheaths before reaching their terminations. Some of them possess complete medullary sheaths throughout, but in no cases are the sheaths as thick or well developed as is the rule with the medullated craniospinal fibers. Thus, nerve-trunks and rami in which sympathetic fibers predominate appear grayish in color and more indefinite, as distinguished from those of the craniospinal nerves, which always appear a glistening white, due to light being reflected from the emulsified myelin of the sheathes of their fibers.

Origin of the sympathetic system.—Not only must the craniospinal and sympathetic systems be considered anatomically continuous and dependent, but also the neurones of the two systems have a common origin, namely, the ectoderm of the dorsal midline of the embryo. The cells of the ganglion crest (see p. 829 and fig. 676) form segmental groups and soon separate into two varieties:—those which will remain near the spinal cord and develop into the spinal ganglia, and those which, during the growth processes, migrate and become displaced further into the periphery and form the sympathetic ganglia.

In the development of the sympathetic system proper the migration from the vicinity of the central system occurs to varying extents, so that in the adult the cells comprise three general groups of ganglia situated different distances away from the central nerve axis.—(1) A large portion of the cells remain near the central system and form a linear series of ganglia which, with the trunks connecting them, become two gangliated *sympathetic trunks* extending along each side, proximal to and parallel with the vertebral column; (2) a still larger portion of the cells migrate further toward the periphery and are accumulated into *collateral ganglia* which assume an intermediate position and which, with the rami associating them with each other and with other structures, form a series of great *prevertebral plexuses*, such as the aortic, cardiac and celiac plexuses; (3) still other cells wander even further away from the locality of their origin and invade the very walls of the organs innervated by the sympathetic system. The latter cells occur as numerous small *terminal ganglia*, most of which are microscopic and which, with the twigs connecting them, form the most peripheral of the sympathetic plexuses. Examples of these are the intrinsic ganglia of the heart and pancreas and the *plexuses of Auerbach* and *Meissner* in the walls of the digestive canal. Small, straggling ganglia may be found scattered between these three general groups. In the head, the sympathetic trunks and great prevertebral plexuses are represented by the ciliary, sphenopalatine, otic and submaxillary ganglia and the plexuses associated with these.

Functional construction of the sympathetic system.—The sympathetic ganglia may be considered as relays in the pathways for the transmission of impulses from the region in which they arise to the tissues in which they are distributed; the cells composing the ganglia are the cell-bodies of the sympathetic neurones interposed in the various neurone chains performing this function. A fiber arising from a cell-body in a given ganglion may pass out of the ganglion and proceed directly to its termination upon a smooth muscle-fiber or gland-cell, or, fibers arising in given ganglia may pass uninterrupted through other ganglia in proceeding to their respective destinations. Several neurones, only one being sympathetic, may be involved in the transmission of a given impulse when sent from a region distant from the tissue to which it is distributed.

The sympathetic neurones receive their impulses by synapsis with fibers originating in the central system and these fibers, since they transmit impulses from the central to the sympa-

thetic are known as *visceral efferent or preganglionic fibers*. In contrast, the axones arising from sympathetic ganglion cells are termed *postganglionic fibers*. In one sense, preganglionic and postganglionic are not literally descriptive since a preganglionic fiber may pass through one or more sympathetic ganglia before reaching that in which it actually terminates and, likewise, a postganglionic fiber may pass through or over other sympathetic ganglia in proceeding from

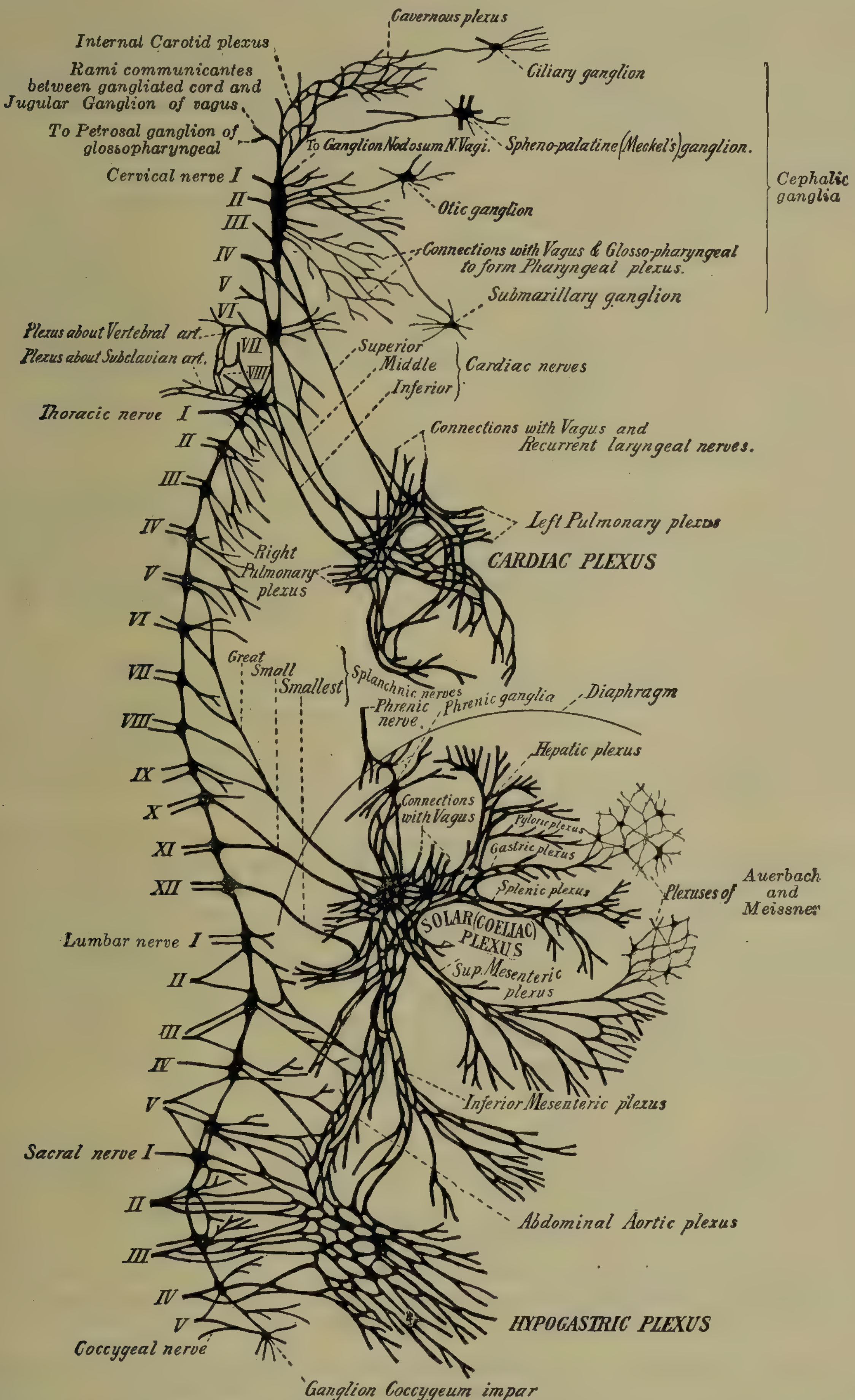


FIG. 857.—SCHEME SHOWING GENERAL PLAN OF THE COARSER PORTIONS OF THE SYMPATHETIC NERVOUS SYSTEM AND ITS PRINCIPAL COMMUNICATIONS WITH THE CEREBROSPINAL SYSTEM. (After Flower, modified.)

that of its origin to the tissue of its destination. Applied to peripheral relations only, the terms presynaptic and postsynaptic would more explicitely describe the functional sequence. The statement is quite generally accepted that, in that part of a neurone chain which bears impulses from the central system to the tissues of the domain of the sympathetic, only one sympathetic neurone is interposed, the other link being the visceral efferent fiber.

Communication between the central nervous system and the sympathetic is established through both efferent and afferent fibers. In the region of the spinal cord both varieties of fibers pass from one system to the other by way of the **rami communicantes**, delicate bundles of fibers connecting the nearby sympathetic trunk with the respective spinal nerves (fig. 818). The cranial nerves are likewise abundantly associated with the gangliated cephalic sympathetic plexuses.

The efferent visceral fibers of the rami arise in the ventral horn (dorsolateral cell-group chiefly) of the spinal cord, emerge through the ventral roots, enter the rami, and terminate about the cells of the sympathetic ganglia. They are of smaller size than is the average for the craniospinal somatic efferent fibers of the ventral root.

The thoracic and lumbar spinal nerves are each connected with the sympathetic trunk by two rami communicantes. Most of both the visceral efferent and also the visceral afferent fibers (which latter arise in the spinal ganglia) pass by way of one ramus. These fibers are of craniospinal type and, being medullated, they give the ramus a white appearance meriting the name, **white ramus communicans.** Fibers of the sympathetic type predominate in the second ramus, the **gray ramus communicans.** The latter consists of (1) fibers centrally directed in the nerve and nerve roots to the blood-vessels of the central nervous system and (2) fibers which join the primary divisions of the nerve trunk and course in them to the peripheral tissues allotted to the sympathetic (fig. 818). The cervical nerves have gray rami but no distinct white rami.

That the cervical nerves have no white rami communicantes is probably due to an arrangement by which at least most of the visceral efferent fibers arising in the cervical segments of the spinal cord pass downward in these segments and join the sympathetic through the white rami of the upper thoracic nerves; others enter the cervical sympathetic trunk and the vagus nerve through the spinal accessory or eleventh cranial nerve, rather than through individual white rami, while others pass into the nerves of the brachial plexus to terminate in the minute ganglia of the plexuses upon the blood-vessels of the limb.

Vasomotor fibers to the intrinsic blood-vessels of the meninges and of the spinal cord proper pass to the spinal nerves by way of the gray rami. Thence they may reach the meninges by one of three ways:—(1) through the delicate recurrent or meningeal branch of the spinal nerve (fig. 818); (2) through the trunk and ventral root of the spinal nerve; (3) probably more rarely, through the trunk and dorsal root of the spinal nerve (fig. 858).

Corresponding communications exist between the cranial nerves and the sympathetic, but the corresponding rami usually extend further toward the periphery and in not so regular a manner as the communications between the spinal nerves and the sympathetic system. The mesencephalon, for example, is chiefly connected with the ciliary ganglion of the sympathetic by fibers which are sent through the oculomotor nerve and which enter this ganglion by way of its short root and terminate about its cells. Visceral efferent fibers from the rhombencephalon pass outward to the sympathetic in the roots of the facial, glossopalatine, glossopharyngeal, vagus, and spinal accessory nerves, all of which have more or less irregularly disposed communicating rami. Likewise twigs of other cranial nerves, especially of the trigeminus, connect with (pass through) the small sympathetic ganglia of the head. The meningeal branches given by certain of the cranial nerves contain vasomotor fibers, and these correspond to the sympathetic fibers in the meningeal rami and in the roots of the spinal nerves.

It is known that spinal ganglia and certain of the ganglia of the cranial nerves contain cell-bodies of sympathetic neurones—cell-bodies which, during the period of the migration peripheralward, remained within the confines of these ganglia (fig. 818). These cell bodies receive efferent impulses from ventral root fibers and send their axones further into the periphery just as if in the sympathetic ganglion. Their relative abundance is not known. It is supposed that the ganglia of the vagus, glossopharyngeus, trigeminus and the geniculate ganglion contain a considerable proportion of such sympathetic cell-bodies.

Components of sympathetic nerves.—It must be kept in mind that, while the more ordinary anatomical usage differentiates the craniospinal system from the sympathetic, yet in relationships and distribution there is actually an intimate functional association between the two varieties of peripheral nerve fibers. In the ordinary dissections this is made evident by the numerous communications between the craniospinal and the sympathetic nerves, and in the more minute study by the comprehensive distribution of craniospinal fibers by way of the sympathetic paths and the distribution by way of the craniospinal nerves of fibers originating in sympathetic ganglia. Incorporated in that division of the system originally termed sympathetic, three varieties of neurones are represented. These include (1) **sympathetic neurones proper,** cell bodies housed in the sympathetic ganglia, large and small (including the cephalic ganglia), whose axones transmit motor and inhibitory impulses for cardiac and all the smooth muscle of the body and control the secretion of all glands. Also, they may supply acces-

sory innervation to skeletal muscle. These neurones may be confined wholly within the sympathetic system or, as in the case of certain of the cell bodies in the ganglia of the sympathetic trunk and in the cephalic ganglia, their axones may pass via their rami into the craniospinal nerves to reach their distribution. (2) The **visceral efferent** fibers above mentioned are craniospinal fibers invading the sympathetic system. These arise from the intermediolateral cell group of the gray substance of the spinal cord (dorsolateral group of the ventral horn) and from certain cell bodies of the nuclei of origin of several cranial nerves and pass by way of the motor roots and white rami or the trunks of the craniospinal to terminate finally by synapsis upon the cells of sympathetic neurones situated either in the ganglia of the sympathetic trunk, the collateral ganglia, or the terminal ganglia of the sympathetic. (3) **Visceral afferent** or sensory fibers originate as the peripheral processes of spinal ganglion cells and cells of the ganglia of sensory cranial nerves, which fibers pass via white rami communicantes or in the trunks of the nerves to the domain of the sympathetic to collect there impulses aroused in the glands

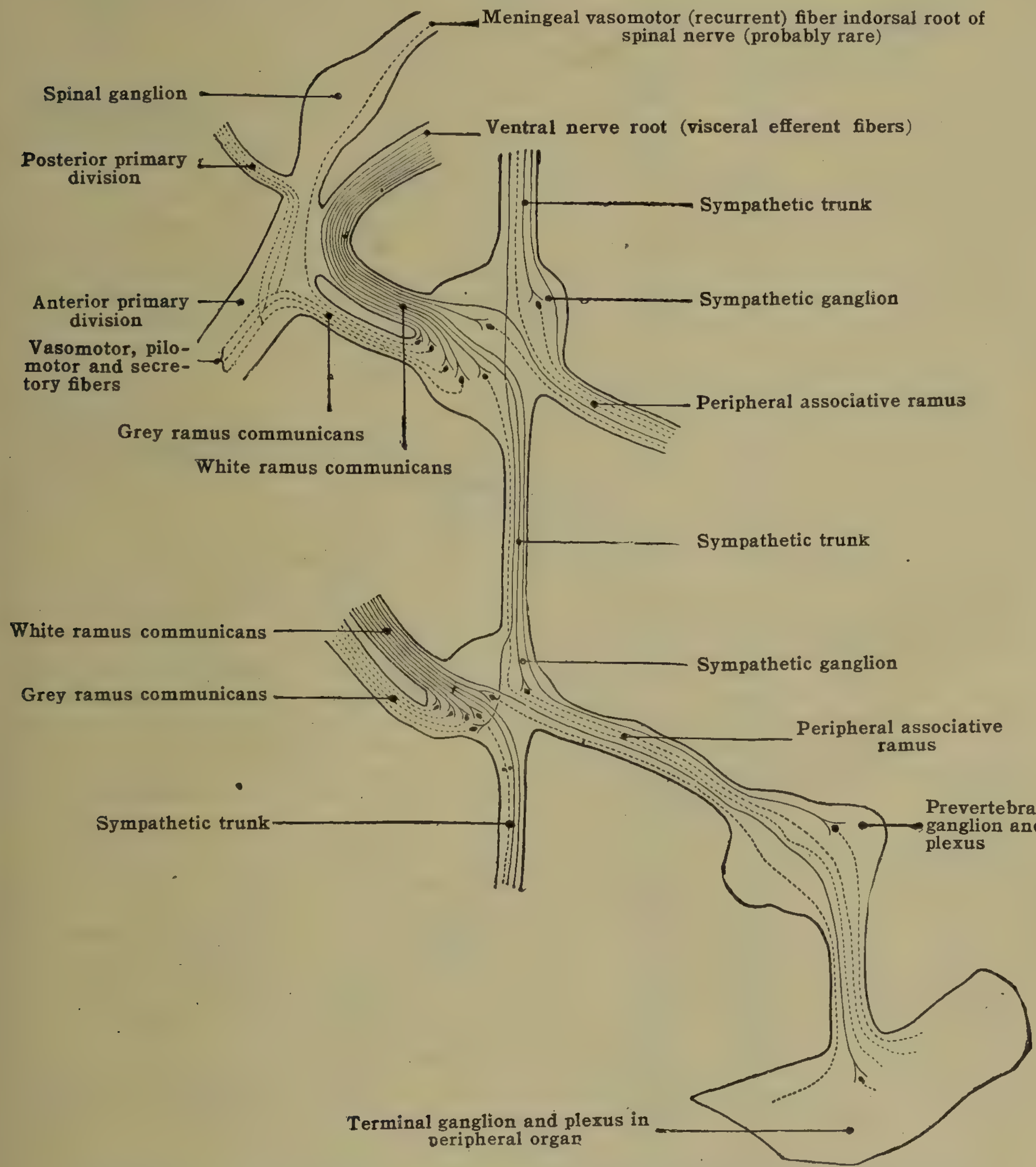


Fig. 858.—Diagram Suggesting the Origin, Course and Connections of Sympathetic Nerve-fibers, Visceral Afferent (Sensory) Fibers Omitted.

epithelium and smooth muscle of the body, especially those of the thoracic and abdominal viscera. The impulses they bear include those giving rise to enteroceptive sensations. Naturally, these axones pass through the sympathetic ganglia without interruption. Their chief service is that of links in visceral reflex chains. Sensations aroused in the central system by the impulses they bring are for the most part vague and indefinite as to location of source. Most of them do not enter consciousness at all. However some do attain sensory areas of the cerebral cortex to be interpreted as violent sensations, often sensations of pain as may result from impulses aroused in the parotid gland, gall bladder, kidney, ureter, etc. The cranial nerves carrying most of the visceral afferent fibers are the trigeminus, vagus and glossopharyngeus. While numerous in the white rami, they are less abundant than the visceral efferent fibers. There is no confirmed evidence (as was once claimed) of sensory fibers arising from any cells of sympathetic ganglia.

The autonomic nervous system.—Corresponding to the levels of the central system in which their cells of origin lie and according to the sympathetic ganglia in which they terminate, the visceral efferent fibers issue from the central axis in three general streams (fig. 859):—

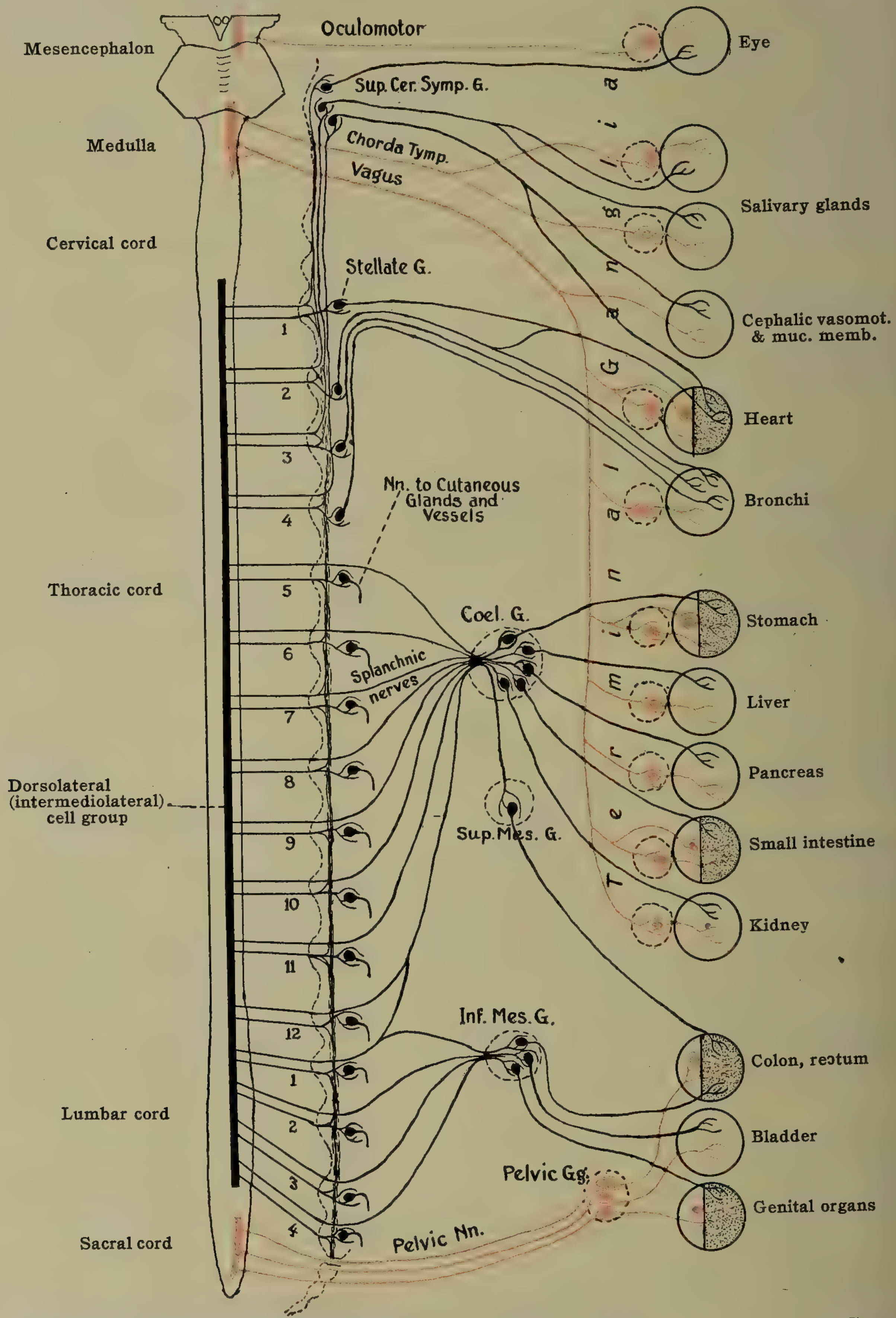


Fig. 859.—Diagram of the Origins, Course and Terminal Relations of the Two General Streams of the Autonomic Nervous System. Visceral Sensory Fibers are Omitted. Black, the Thoracolumbar Stream, Chiefly Vasomotor and Secretory; Red, the Craniosacral Stream, Partly Inhibitory. (From Meyer and Gottlieb, modified.)

(1) A **thoracolumbar stream,** comprising visceral efferent fibers which pass from their origin in the spinal cord almost wholly by way of the white rami from the first thoracic to the second lumbar spinal nerves inclusive and terminate (transfer their impulses) for the most part in the ganglia of the sympathetic trunk. Many terminate in the collateral ganglia of the prevertebral plexuses. None are thought to terminate in the terminal ganglia. Of those terminating in the ganglia of the trunk, some terminate in the nearest ganglia or those corresponding to their respective spinal nerves. Others enter the trunk to ascend or descend in it and terminate in the ganglia of higher or lower levels. In general, fibers in the white rami to

the upper part of the stream run upward in the trunk, and those to the lower part run downward. The medullated fibers of the sympathetic trunks consist largely of these ascending and descending fibers. Fibers arising from the cells of the ganglia of the trunks pass out either by way of their peripheral branches or, by way of the gray rami, join the divisions of the spinal nerves to course to their destinations in the terminal branches of these divisions.

(2) **A sacral or pelvic stream,** which arises within the sacral segments of the spinal cord and emerges almost wholly by way of the white rami of the second, third and fourth sacral nerves, usually chiefly by way of those of the second and third or third and fourth. The visceral efferent fibers of this stream do not terminate in the ganglia of the trunk, but either pass by them without connection, or over or through them without interruption to terminate chiefly in the terminal ganglia of the sympathetic. Some few may terminate in the collateral ganglia of the hypogastric plexus.

(3) **A cranial stream.**—The visceral efferent fibers arising from the brain pass outward almost entirely by way of the oculomotor, glossopalatine, facial, glossopharyngeal, vagus and spinal accessory nerves. These fibers terminate not only in the ganglia of the cephalic sympathetic plexus but also in the terminal ganglia of the thoracic and abdominal viscera.

Were the four pairs of the larger cephalic ganglia considered as parts of upward extensions of the sympathetic trunks of either side by way of the superior cervical sympathetic ganglion and its branches, then the cranial stream would be similar in part to the thoracolumbar stream. However, the cephalic ganglia are classed as terminal ganglia. Most of the visceral efferent fibers of the oculomotor, glossopalatine and facial nerves, and some of those of the glossopalatine and probably a few of the vagus, terminate in these cephalic ganglia. On the other hand, a very large proportion of those in the spinal accessory and vagus are not concerned at all with the cephalic ganglia, large or small, but course to terminate in the terminal ganglia below, far removed from the region of the head. The sympathetic trunk being considered as ending above with the superior cervical sympathetic ganglion and its branches of distribution to the head, thus placing the cephalic ganglia among the terminal ganglia, makes the visceral efferent fibers of the cranial nerves similar in distribution to those of the sacral stream. Therefore, it is possible to refer to only two general streams, *a thoracolumbar* and *a craniosacral stream* (fig. 859).

There are functional distinctions between the thoracolumbar and craniosacral streams. By way of them the visceral organs receive a double innervation, one regulating contractions of cardiac and smooth muscle, such as rhythmic and vasoconstrictor, pilomotor and peristaltic activities, and the functioning of glands, the other inhibiting these. Also, by one stream muscular contractions may be excited antagonistic to the contractions excited by the other. As an example of the latter, the pupil is contracted by way of the cranial stream and its dilation may be accomplished by way of the thoracolumbar stream. 'Inhibitory fibers' are not wholly confined to either stream. The craniosacral stream carries fibers inhibitory to the heart (vagus fibers) and fibers which excite the smooth muscle of the digestive apparatus, while the thoracolumbar stream carries accelerator fibers for the heart and fibers inhibiting peristalsis in the stomach and intestine. Possibly inhibitory fibers may be classed with secretory visceral efferent fibers, fibers of reflex chains, acting with depressor (sensory) fibers, inducing the production of a substance in the tissues concerned (some antihormone, acetylcholine?) which renders the muscle incapable of contracting.

In recognition of these functional distinctions between the two streams, the name, '*sympathetic system,*' has been allotted to the visceral efferent neurones of the thoracolumbar stream, together with the sympathetic ganglion neurones with which they may synapse; and the name, '*parasympathetic system,*' has been given in contrast to the neurones of the craniospinal stream, together with the sympathetic neurones with which the fibers of this stream make synapses.

The term '*autonomic nervous system,*' was suggested by Langley as a collective designation for these two streams of visceral efferent fibers, together with the sympathetic neurones with which they make synapses. Thus the term is inclusive of the sum total of all the craniospinal visceral efferent neurones (preganglionic fibers, thoracolumbar and craniosacral) and all the sympathetic neurones in the body. The name must include those postganglionic fibers which arise in sympathetic ganglia and enter and course to their destinations in the trunks and branches of the craniospinal nerves; that is, it includes the entire efferent innervation of all glands and all cardiac and smooth muscle. It must include also the cell bodies situated in the spinal cord and brain which give rise to the visceral efferent fibers. In microscopical anatomy, these latter belong to the central nervous system. While this division of the nervous system designated 'autonomic' is not 'selfcontrolling' or 'independent' and is as misleading as to function implied as the old term, 'sympathetic,' physiologists have used the term in honor of Langley and the work he has done. It is anatomically more comprehensive and a better physiological name has not been found.

Myenteric visceral (*local enteric*) *reflexes.*—The above descriptions have to do with reflex chains operating through the central nervous system via the visceral efferent fibers issuing from it and linked with postganglionic fibers. There is evidence that purely local reflexes are possible within the visceral organs, such as the intestine. If such arcs exist they must lie within the terminal ganglionated plexuses (of Auerbach and Meissner in the wall of the gut) and their neurones must be in addition to the postganglionic neurones. In exercising a local, independent regulatory control, they must comprise an anatomical mechanism different from that of all other reflex arcs, but the mechanism is unknown. Herrick suggests that their neurones may be related in the form of a nerve net, a syncytium, thus retaining an early embryonic form of the neural tube and thus representing the most primitive level of mature nervous differentiation. The elements of this supposed mechanism for myenteric visceral reflexes is called by Herrick '*the peripheral autonomous visceral nervous system.*'

From the above it may be seen that the ganglia and connecting trunks and rami of the sympathetic system may be divided as follows:—(1) The two gangliated **sympathetic trunks** lying adjacent to and parallel with the vertebral

column; (2) the **great prevertebral plexuses,** containing the intermediate or collateral ganglia, of which plexuses there are roughly four, one in the head, one in the thorax, one in the abdomen, and one in the pelvic cavity (fig. 857), each of which is subdivided; (3) the numerous **terminal ganglia and plexuses** situated either within or close to the walls of the various organs; (4) the **trunks** and **rami** connecting the ganglia with each other and thus contributing to the plexuses, or connecting the ganglia with other nerves or with organs with whose innervation they are concerned. The trunks and rami may be divided into—(*a*) the *rami communicantes,* or *central branches,* connecting the sympathetic with the craniospinal system and the central system; (*b*) *communicating trunks,* best considered as those which connect with each other sympathetic ganglia situated on the same side of the body; (*c*) *commissural branches,* or those which pass between ganglia situated on opposite sides of the midline of the body, such as the transverse connecting branches between the sympathetic trunks in the lumbosacral region (fig. 860), or all the trunks between the ganglia of the unpaired plexuses occupying the midregion of the body; (*d*) *terminal* or *peripheral branches,* or branches of distribution which pass from the ganglia to their final distribution in the tissues they innervate, apparently uninterrupted by other ganglia (fig. 815).

THE SYMPATHETIC TRUNKS

The **sympathetic trunks,** or gangliated cords, of the sympathetic system are two symmetrical trunks with ganglia interposed in them at intervals of varying regularity, and extending vertically, one on each side of the ventral aspect of the vertebral column, from the second cervical vertebra to the first piece of the coccyx (figs. 857, 860). Upon the coccyx the two trunks unite and terminate in a single median ganglion, the **ganglion coccygeum impar.** The various ganglia of the trunk are connected with the craniospinal nerves by the rami communicantes. Morphologically, each trunk might be expected to include thirty-one ganglia, one for each spinal nerve, but, owing to the fusion of adjacent ganglia in certain regions, especially in the cervical, there are in the adult only twenty-one or twenty-two ganglia in each trunk. These occur as *three cervical ganglia, ten or eleven thoracic ganglia, four lumbar and four sacral ganglia,* and the *ganglion coccygeum impar,* which is common to both trunks. They are sometimes referred to as the *vertebral ganglia.*

In the cervical region the sympathetic trunks lie in front of the transverse processes of the vertebræ, from which they are separated by the longus capitis and longus colli; in the thoracic region they lie at the sides of the bodies of the vertebræ and on the heads of the ribs; in the lumbar region they are placed more ventrally with reference to the spinal nerves and more in front of the bodies of the vertebræ and along the anterior borders of the psoas muscles; in the pelvis the ganglia lie between and ventral to the openings of the sacral foramina. In the lower lumbar and sacral region one ganglion may send rami communicantes to two spinal nerves and one spinal nerve may be connected with two ganglia. The ganglia of the trunks throughout give off communicating branches to the ganglia of the prevertebral plexuses and branches to the nearby viscera and blood-vessels. These branches may appear either white or gray according to the predominance of medullated or non-medullated fibers in them. In the lumbosacral region commissural or transverse branches between the ganglia of the two trunks are especially abundant (fig. 860). In trunks having a whiter appearance, the greater part of the medullated fibers producing it are sensory and visceral efferent fibers from the spinal nerves which have passed through the sympathetic ganglia without termination. The nerve trunks connecting the ganglia of the sympathetic trunks all contain three varieties of fibers:—(1) visceral efferent fibers which have entered them in the white rami communicantes from the spinal nerves of higher or lower levels, and which are coursing in them to terminate in other ganglia, either in the trunks above or below or to pass out of them to terminate in ganglia not belonging to the trunks; (2) fibers arising in sympathetic ganglia of a higher or lower level and passing upward or downward to issue from the trunk and proceed to the tissues they supply; (3) visceral afferent or sensory fibers arising in the spinal ganglia.

THE CEPHALIC AND CERVICAL PORTIONS OF THE SYMPATHETIC TRUNK

The cephalic portion of the sympathetic system consists of numerous small ganglia and of numerous plexuses connected with the internal carotid nerve, the ascending branch given off by the superior cervical sympathetic ganglion. The cephalic ganglia are all relatively small. There are four considered in the ordinary macroscopic dissections, namely, the ciliary (ophthalmic), the sphenopalatine (Meckel's ganglion), the otic, and the submaxillary. To these may be added a portion of the superior cervical sympathetic ganglion, the sympathetic

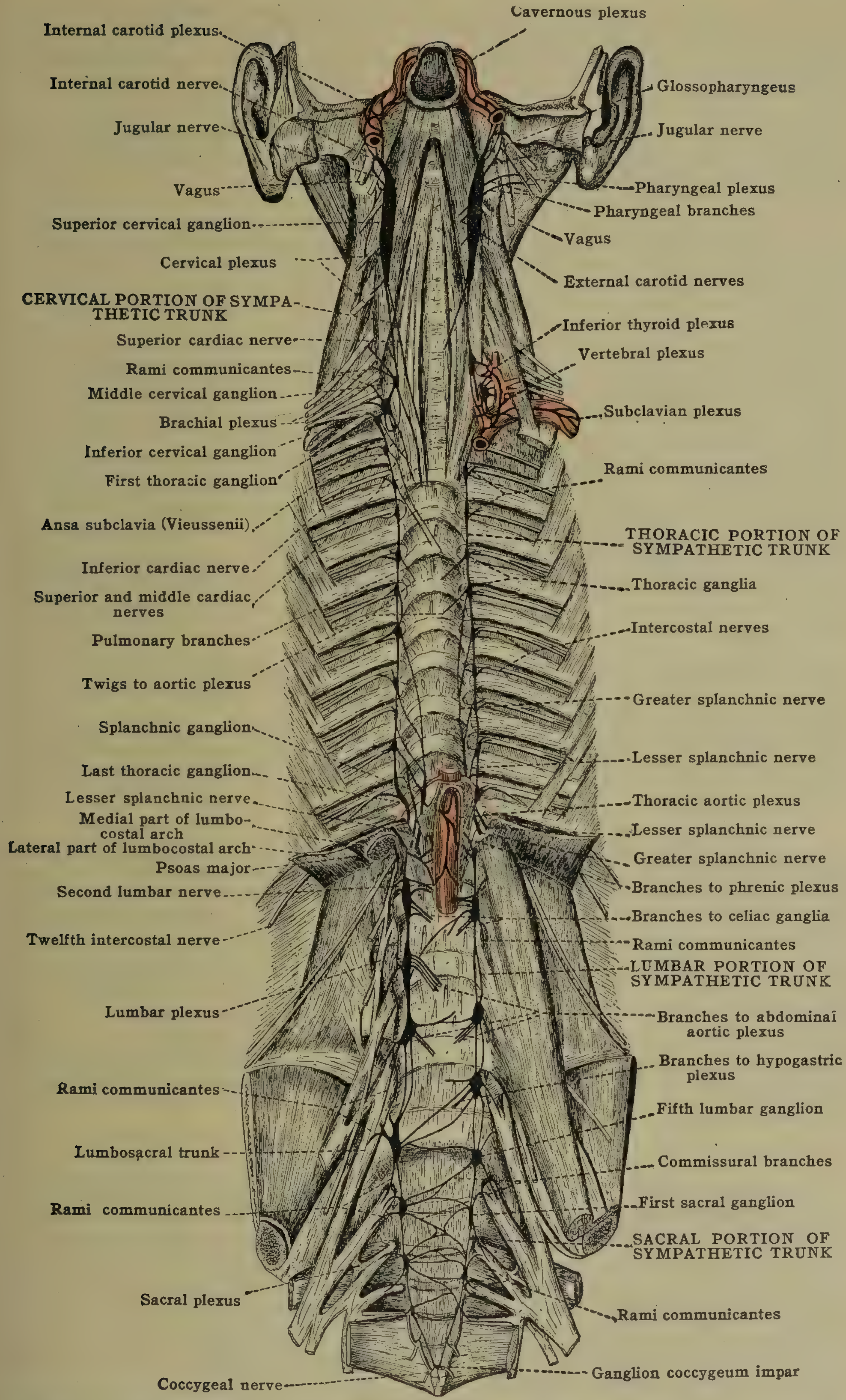


Fig. 860.—Showing the Gangliated Sympathetic Trunks in their Relation to the Vertebral Column, to the Spinal Nerves, and to each Other. (Modified from Toldt. 'Atlas of Human Anatomy,' The Macmillan Company.)

portions of the nodosal, petrous, geniculate and semilunar ganglia, and the various small ganglia dispersed in the plexuses. These ganglia with their roots or communicating branches have been described in their relations with the divisions of the trigeminus and with the oculomotor, glossopalatine, vagus and facial nerves. (See GANGLIATED CEPHALIC PLEXUS.)

The internal carotid nerve, the chief **ascending branch** from the superior cervical sympathetic ganglion, may be regarded as an upward prolongation of the primitive sympathetic trunk.

It arises from the upper end of the superior cervical ganglion and passes through the carotid canal into the cranial cavity. It divides into two branches which subdivide to form a coarse plexus, the *internal carotid plexus,* which partly surrounds the internal carotid artery before the latter enters the cavernous sinus (figs. 810 and 860). It passes with the artery to the cavernous sinus, where it grades into the finer meshed *cavernous plexus.*

The **internal carotid plexus** supplies offsets to the artery and receives branches from the tympanic plexus through the inferior caroticotympanic nerve and from the sphenopalatine ganglion through the great deep petrosal nerve. It also communicates by fine branches with the semilunar (Gasserian) ganglion and with the abducens nerve.

The **cavernous plexus** gives branches of communication to the oculomotor and trochlear nerves and to the ophthalmic division of the trigeminus. According to Toldt and Spalteholz, it communicates with the **tympanic plexus** through the superior caroticotympanic (small deep petrosal) nerve. It also communicates with the ciliary ganglion through the *long root of the ciliary ganglion* and usually through a separate *sympathetic root* of this ganglion. These branches may pass through the superior orbital (sphenoidal) fissure either separately or with the nasociliary (nasal) nerve.

The cavernous plexus also give branches to the posterior communicating artery and filaments of the plexus accompany small branches of the artery to the hypophysis (pituitary body) and to the dura mater on the sphenoid bone.

The *terminal branches* of the cavernous plexus consist of delicate filaments that anastomose freely, forming fine plexuses, and pass from the cavernous plexus along the terminal divisions of the internal carotid artery and their branches. These fine plexuses take the name of the artery on which they lie. The four larger of them are the plexuses of the anterior and middle cerebral arteries, the plexus of the choroid artery, and the ophthalmic plexus.

The **cervical portion of the sympathetic trunk** extends upward along the great vessels of the neck (fig. 860). No white rami communicantes connect it directly with the spinal cord, but instead it receives visceral efferent fibers from the upper thoracic spinal nerves through the sympathetic trunk, and probably also from the cervical spinal cord through the spinal acessory nerve and the connections with the vagus. It sends **gray rami communicantes** to each of the cervical nerves. It extends from the subclavian artery to the base of the skull, lying dorsal to the sheath of the great vessels and in front of the longus capitis and longus colli, which separate it from the transverse processes of the cervical vertebræ. It usually has but three **ganglia,** one at each end, the superior and inferior, and one between these two, called the middle ganglion. The latter varies somewhat in position and is sometimes absent.

1. SUPERIOR CERVICAL GANGLION

The **superior cervical ganglion** (figs. 810, 857, 860) is usually fusiform in shape and is sometimes marked by one or more constrictions. There is ground for the belief that it is formed by the coalescence of four ganglia corresponding to the first four cervical nerves. It varies from 2.5 to 3.7 cm. in length, lying dorsal to the upper part of the sheath of the great vessels of the neck and in front of the transverse processes of the second and third cervical vertebræ. It occasionally extends upward as high as the transverse process of the first vertebra. It is connected with the middle cervical ganglion by the intervening trunk, and it gives off a large number of communicating branches.

Rarely, the ganglion may be double or split with a ventral portion lying superficial to the carotid sheath and a dorsal portion dorsal to the sheath, connected by sympathetic filaments near the superior and inferior extremities of the ganglion.

Communications:—(1) Four gray rami communicantes associate the ganglion with the anterior primary divisions of the first four cervical nerves.

(2) **Communicating branches to the cranial nerves.**—An irregular number of small twigs pass between the superior cervical ganglion and the hypoglossal nerve and to the ganglion nodosum of the vagus. A named branch, the *jugular nerve*, runs upward to the base of the skull and divides into two branches, one of which enters the jugular foramen and joins the jugular ganglion of the vagus, and the other passes through or over the petrous ganglion of the glossopharyngeal and contributes to the tympanic nerve and plexus. (See fig. 810.)

(3) Four or five **laryngopharyngeal branches** come from the superior ganglion and the plexus extending downward from it, and pass forward and medialward, medial to the carotid vessels, to the wall of the pharynx, where they unite on the middle constrictor with the pharyngeal branches of the glossopharyngeus and vagus, forming with them the *pharyngeal plexus*, from which branches are distributed to the walls of the pharynx and to the superior and external laryngeal nerves (fig. 860).

(4) The **superior cervical cardiac nerve** springs from the lower part of the ganglion or from the trunk immediately below it. It passes downward behind the carotid sheath, either in front of or dorsal to the inferior thyroid artery, and in front of the longus colli, and establishes communications with the upper cervical cardiac branch of the vagus, the middle cervical cardiac branch of the sympathetic, and with the inferior and external laryngeal nerves. At the root of the neck the nerve of the *right side* passes in front of or behind the first part of the right subclavian artery, and is continued along the innominate artery to the front of the bifurcation of the trachea, where it joins the deep part of the cardiac plexus. The *left nerve* passes into the thorax along the front of the left common carotid artery, crosses the front of the arch of the aorta immediately anterior to the vagus, and joins the superficial part of the cardiac plexus (fig. 861). Filaments from both the right and left nerves pass to the inferior thyroid plexus.

(5) The **external carotid nerves** (fig. 860) pass forward from the superior cervical ganglion to the external carotid artery, where they divide into branches which anastomose freely to form around the artery the **external carotid plexus.** This plexus extends to the beginning of the artery, and is continued upon the common carotid artery as the **common carotid plexus.** From the external carotid plexus, filaments pass to form secondary plexuses around each of the branches of the external carotid artery. These plexuses take the names of the arteries which they follow, namely, the **superior thyroid plexus, lingual plexus,** etc. Filaments pass from the external carotid plexus to the *glomus caroticum* (the carotid gland), and from the superior thyroid plexus to the thyroid gland.

From the **external maxillary** (facial) **plexus** passes the *sympathetic root of the submaxillary ganglion.*

A part of the **internal maxillary plexus** is continued upon the middle meningeal artery as the **meningeal plexus.** From this plexus filaments pass to the otic ganglion, and sometimes a branch, called by British anatomists the **external superficial petrosal nerve,** passes to the geniculate ganglion.

(6) Small **branches to the ligaments and bones** of the upper part of the vertebral column.

(7) The **internal carotid nerve** (**ascending branch**) and plexus have been described with the cephalic portion of the sympathetic system.

2. The Middle Cervical Ganglion

The **middle cervical ganglion** is small and somewhat triangular in outline. It is sometimes absent. Its position is variable, but it commonly lies about the level of the cricoid cartilage, in front of the bend of the inferior thyroid artery (fig. 860), and it is associated with the superior cervical ganglion and with the inferior cervical ganglion by the intervening portions of the sympathetic trunk. From the lower part of the middle ganglion some filaments pass dorsal to the subclavian artery, while others pass in front of and beneath that artery and anastomose with the first-mentioned filaments to form a loop, the **ansa subclavia** (*ansa Vieussenii*) (figs. 821, 860). Filaments from this loop to the inferior cervical ganglion thus form another communication between the middle and inferior cervical ganglia.

Connections.—The middle cervical ganglion gives off four or more rami.

Two (*a* and *b*) are gray rami communicantes which connect the middle ganglion with the anterior primary divisions of the fifth and sixth cervical nerves.

(*c*) One or more peripheral branches pass along the inferior thyroid artery and anastomose with branches from the superior and middle cardiac nerves and from the inferior cervical ganglion, thus taking part in the formation of the **inferior thyroid plexus,** from which branches pass to the thyroid gland.

(*d*) The **middle cardiac nerve** arises by one or more branches from the ganglion, or from the trunk, and passes downward dorsal to the common carotid artery and, on the right side, either in front of or dorsal to the subclavian artery, and then along the innominate artery to the deep part of the cardiac plexus (figs. 860 and 861). It is frequently larger than the superior cardiac nerve. On the left side the nerve runs between the subclavian and common carotid arteries. On both sides the nerve communicates with the inferior laryngeal nerve and external laryngeal nerve.

The middle cervical ganglion also gives branches to the common carotid plexus.

3. The Inferior Cervical Ganglion

The **inferior cervical ganglion** is irregular in form. It is larger than the middle cervical ganglion, and it lies deeply in the root of the neck dorsal to

the vertebral artery or to the first part of the subclavian artery, and ventral to the interval between the transverse processes of the last cervical and the first thoracic vertebræ (figs. 821, 860). It is connected with the middle cervical ganglion by the sympathetic trunk, and by filaments passing to the ansa subclavia, and it is either blended directly with the first thoracic ganglion or connected with it by a short stout portion of the trunk. It gives gray rami to the last two cervical nerves and peripheral branches to the vertebral and internal mammary arteries, to the heart, and to the inferior thyroid plexus.

Connections.—(1) The rami to the seventh and eighth cervical nerves are **gray rami communicantes.**

(2) The **branches to the vertebral artery** are large and they unite with similar branches from the first thoracic ganglion to form a plexus, the **vertebral plexus** (fig. 860), which accompanies the artery into the posterior fossa of the cranium, where it is continued on the basilar artery. The plexus communicates in the neck by delicate threads with the cervical spinal nerves. These are probably meningeal rami.

(3) The branches to the internal mammary artery form the **internal mammary plexus.**

(4) The **inferior cardiac nerve** may arise from the inferior cervical ganglion, from the first thoracic ganglion, or by filaments from both these ganglia (figs. 860, 861). It communicates with the recurrent laryngeal nerve and with the middle cardiac nerve, and passes to the deep part of the cardiac plexus. On the left side it frequently joins the middle cardiac nerve to form a common trunk.

Construction of the cervical portion of the sympathetic trunk.—This portion of the trunk contains both medullated and non-medullated fibers, and a large part of the former are of craniospinal origin. In the absence of white rami communicantes to this portion of the sympathetic trunk, it is evident that few if any of the craniospinal **visceral efferent fibers** are contributed to it below the superior ganglion by the cervical region of the spinal cord. Instead, such fibers are known to enter by way of the white rami from the upper thoracic nerves, and to ascend to this portion of the sympathetic trunk. Most of these fibers terminate about the cells of the superior, middle, and inferior cervical ganglia, and these cells in their turn give off sympathetic fibers which pass by way of the branches mentioned above for the cephalic and cervical portions, to their distribution in the structures of the head, neck, and thorax. The visceral efferent fibers which terminate in the superior ganglion especially are among those which mediate—(1) vasomotor impulses for the head; (2) secretory impulses for the submaxillary gland; (3) pilomotor impulses for the hairs of the face and neck; (4) motor impulses for the smooth muscle of the eyelids and orbit, and (5) dilator impulses for the pupil. The sympathetic or gray fibers in the cervical portion of the sympathetic trunk arise from the cells of the upper thoracic and the cervical ganglia, and are passing to enter the peripheral branches and proceed to their terminal distribution by way of the trunk.

Stimulation of the skin of the back of the upper thorax and of the back of the neck gives reflex dilation of the pupil and wider opening of the eyelids. This is explained as accomplished by the sensory impulses aroused in these skin areas passing in sensory thoracic or cervical spinal nerves to the spinal cord and there transferred to visceral efferent neurones whose axones form synapses within the cervical sympathetic ganglia, whence ascend axones to the dilator muscle of the iris and the smooth (Müller's) muscle of the eyelids (fig. 783). Hence, a symptom of severed sympathetic trunk above the first thoracic nerve is narrowing of the pupil and a greater narrowing of the lids than is usual for the patient affected.

THE THORACIC PORTION OF THE SYMPATHETIC TRUNK

The thoracic part of the gangliated trunk (figs. 857, 860) extends along the heads of the ribs from the first to the tenth, and then passes a little ventralward on the sides of the bodies of the lower two thoracic vertebræ. Above it is continuous with the cervical portion at the root of the neck, dorsal to the vertebral artery. Below it leaves the thorax dorsal to the medial lumbocostal arch (arcuate ligament), or sometimes dorsal to the lateral lumbocostal arch, and continues into the lumbar portion of the trunk. It lies behind the costal pleura and crosses over the aortic intercostal arteries.

The number of ganglia in this part of the trunk is variable. There are usually ten or eleven, but the first is sometimes fused with the inferior cervical ganglion (fig. 821) and occasionally other ganglia fuse. The ganglia are irregularly angular or fusiform in shape, and lie on the head of the ribs, on the costovertebral articulations, or on the bodies of the vertebræ. The portions of the trunk connecting the ganglia usually are single, but sometimes they are composed of two or three small cords in juxtaposition. Each ganglion, with the rare exception of the first, receives a *white ramus communicans* from a thoracic nerve and all give off *gray rami communicantes* to these nerves.

The **white rami communicantes,** as they approach the sympathetic trunk, quite often appear double, due to the separation of a large portion of their fibers into two main directions, one passing upward in the sympathetic trunk, and one passing downward. Of the white rami from the upper five thoracic nerves, the upward stream of fibers is much larger than the downward, due to the fact that a greater part of the visceral efferent fibers from these nerves are distributed

through the cervical portion of the sympathetic trunk, as noted above in the construction of that portion.

Usually the white rami from the spinal nerves pass directly to the corresponding ganglia of the trunk, and thus lie in company with the corresponding gray rami. Sometimes, however, they may join the intermediate portions of the trunk, and in the lower thoracic region especially a ramus may pass from a nerve to the ganglion corresponding to the nerve above or below. The fibers of the white rami from the lower thoracic nerves are in greater part directed downward in the sympathetic trunk, and also downward in its peripheral branches, to be distributed to the ganglia of the abdominal viscera. In all cases, however, some of the fibers of the thoracic white rami terminate in the ganglia nearest their junction with the trunk, while others pass to the ganglia above or below or into the nearest peripheral branches. In this way the white rami from the thoracic spinal nerves, are directly concerned in the innervation of both the thoracic viscera and also (chiefly through the splanchnic nerves) the abdominal viscera.

The **first thoracic ganglion** is larger than the other ganglia of this region and is irregular in form. It may be narrowly ovoid or semilunar. It lies in front of the neck of the first rib, behind the pleura, and on the medial side of the costocervical trunk (superior intercostal artery), which vessel separates it from the prolongation of the portion of the first thoracic nerve which passes to the brachial plexus. It sometimes fuses with the inferior cervical ganglion, and, on the other hand, sometimes extends to the upper part of the second rib to fuse with the second thoracic ganglion. The result of the latter fusion resembles the **stellate ganglion** of the carnivora (ganglion cervicothoracale or stellare NK). When well developed, the first ganglion sends a branch to the cardiac plexus, forming the fourth cardiac nerve of Valentin.

The **second thoracic ganglion,** triangular in shape and almost as large as the preceding, is sometimes placed on the costovertebral articulation, and is sometimes partly concealed by the first rib.

The **third to the ninth thoracic ganglia** are usually placed opposite the heads of the corresponding ribs, but the **tenth** and **eleventh** may lie on the bodies of the vertebræ.

The fibers passing from the ganglia form two groups of branches, the *central* and the *peripheral.*

The **central** branches are the **gray rami communicantes,** which pass from the ganglia to the corresponding spinal nerves. After they have joined with the anterior primary divisions of the nerves, the fibers of these rami divide into three groups:—(1) Fibers which pass medialward along the roots of the nerves to supply vessels of the membranes of the spinal cord, or enter a meningeal or recurrent branch for the same purpose; (2) fibers which pass dorsalward into the posterior primary divisions of the nerves; (3) fibers which pass lateralward in the anterior primary divisions of the nerves. The last two groups of fibers are distributed chiefly to the muscle of the blood-vessels of the body-walls, to the skin-glands, and to the muscles of the hairs of the body.

The **peripheral branches** of the ganglia form two series, an upper and a lower.

Those of the *upper series* pass from the upper four or five ganglia ventralward to be distributed as follows (figs. 857, 861):—

(1) **Pulmonary branches** which accompany the intercostal arteries toward their aortic origin without forming plexuses around them, and pass to the posterior pulmonary plexus.

(2) **Aortic branches,** some of which arise directly from the ganglia and some from the pulmonary branches, and unite with branches from the cardiac plexus and from the splanchnic nerves to surround the aorta as the **thoracic aortic plexus.** This plexus accompanies the aorta into the abdomen and there joins with the celiac (solar) plexus.

(3) **Esophageal branches** join with the esophageal plexus of the vagus.

(4) **Vertebral branches,** some of which pass with the nutrient arteries into the bodies of the vertebræ and some of which pass to the median line and there anastomose with similar branches from the opposite side (commissural branches).

The peripheral ganglionic branches forming the *lower series* consist largely of fibers arising in the ganglia of the trunk and visceral afferent fibers from the spinal nerves, which pass through the ganglia and reinforce the sympathetic filaments proper. Thus composed, these branches run ventralward and medialward on the sides of the bodies of the vertebræ and unite to form the *splanchnic nerves* concerned with the abdominal organs, (figs. 676, 857). The visceral afferent fibers serve to collect sensory impulses in this domain of the sympathetic.

(1) The **great splanchnic nerve** is usually formed by branches from all the thoracic ganglia from the fifth to the tenth inclusive, or it may receive fibers from only two or three of these

ganglia (figs. 857, 860). The superior branch, usually the largest, receives smaller inferior branches from the lower ganglia as it passes downward on the sides of the bodies of the vertebræ in the posterior mediastinum. The nerve enters the abdominal cavity by passing through the crus of the diaphragm, and joins the upper end of the celiac (semilunar) ganglion of the celiac (solar) plexus. Near the disk between the eleventh and the twelfth thoracic vertebra there is formed on the nerve the **splanchnic ganglion** (fig.860). Filaments from the nerve and ganglion pass along the intercostal arteries to the aorta, esophagus, and the thoracic duct, and some fibers from the right side pass to the vena azygos (major). Sometimes this nerve divides into two cords, giving off numerous branches which anastomose with each other and with the lesser splanchnic nerve to form a plexus, in the meshes of which are found some small ganglia.

(2) The **lesser splanchnic nerve** receives fibers from the ninth and tenth ganglia. Its course is similar to that of the great splanchnic nerve (figs. 857, 860), but on a more dorsal plane, and it joins the celiac (solar) and renal plexuses.

(3) The **least splanchnic nerve,** not always present, arises from the last thoracic ganglion or sometimes from the lesser splanchnic nerve. It passes through the crus of the diaphragm and joins the renal plexus.

Construction of the thoracic portion of the trunk.—Being part of the general *thoracolumbar stream,* the majority of the visceral efferent fibers which pass from the central nervous system enter the thoracic portion of the sympathetic trunk and terminate there in synapsis with the cells of its ganglia (fig. 859), while others merely pass through on their way to terminate in the collateral ganglia With regard to those which terminate in the ganglia of the trunk, it has been shown that in the dog and cat many end in the ganglion stellatum which corresponds to the last cervical and the upper three or four thoracic ganglia in man. Among these are the fibers conveying secretory impulses to the sweat-glands of the upper limb. Such emerge from the spinal cord in the thoracic nerves from the sixth to the ninth, and with them, in the dog, are fibers which convey and transfer vasoconstrictor impulses to the sympathetic neurones supplying the pulmonary blood-vessels. These latter visceral efferent fibers leave the spinal cord in the second to the seventh thoracic nerves. Other fibers which terminate upon the thoracic sympathetic ganglion-cells in the dog and cat are the vasoconstrictor fibers for the upper limbs and some of the vasoconstrictor fibers for the lower limbs.

Of the fibers which traverse the thoracic portion of the sympathetic trunk to gain more distant terminations, some ascend to the cervical region (p. 1110), others descend to the lumbar region, and others pass by the immediate peripheral branches to the splanchnic nerves and terminate in the ganglia of the abdominal plexuses.

Among those visceral efferent (preganglionic) fibers which descend to the lumbar region of the trunk are pilomotor fibers, vasomotor fibers, and secretory fibers to the lower limb, some vasoconstrictor fibers to the abdominal blood-vessels, motor fibers to the circular, and inhibitory fibers to the longitudinal muscle of the rectum. The latter enter the sympathetic trunk by the lower thoracic nerves and pass in the lumbar peripheral branches to the aortic plexus, and terminate around the cells of the inferior mesenteric ganglion.

The visceral efferent fibers which pass through the thoracic ganglia to the splanchnic nerves are mainly vasomotor fibers for the abdominal blood-vessels; the majority of them probably terminate around the cells of the ganglia in the celiac (solar) plexus, but those for the renal blood-vessels no doubt end in the ganglia of the renal plexus. In addition to all the above-mentioned fibers there are in the thoracic part of the sympathetic trunk afferent fibers of the spinal ganglia which pass into the dorsal roots of the thoracic spinal nerves.

Referred Visceral Sensations

Referred cardiac pain.—Sensation of pain localized as from the heart itself is a rare symptom of cardiac disease. On the other hand, hyperexcitation of sensory fibers to the heart is referred to the wall of the upper thorax in those cases termed *angina pectoris.* This pain in angina pectoris is most commonly localized in the sternal region, the left side of the chest in the region supplied by the first three thoracic nerves, and in the ulnar or medial (postaxial) side of the left arm to the elbow. It often extends to the wrist and sometimes even to the ulnar side of the hand, depending doubtless upon the extension there of the distribution of the first thoracic into the area of the eighth cervical nerve. Anginal pain occurs in agonizing paroxysms and, in severe attacks, may be accompanied secondarily by sweating on the upper thorax and even on the left side of the head, with temporary narrowing of the eyelids.

The actual seat of origin of the pain has been determined with considerable certainty to be in the first part of the aorta and especially in the coronary arteries, when these are excessively irritated by disease. To some extent it may also arise in the adjacent region of the wall of the left ventricle. Some cases of angina pectoris have been explained as resulting from thrombosis in the coronary arteries. The paroxysmal nature of the pain is due to vascular spasm in these diseased vessels. That the pain normally involves the left side of the thorax is explained by the fact that the aorta, its coronary branches and the left ventricle arise from the left end of the *bulbus cordis* of the embryo.

Though other nerve paths have been suggested as mediating this referred or anginal pain, anatomical evidence indicates that it probably must be wholly accounted for by neurone chains involving sensory fibers carried in the first three or four thoracic nerves. While the vagus nerve carries a few afferent fibers of the larger type, some of which may be proprioceptive, in addition to its many smaller sensory (depressor and other enteroceptive) fibers, it is quite probable that few, if any, of the afferent impulses carried in the thoracic portion of the vagus trunk ever reach the threshold of consciousness. On the other hand, the spinal ganglia of the first to the fourth thoracic nerves send sensory fibers by way of their white rami up the sympathetic trunk and through the stellate and the inferior and possibly the middle cervical sympathetic ganglia, and thence to the cardiac plexuses in the small cardiac nerves, most directly via the middle and the inferior cardiac nerves, some via the ansa subclavia. There are no sensory fibers in the sympathetic trunk between its middle and superior cervical ganglia and there are none in the superior cardiac nerve.

Any of these thoracic sensory fibers terminating in the diseased walls of the first part of the orta and in the coronary arteries must suffer hyperexcitation, especially during any vasoconstrictor spasm. The supranormal impulses thus aroused in them pass along their course to nd down the cervical sympathetic trunk, through the white rami and dorsal roots of the horacic nerves mentioned, into the spinal cord. In the cord these fibers become links in one r the other of two probable neurone chains:—(1) They form synapses with cell bodies of the lorsal horn whose axones course in the spinal lemniscus and, via the lateral thalamic nuclei, he impulses they bear are conveyed to that area of the cerebral cortex which habitually interrets such impulses as if they were aroused in those segments of the wall of the thorax which are upplied by the sensory fibers in the anterior divisions of the first to the fourth thoracic nerves, nstead of being carried in their white rami via the sympathetic trunk. These impulses attain he threshold of consciousness and, because aroused by hyperexcitation or unusually intense timuli, they are interpreted as sensations of pain from the body wall.

(2) A more complicated chain but one considered more probable is that these visceral ensory neurones from the first to the fourth thoracic nerves which terminate in the heart esion form synapses in the cord with those neurones of the dorsolateral (visceral efferent) cell roup of the ventral horn whose axones pass out in the ventral roots and the white rami and, eing part of the thoracolumbar stream, transfer their impulses to the neurones of the correponding ganglia of the sympathetic trunk. The axones arising from the cells concerned in hese ganglia pass via the gray rami into the anterior divisions of the same thoracic nerves and rom them terminate as vasoconstrictors upon the smooth muscle of the blood vessels supplying oth the skeletal muscles and the integument of the corresponding segments of the wall of the horax. Some terminate as effector fibers upon the arrectores pilorum and the sweat glands. During the spasms the supranormally intense stimuli brought to this smooth muscle produce eactions sufficiently violent to produce 'contraction irritation' of the terminals of the sensory ibers distributed to these segments of the body wall by the first three or four thoracic nerves, mpulses which, in the cord, are transferred to the spinal lemniscus and transmitted to the area f cortex by which such impulses are interpreted as sensations of pain located in these segments f the thoracic wall. Secretory fibers to the sweat glands explain the sweating which sometimes ccompanies the paroxysms of angina pectoris.

Surgical relief of the referred or anginal pain has been obtained by removal of the superior ervical sympathetic ganglion; likewise by merely severing the superior cardiac nerve and all ther cardiac branches from the ganglion. Such relief can not be explained as resulting from he severing of sensory fibers to the heart from the thoracic nerves concerned, for there are one such in the field of operation. It must be due to the disconnection of the vasoconstrictor bers passing from the region of the ganglion to the heart, coronary arteries especially, the evering thus eliminating the vascular spasms. The cardiac components of the vagus include a mall proportion of vasoconstrictor fibers but not enough to warrant cutting the vagus. Considerable relief from the pain has been reported from cutting the dorsal root of the left econd thoracic nerve. Severing the dorsal roots of the first three or four thoracic nerves would e the logical procedure, but of course severe thoracic anesthesia then would result.

Anatomical explanations, similar to those for angina pectoris, can be advanced for the cases f referred pain in the sixth and seventh thoracic segments of the body wall in cases of mitral tenosis with dilation of the left atrium. That the body segments are lower than those involved n angina pectoris is because the atria are derived from the caudal or venous end of the embryonic eart. Likewise an explanation is possible for that symptom of aneurism of the thoracic aorta ommonly manifest as referred pain in that domain of the intercostal nerves corresponding to he level of the aneurism. Such is also usual in the domain of the nerves of one side only.

Also in like manner may be explained the area of 'skin tenderness,' together with an area f rigidity of abdominal muscle, which is sometimes found overlying an inflamed vermiform ppendix (in the region of McBurney's point). Here hyperexcitation of the visceral sensory bers terminating in the appendix may give rise to impulses which are distributed in the orresponding segments of the thoracic cord to visceral efferent neurones for the contraction of mooth muscle of the corresponding body segment and, in this case, also distributed to somatic fferent neurones sending fibers to the abdominal skeletal muscle. The impulses aroused by the ontraction irritation in both varieties of muscle are carried in sensory fibers from the correponding body wall to the cord and there transferred to neurones of the spinal lemniscus to be nterpreted by the brain as painful sensations. Of course this explanation does not apply in ase of direct pain from peritoneal abscess on the inner body wall and peritonitis resulting from suppurating or perforated appendix.

THE LUMBAR PORTION OF THE SYMPATHETIC TRUNK

The lumbar portion of each trunk lies on the fronts of the bodies of the vertebræ along the anterior border of the psoas muscle, and nearer to the median line han the thoracic portion. It is connected with the thoracic portion of the ympathetic trunk by a slender intermediate portion of the trunk that may pass hrough the diaphragm or dorsal to it (figs. 857, 860). The continuation of the umbar into the sacral portion is also slender, and descends dorsal to the common liac artery. The right trunk is partly covered by the vena cava inferior and the eft by the aorta.

The lumbar **ganglia**, which are small and oval, vary in number from three to ight, but are usually four. Rarely they form one continuous ganglion.

White rami communicantes pass to the ganglia from the first two to four umbar nerves only (fig. 859). This portion of the sympathetic trunk also eceives visceral efferent and afferent fibers which are derived from the white

rami communicantes of the lower thoracic nerves and continue downward in the trunk, the visceral efferent to pass out with the lumbar part of the thoracolumbar stream.

Branches.—As in the thoracic region, the branches from the ganglia are central and peripheral. The central are **gray rami communicantes.** There may be two rami to a nerve or one ramus may divide so as to join two adjacent spinal nerves. Sometimes a spinal nerve may receive as many as five gray rami from the sympathetic trunk.

The **peripheral branches** (sympathetic and visceral afferent and efferent fibers) include:—(*a*) Branches passing to the aorta and taking part in the formation of the aortic plexus; (*b*) branches which descend in front of the common iliac artery to the hypogastric plexus; and (*c*) branches to the vertebræ and ligaments.

THE SACRAL PORTION OF THE SYMPATHETIC TRUNK

The sacral part of each trunk passes downward in front of the sacrum, immediately lateral to the medial borders of the anterior sacral foramina. It is continuous above with the lumbar portion of the trunk, and below it anastomoses freely in front of the coccyx with the trunk of the other side to form a plexus in the terminus of which is the inconstant **coccygeal ganglion** (*ganglion coccygeum impar*) (fig. 860). Like the cervical and lower lumbar portions of the sympathetic trunk, the sacral part receives no white rami communicantes from the spinal nerves. The visceral efferent fibers arising from this portion of the spinal cord form the sacral part of the general *craniosacral stream.* They pass by the ganglia of the trunk to terminate in the terminal ganglia of the visceral organs, and to some extent in the collateral ganglia.

The sacral **ganglia** are small in size, and usually four in number. The variation both in size and number is more marked in this portion of the trunk than in the two parts above.

Branches.—The branches of the sacral ganglia include:—

(1) Gray rami communicantes to the sacral nerves.

(2) Branches to the front of the sacrum which anastomose with their fellows of the opposite side (commissural branches).

(3) Branches which enter into the formation of the plexus on the middle sacral artery.

(4) Branches which join the pelvic plexuses.

(5) Branches given off by the ganglion coccygeum impar to the coccyx and its ligaments and to the *glomus coccygeum* (coccygeal gland).

Construction of the lumbar and sacral portions of the gangliated trunk.—The ganglia of both these portions of the trunk are very variable in shape, size, position, and number. There are usually four ganglia belonging to each portion, but sometimes as many as eight may be distinguished in the lumbar and at other times there may be as many as six in the sacral portion. In the majority of cases, especially in the sacral region, these masses of cells are so fused that their number is less than the number of the spinal nerves with which they are associated. As noted above, only the first two to four lumbar spinal nerves send white rami which enter these ganglia directly as such. However, visceral efferent fibers descend this entire stretch of the trunk, through both the lumbar and sacral portions, from the white rami of the lower thoracic and the upper lumbar nerves above. These fibers terminate in the various ganglia of the trunk here; many, via the white rami of the second, third and fourth sacral nerves especially pass, uninterrupted to the more distant sympathetic cell-bodies which are concerned in impulses that are vasomotor to the genital organs, motor for the uterus, the ductus deferens, and the muscular coats (circular coat especially) of the bladder. Also, some of them convey secretory, pilomotor, and vasomotor impulses for the glands, skin, and vessels of the lower extremity, in addition to the similar impulses conveyed in the peripheral branches from the lower part of the thoracic portion of the sympathetic trunk. The motor impulses for the uterus or ductus deferens and for the bladder pass, in most part probably, by way of the peripheral branches from the lumbar portion of the trunk, through the aortic plexus to the inferior mesenteric ganglion; others, the vasomotor impulses to the genital organs especially, pass by way of the sacral ganglia and the peripheral branches from them to the hypogastric or pelvic plexus and the appropriate subplexuses of this region. Of the vasomotor fibers for the penis, some of the constrictor fibers pass down the sacral portion of the sympathetic trunk and terminate about the cells of the sacral ganglia, and these cells send out sympathetic fibers which join and course in the pudic nerve (n. pudendus).

All of both the lumbar and sacral spinal nerves receive gray rami from the gangliated trunk. These, just as those from the other portions of the trunk, consist of—(1) vasomotor fibers to vessels of the meninges and the vertebral canal; and (2) those which reach their destination via the branches of the trunks of the spinal nerves.

In addition to the visceral efferent fibers, the branches of the lumbosacral portion of the sympathetic trunk carry visceral afferent fibers—sensory fibers arising in the spinal ganglia of this and the lower thoracic region.

There are no white rami proper passing from the sacral spinal nerves to course or terminate in the sympathetic trunk. Visceral efferent fibers are given off by these nerves in abundance, but, instead of entering the trunk and its ganglia, they form bundles which pass over the trunk and directly into its peripheral branches to end for the most part upon the cells of the terminal ganglia. The bundles passing from the second, third, and fourth sacral nerves are large and

especially definite. They constitute the chief sacral component of the craniosacral stream of the autonomic system. While homologous to white rami, such bundles are better known as the *visceral branches* of the sacral nerves, or the **pelvic splanchnics.** They contain some spinal sensory fibers, but consist for the most part of visceral efferent, conveying impulses, vasomotor (vasodilator, chiefly) to the genital organs, both motor and inhibitory for the rectum, uterus, and bladder (longitudinal coat especially), and secretory for the prostate gland. These fibers contribute to the hypogastric plexus and its terminal subplexuses, named according to the various urogenital organs concerned.

THE GREAT PREVERTEBRAL PLEXUSES

The great prevertebral plexuses, in the body cavities, are three in number—the cardiac, the celiac (solar or epigastric), and the hypogastric or pelvic (fig. 857). Their ganglia belong to the intermediate or collateral group. The cardiac plexus lies behind and below the arch of the aorta, and the celiac and hypogastric plexuses are situated in front of the lumbar vertebræ. Each plexus receives not only sympathetic fibers which have passed from the ganglia of the sympathetic trunks of either side, but also both visceral afferent and efferent nerve-fibers derived directly from the spinal nerves. The spinal visceral efferent fibers which terminate in the collateral ganglia belong for the most part to the thoracolumbar stream of the autonomic system. In addition the cardiac and celiac plexuses receive both visceral efferent and visceral afferent fibers from both vagus nerves.

1. The Cardiac Plexus

The cardiac plexus is formed by the cardiac branches from both vagus nerves and from both sympathetic trunks. It lies beneath and dorsal to the arch of the aorta, in front of the bifurcation of the trachea, and extends a short distance upward on the sides of the trachea. It is composed of a superficial and a deep part (fig. 861).

The **superficial part of the cardiac plexus** (plexus cardiacus superficialis NK) is much smaller than the deep part, and lies beneath the arch of the aorta in front of the right pulmonary artery. It is formed chiefly by the cardiac branches of the left vagus and by the left superior cardiac nerve, but sometimes receives filaments from the deep cardiac plexus. The **cardiac ganglion (ganglion of Wrisberg)**, usually found connected with this plexus, lies on the right side of the ligamentum arteriosum.

Branches.—From this plexus some branches pass to the left half of the deep cardiac plexus and others accompany the left pulmonary artery to the *left anterior pulmonary plexus.* It also sends branches to the *right anterior coronary plexus.*

The **deep portion of the cardiac plexus** (plexus cardiacus profundus NK) lies dorsal to the arch of the aorta at the sides of the lower part of the trachea and in front of its bifurcation. It consists of two lateral parts, more or less distinct, connected by numerous branches, which pass around the lower part of the trachea. It is formed by the superior, middle, and inferior cervical cardiac branches from the right sympathetic rrunk, the middle and inferior cervical cardiac branches from the left trunk, and all the cervical and thoracic cardiac branches of the vagus except the superior cervical cardiac branch of the left vagus. It also receives branches from the superficial cardiac plexus.

The *left part of the deep cardiac plexus* gives branches to the left atrium (auricle) of the heart, to the left anterior pulmonary plexus, to the left coronary plexus, and sometimes to the superficial part of the cardiac plexus (see fig. 861).

The *right part of the deep cardiac plexus* gives branches to the right atrium, to the right anterior pulmonary plexus, and to the right and the left coronary plexuses (fig. 861). The branches to the left coronary plexus pass behind the pulmonary artery. Some of those to the right coronary plexus pass anterior and some posterior to the right pulmonary artery.

The **coronary plexuses** are formed by branches given off by both parts of the cardiac plexus. They accompany the coronary arteries and are right and left.

The *right* (*anterior*) *coronary plexus* receives filaments from the superficial part of the cardiac plexus, but is formed chiefly by filaments from the right portion of the deep cardiac plexus (fig. 861). Its distribution to the heart follows that of the right coronary artery.

The *left* (*posterior*) *coronary plexus* is larger than the right plexus, and is formed for the most part by filaments from the left portion of the deep cardiac plexus, but it receives some filaments from the right portion of the deep cardiac plexus (fig. 861). Its distribution to the heart follows that of the left coronary artery.

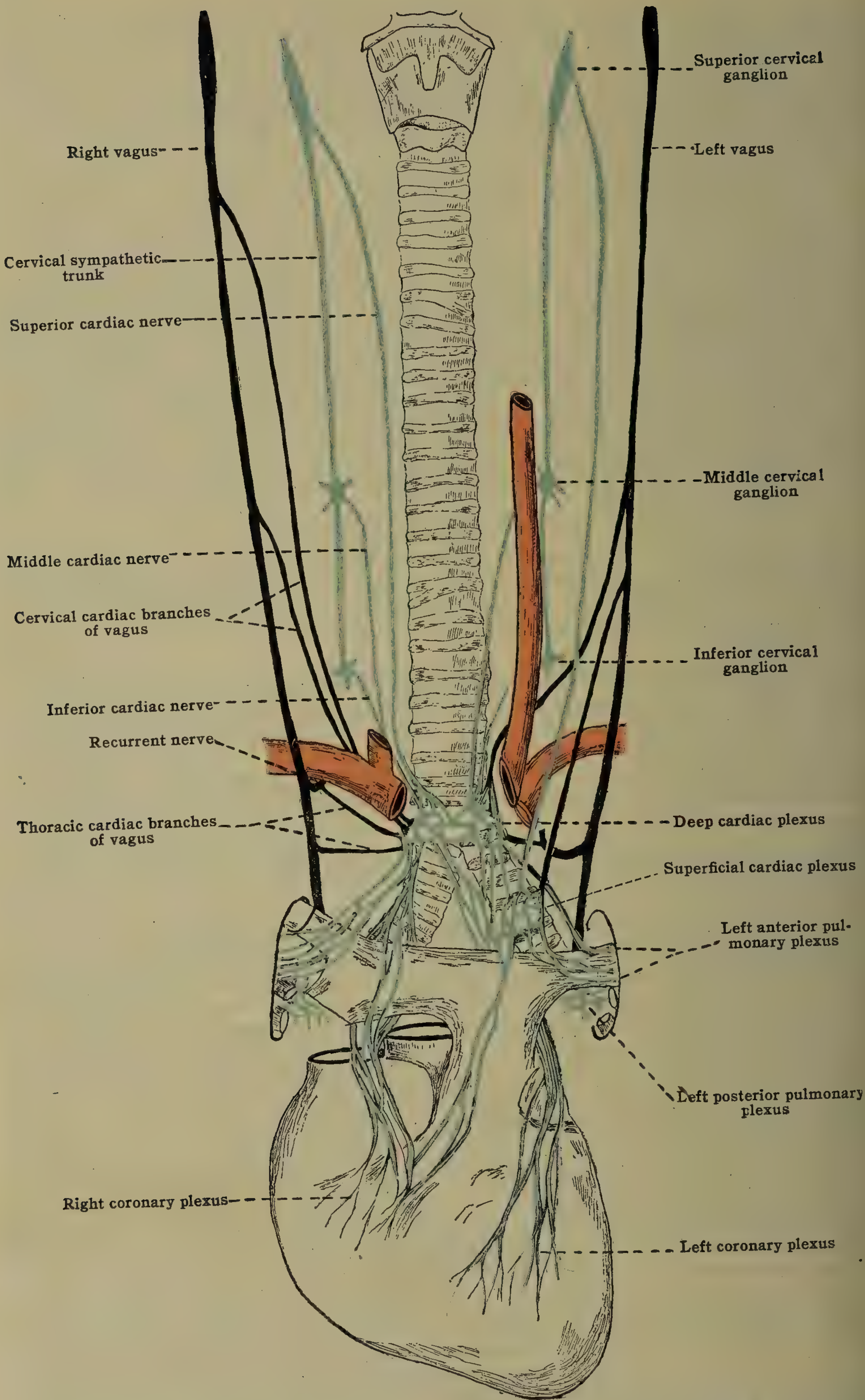


FIG. 861.—DIAGRAM OF THE CARDIAC, PULMONARY, AND CORONARY PLEXUSES. The anastomoses between superficial and deep cardiac plexuses are exaggerated. (Modified from Cunningham.)

The cardiac plexus and the network of nervous structures in the walls of the atria are the remains of the primitive plexuses found in the embryo, which are called the *bulbar*, the *intermediate*, and the *atrial* plexuses, terms which sufficiently indicate their relative positions. The bulbar plexus gives off the coronary nerves and is transformed into the superficial part of the deep cardiac plexus; the remainder of the deep cardiac plexus is formed by the intermediate plexus, and the atrial plexus becomes the network of the atrium.

The fibers which pass to the cardiac plexus are medullated and non-medullated; the former are the so-called inhibitory, the latter motor. The inhibitory impulses leave the central nervous system by the vagus and spinal accessory nerves and are transferred by synapses to the nerve cells of the intrinsic terminal ganglia of the heart. The accelerator fibers leave the spinal cord by the ventral roots and white rami communicantes of the thoracic nerves and terminate about the cells of the ganglia of the sympathetic trunk; some probably about cells in the ganglia of the intervening collateral plexuses. From the cells of these ganglia arise the non-medullated (gray) fibers of the plexus and these are thought to terminate directly upon the fibers of cardiac muscle. The visceral sensory fibers passing through the coronary plexuses to the coronary arteries of both sides and first part of the aorta are almost wholly from the first four thoracic spinal nerves of the left side. (See Referred Cardiac Pain.)

2. The Pulmonary Plexuses

The **pulmonary plexuses** are a continuation of the cardiac plexuses. The two are so intimately joined that it is difficult to distinguish them as separate plexuses. The pulmonary are formed by fibers from both vagus and sympathetic nerves. The anterior and posterior pulmonary branches of the vagus unite, dorsal to the bifurcation of the trachea, with fibers from the second, third and fourth ganglia of the thoracic portion of the sympathetic trunk to form the anterior and posterior pulmonary plexuses that lie ventral and dorsal to the bifurcation of the trachea. Here the pulmonary plexuses of both sides connect with each other freely. Leaving the trachea, the plexuses pass into the lungs along the pulmonary arteries (figs. 813, 861). The parts of the plexus of each side are named according to their position anterior or posterior to the right and left pulmonary arteries; thus, there is a **right anterior** and a **right posterior**, a **left anterior** and a **left posterior pulmonary plexus.**

3. The Celiac Plexus

The **celiac** (solar or epigastric) **plexus** [plexus cœliacus] is the largest of the trevertebral plexuses. It is unpaired, and is continuous above with the aortic plexus of the thorax and below with the abdominal aortic and superior mesenteric plexuses. It lies in the epigastric region of the abdomen behind the bursa omenpalis (lesser sac) and the pancreas, upon the crura of the diaphragm and over the abdominal aorta, and around the origin of the celiac and the superior mesenteric arteries. It occupies the interval between the suprarenal glands and extends downward as far as the renal arteries. It is joined by the great and the lesser splanchnic nerves of both sides, by celiac branches of the right vagus, and by filaments from the upper lumbar ganglia of the sympathetic trunk. It sometimes receives celiac branches from the left vagus. It contains two large collateral ganglia, the right and left celiac (semilunar) ganglia (fig. 862).

The **celiac (semilunar) ganglia** are two large, flat, irregularly shaped masses, separable into a varying number of ganglia. These two masses, or rather the smaller ganglia which compose them, are connected by a varying number of communicating branches. Each mass, right and left, lies upon the corresponding crus of the diaphragm, at the medial border of the corresponding suprarenal gland, being sometimes overlapped by this body. The right mass lies behind the inferior vena cava. Each celiac ganglion receives at its upper border the greater splanchnic nerve, and, near its lower border, lying over the origin of the renal artery, is a more or less detached part, known as the **aorticorenal ganglion.** This ganglion receives the lesser splanchnic nerve and may seemingly give origin to the greater part of the renal plexus. Another part of the celiac ganglion, often found dorsal to the origin of the superior mesenteric artery, is known as the **superior mesenteric ganglion** (fig. 862).

From the celiac plexus and its ganglia subordinate plexuses are continued upon the aorta and its branches. These comprise both paired and unpaired plexuses. The paired plexuses are the phrenic, suprarenal and renal, the spermatic in the male, and, in the female, the ovarian plexuses. The unpaired plexuses are the aortic, hepatic, splenic, superior gastric, inferior gastric, superior mesenteric, and inferior mesenteric.

That part of the celiac plexus surrounding the celiac artery was formerly described as the *celiac plexus*. It is better considered as an unnamed part of the larger celiac (solar) plexus. This part of the plexus receives fibers from both vagus nerves, and gives filaments that form plexuses around the branches of the celiac artery and their ramifications.

The paired subordinate plexuses of the celiac.—(1) The **phrenic (diaphragmatic) plexuses** consist of fibers from the upper part of the celiac ganglia, which follow the inferior phrenic arteries and their branches on the under surface of the diaphragm (fig. 862). Filaments are given off by the roots of the plexuses to the suprarenal bodies, and others unite with the terminal branches of the phrenic nerves. The point of junction with the right phrenic nerve is marked by the **phrenic ganglion**, from which branches are distributed to the inferior vena cava,

Fig. 862.—Abdominal Plexuses of the Sympathetic. (After Toldt, 'Atlas of Human Anatomy,' The Macmillan Company.)

to the right suprarenal body, and to the hepatic plexus.

(2) The **suprarenal plexuses** are comparatively large plexuses, formed mainly by branches from the celiac (semilunar) ganglia. However, fibers come to them from the celiac plexus along the suprarenal arteries, from the phrenic plexus along the inferior phrenic arteries, and from the renal plexus along the inferior suprarenal arteries. They are distributed to the substance of the suprarenal glands. Cell-bodies of sympathetic neurones are enclosed within the suprarenal gland forming intrinsic ganglia. The medulla of the suprarenal is of ectodermal origin and considered as derived from embryonic components similar to those giving origin to the sympathetic nervous system.

(3) The **renal plexuses** (fig. 862) receive fibers from the lower part of the celiac ganglia and from the celiac and aortic plexuses. They also receive filaments from the least splanchnic nerves, when these nerves are present, and sometimes filaments from the lesser splanchnic nerves and from the first lumbar ganglion of the sympathetic trunk. These plexuses pass along the

renal arteries into the substance of the kidneys. Most of the fibers of each renal plexus are gray or postganglionic fibers, and as they pass to the kidneys small *renal ganglia* are present among them. Both renal plexuses give branches to the corresponding spermatic plexuses and to the ureter, and the right renal plexus gives filaments also to the inferior vena cava.

(4a) The **spermatic plexuses** (fig. 862) are formed by fibers from the renal and aortic plexuses. They accompany the spermatic arteries and are joined at the abdominal inguinal (internal abdominal) ring by fibers that have passed along the ductus deferens from the pelvic plexuses. Their terminal filaments (chiefly postganglionic fibers) are distributed to the testis and the epididymis.

(4b) The **ovarian plexuses** are formed in the female like the spermatic plexuses in the male. They accompany the ovarian arteries and, in the broad ligament, receive fibers from the uterovaginal plexus. They supply the ovaries, the broad ligaments, and the Fallopian tubes, and send some fibers to the fundus of the uterus, where they become continuous with the uterovaginal plexus.

The unpaired subordinate plexuses:—(1) The **abdominal aortic plexus** is formed by two strands of fibers which descend along the sides of the aorta and communicate with each other across its ventral aspect. It is connected above with the renal plexuses, and it receives peripheral branches from some of the lumbar ganglia of the sympathetic trunk on each side. It often contains a number of ganglia, which are situated at the points where the peripheral branches join the plexus, and it terminates below, chiefly by anastomoses with the hypogastric plexus (figs. 862 and 863). Besides giving filaments to the inferior vena cava, it also gives fibers that form plexuses along each of the branches of the aorta. The fibers that pass from the lower end of the aortic plexus upon the common iliac artery form the **iliac plexus**, which is continued along the femoral artery as the **femoral plexus**, and still further along the popliteal artery as the **popliteal plexus**.

(2) The **superior gastric (coronary) plexus**, receiving filaments from the celiac plexus, accompanies the left gastric (coronary) artery along the lesser curvature of the stomach. Its filaments anastomose with filaments of the vagus nerves and with the plexus that accompanies the right gastric (pyloric) artery (fig. 862), and it gives three varieties of fibers to the walls of the stomach:—(1) visceral afferent fibers, derived chiefly from the vagi; (2) sympathetic or postganglionic fibers, and (3) visceral efferent fibers (craniosacral, chiefly exciting peristalsis), which terminate within the walls, about the cell-bodies of the delicate gangliated plexus myentericus and plexus submucosus (plexuses of Auerbach and Meissner). These fibers innervate the glandular epithelium and the smooth muscle of the stomach walls and its vessels.

(3) The **inferior gastric plexus** receives from the splenic plexus filaments that accompany the left gastroepiploic artery. It gives filaments to the walls of the stomach, which terminate as in the superior gastric plexus. It receives filaments from the vagus nerves and from the plexus that accompanies the right gastroepiploic artery.

(4) The **hepatic plexus** receives filaments from the celiac plexus and from the left vagus. It accompanies the hepatic artery and gives fibers that form plexuses on the branches of the artery and on their ramifications within the liver and gives secretory fibers to the liver cells. It also gives filaments to the portal vein (fig. 862).

The **splenic** or **lienal plexus** is formed by filaments from the celiac plexus, the left celiac (semilunar) ganglion, and from the right vagus. It accompanies the splenic artery and gives filaments which form plexuses on the branches of this artery, and which pass with the branches to supply fibers to the stomach and the pancreas (fig. 862).

(5) The **superior mesenteric plexus** is formed chiefly by filaments from the lower part of the celiac plexus, but it also receives fibers from the right vagus and fibers direct from the celiac (semilunar) ganglia. At the origin of this plexus, dorsal to the superior mesenteric artery, lies the *superior mesenteric ganglion* (fig. 862). The filaments of the plexus, which are white and firm, accompany the superior mesenteric artery and, following its branches and their ramifications, are distributed to the walls of the small intestine, the cecum, and the ascending and transverse colon. From the *secondary plexuses* that accompany the branches of the artery fibers pass to form still other plexuses that lie near the wall of the intestine, between the branches of the artery and between the layers of the mesentery. Filaments pass with the branches of the arteries and from plexuses between them into the intestinal wall, and there join, between the longitudinal and circular muscle-layers of the intestine the fine gangliated **plexus myentericus** (plexus of Auerbach), and filaments from this plexus join, in the submucosa, the delicate **plexus submucosus** or plexus of Meissner. From these latter plexuses fibers arise which terminate upon the gland cells and smooth muscle-fibers of the intestinal wall and its vessels. The white appearance of the filaments of the superior mesenteric plexus is due to the large number of craniosacral visceral efferent and afferent fibers (from the vagi and sacral nerves, especially) in it.

(6) The **inferior mesenteric plexus** is derived chiefly from the left side of the aortic plexus. It descends upon the inferior mesenteric artery and gives off filaments which accompany the branches of the artery and are distributed to the descending colon and to the sigmoid colon (figs. 862 and 863). The filaments which accompany the left colic branch of the inferior mesenteric artery anastomose with the filaments of the superior mesenteric plexus which accompany the middle colic artery. The filaments which accompany the superior hemorrhoidal artery form the **superior hemorrhoidal plexus** (plexus rectalis cranialis NK). This plexus gives off the *superior hemorrhoidal nerves* (nn. rect. craniales NK) (fig. 863) which supply the upper part of the rectum and anastomose with the *middle hemorrhoidal plexus*.

4. The Hypogastric Plexus

The hypogastric plexus lies partly in the abdominal cavity and partly in the pelvic cavity. It is formed chiefly by filaments continued downward from the aortic plexus, and by the pelvic splanchnics and peripheral branches from the

lumbar nerves and sympathetic trunk and from white rami of the sacral nerves (figs. 857, 863). The *abdominal part* of this plexus consists of plexiform bundles of fibers descending between the common iliac arteries and interlacing in front of the fifth lumbar vertebra to form a broad, flattened, plexiform mass. In its extent it receives branches from the lumbar ganglia of the sympathetic trunk. This plexiform mass then divides into two parts, right and left, which descend

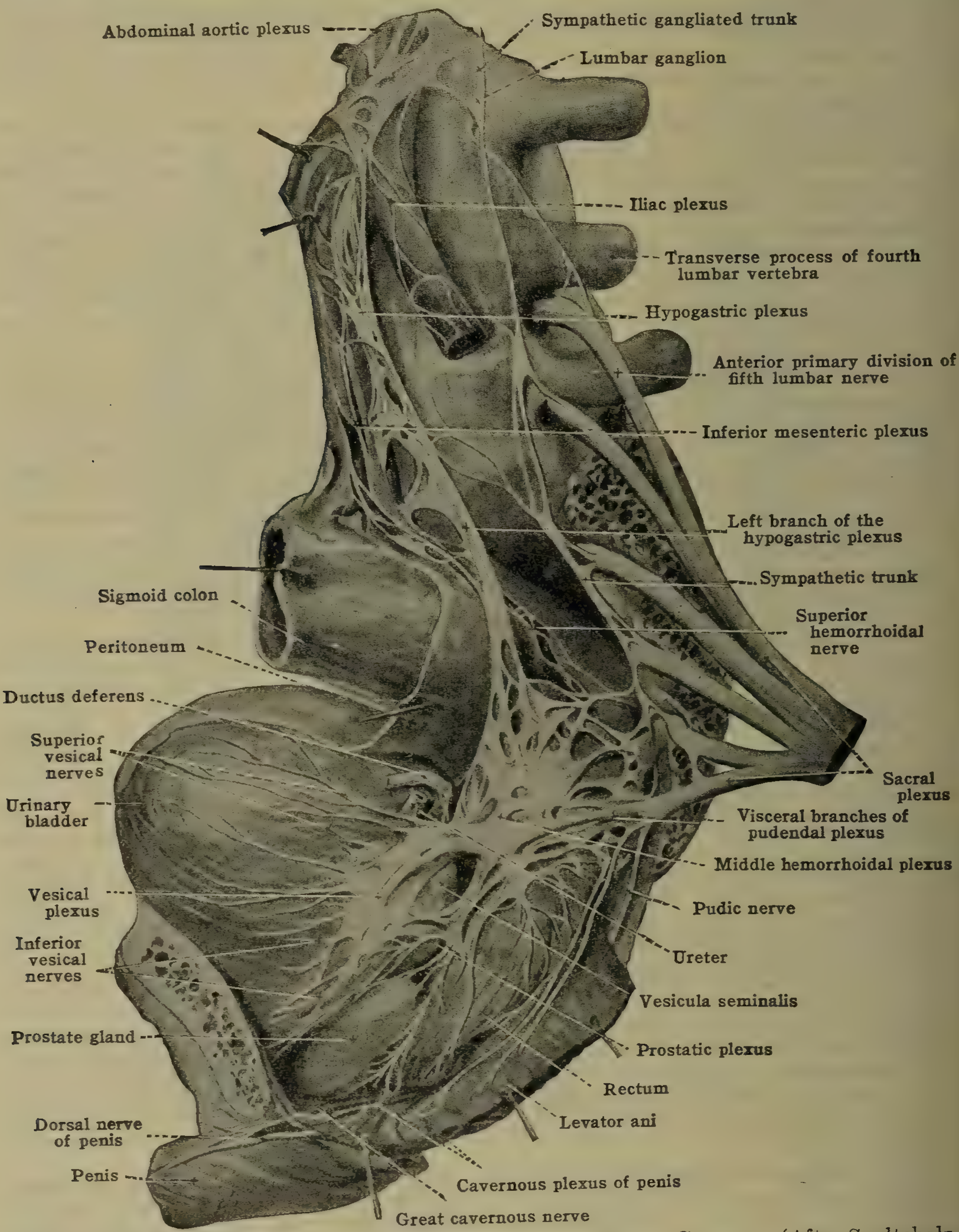


Fig. 863.—The Hypogastric and Subplexuses of the Pelvic Cavity. (After Spalteholz.)

into the pelvic cavity and which, by British authors, are frequently designated as the *pelvic plexuses.*

The *pelvic parts* of the hypogastric plexus (pelvic plexuses) lie at the sides of the rectum in the male, and at the sides of the rectum and the vagina in the female. They receive peripheral branches (postganglionic) from the sacral ganglia of the sympathetic trunk and visceral efferent fibers (preganglionic) by way of the *pelvic splanchnics* from the second and third or third and fourth sacral spinal nerves. Each pelvic part of the plexus accompanies the corresponding hypogastric (internal iliac) artery, and gives off secondary plexuses that continue on the

branches of the artery to the pelvic viscera. Of these secondary plexuses, the middle hemorrhoidal and the vesical plexus are common to both sexes and are paired.

The **middle hemorrhoidal plexus** (plexus rectalis caudalis NK) passes on each side along the middle hemorrhoidal artery to the rectum, where it receives the superior hemorrhoidal nerves and sends filaments into the wall of the rectum (fig. 863).

The **vesical plexus** receives some branches from the pelvic parts of the hypogastric plexus, but is largely reinforced with spinal nerve fibers by way of the pelvic splanchnics, from the third and fourth sacral nerves. On each side it passes along the corresponding vesical arteries to the bladder, and gives off two sets of branches, namely, the *superior vesical nerves* (fig. 863), which supply the upper part of the bladder-wall and send some branches to the ureter, and the *inferior vesical nerves*, which supply the lower part of the bladder and, in the male, give secondary **deferential plexuses** to the ductus deferens. These plexuses surround the ductus deferens and the vesiculæ seminales and anastomose with the spermatic plexuses.

The **prostatic plexus,** found only in the male, is formed in two parts by nerves of considerable size, and lies chiefly on the sides of the prostate gland between it and the levator ani (fig. 863). Each of these parts supplies the gland and the prostatic part of the urethra, and sends offsets to the neck of the bladder and the vesiculæ seminales. This plexus is continued forward on either side to form the **cavernous plexus of the penis** (fig. 863), which anastomoses with branches of the dorsal nerve of the penis, gives off branches to the membranous part of the urethra, and also gives origin to two sets of nerves, namely, the large and the small cavernous nerves of the penis.

The **large cavernous nerve** [n. cavernosus penis major], one on each side, runs forward to the middle of the dorsum of the penis where it anastomoses with the dorsal nerve of the penis on the corresponding side, and ends in twigs which are distributed chiefly to the walls of the sinuses of the corpus cavernosum penis, but some of the terminal filaments supply the corpus cavernosum urethræ (corpus spongiosum) (fig. 863).

The **small cavernous** nerves [nn. cavernosi penis minores], are small filaments which pierce the urogenital diaphragm and the sphincter urethra, and enter the posterior part of the corpus cavernosum.

The **uterovaginal plexus,** found in the female, is formed in its *upper part* on each side largely by fibers derived from the pelvic part of the hypogastric plexus, but it receives some fibers from the pelvic splanchnics of the third and fourth sacral nerves. The nerves from this part of the plexus accompany the uterine arteries as they pass between the layers of the broad ligament. Some accompany each uterine artery and its branches to their termination, but a considerable number of fibers leave the artery and pass into the body of the uterus to supply the smooth muscle of its lower part and cervix. Between the layers of the broad ligament this plexus anastomoses with the ovarian plexus and sends some filaments to the uterine tube (Fallopian tube). The *lower part* of the plexus uterovaginalis receives some fibers on each side from the pelvic part of the hypogastric plexus, but it is formed chiefly by visceral efferent fibers from the second, third, and fourth sacral nerves. These fibers terminate in contact with intrinsic nerve cell-bodies whose axones supply the wall and mucous membrane of the vagina and urethra. From the plexus on the anterior surface of the vagina fibers pass to form the **cavernous plexus of the clitoris,** which gives off the great and lesser **cavernous nerves of the clitoris** for the supply of the clitoris. The uterovaginal plexus of the female corresponds to the prostatic plexus of the male.

References for the nervous system.—**General:** Barker, Nervous System, 1899; Edinger, Vorlesungen, 1908; Johnston, Nervous System, 1907; Villiger, Gehirn und Rückenmark, 1912; Bechterew, Funktion der Nervencentra, 1908; Herrick, Introduction to Neurology, 1931; Ranson, Anatomy of the Nervous System, 1920.

Central system: (*Functions; cerebrum*), Bolton, Brain, Vol. 33; Brodman, Jour. für Psychol. und Neurol., Vol. 10; Brown and Sherrington, Jour. of Physiol., Vol. 46; Cushing, Brain, Vol. 32; Donaldson, Jour. Ner. and Ment. Dis., 1900; Head Brain, vol. 41; Leyton and Sherrington, Quart. Jour. Exper. Physiol., Vol, 11; Mellus, Anat. Rec., Vol. 5; Sachs, Brain, Vol. 34; Shimazono, Arch. für Anat. und Entwickl., 1912; Smith, Jour. Anat. and Physiol., Vol. 34; Flechsig, Leipzig, 1896; Wilson, Brain, vol. 36. (*Cerebellum*), André-Thomas and Durupt, Paris, 1914; Bárány, Wiener Klin. Wochs., Vol. 25; Bolk, Jena, 1906; Black, Jour. Lab. Clin. Med., Vol. 1; Smith, Anat. Anz., Vol. 23; Strong, Jour. Comp. Neur., Vol. 25; Van Rynberk, Ergebn. der Physiol., Vols. 7 and 11. (*Tracts*), Bregman, Anat. Anz., Vol. 48; Goldstein, Neurol. Centralb., 1910; Head and Thompson, Brain, Vol. 29; Horrax, Anat. Rec., Vol. 9; Linowiecki, Jour. Comp. Neur., Vol. 24; Tschermak, Arch. für Anat. und Physiol., 1898. (*Anatomy and development*) Cameron, Jour. Canadian Med. Assoc., 1917; Streeter, Am. Jour. Anat., Vol. 4 and Anat. Rec., Vol. 2; Sugita, Jour. Comp. Neur., Vol. 29; Symington and Crymble, Jour. Anat. and Physiol., Vol. 47; Kolmer, Zeitschr. f. Anat., Bd. 93.

Peripheral system: (*Cranial nerves*), Brookover, Jour. Comp. Neur., Vol. 28; Bremer, Am. Jour. Anat., Vol. 28; Feiling, Brain, Vol. 36; Hulles Arb. a. d. Neurol. Inst. Wiener Univ., Vol. 13; Koch, Jour. Comp. Neur., Vol. 26; Larsell, Jour. Comp. Neur., Vol. 30; Willems, E Névraxe, Vol. 12. (*Spinal nerves and plexuses*), Bardeen, Anat. Anz., Vol. 19 and Am. Jour. Anat., Vol. 1; Compton, Jour. Anat. and Physiol., Vol. 51; Harrison, Am. Jour. Anat., Vol. 5; Ingbert, Jour. Comp. Neur., Vol. 14; Johnson and Mason, Jour. Comp. Neur., Vol. 33; Kerr, Am. Jour. Anat., Vol. 23; Stopford, Jour. of Anat., Vol. 53. McCrea, Jour. Anat., Vol. 59. (*Sympathetic system*), Carpenter Psychol. Bull., Vol. 14; Carpenter and Conel, Jour. Comp. Neur., Vol. 24; Johnson, Jour. Comp. Neur., Vols. 29, 33; Langley, Brain, Vol. 26; Ranson and Billingsley, Jour. Comp. Neur., Vol. 29; Holmes and Ranson, Jour. Lab. and Clin. Med., vol. 10; Sherrington, New York, 1906 and Quart. Jour. Exper. Physiol., Vol. 2. Rossi, Jour. Comp. Neur., Vol. 34. Agduhr, Verslag van Gew. Vergad. Wis.-Natuurk., D. 27.

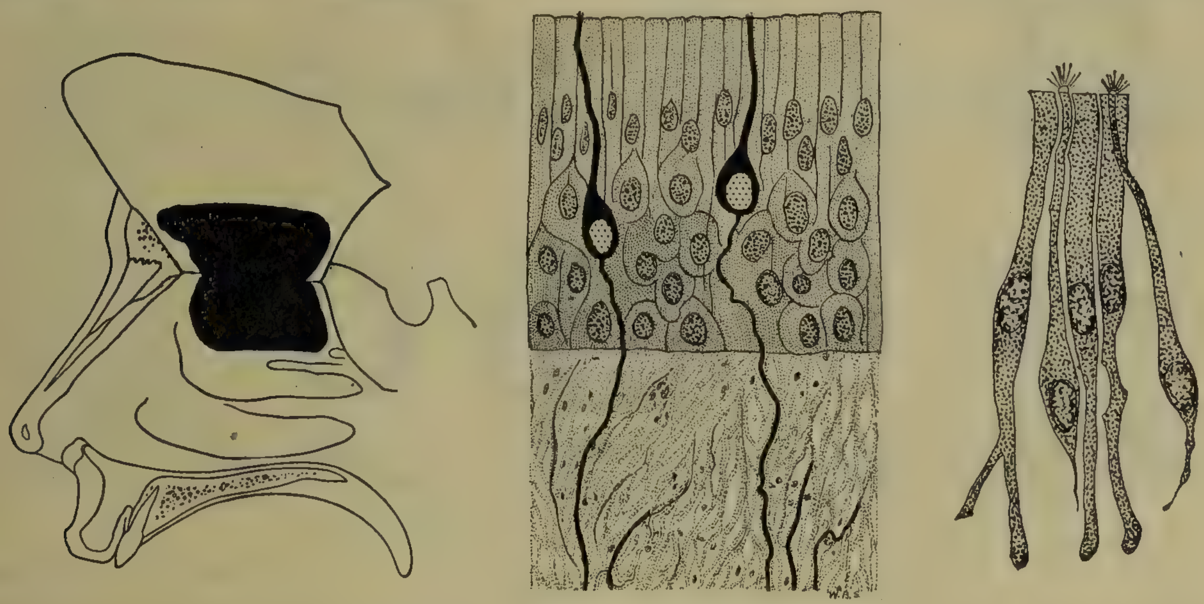
SECTION IX

SPECIAL SENSE ORGANS

By LESLIE BRAINERD AREY, Ph.D.

ROBERT LAUGHLIN REA PROFESSOR OF ANATOMY, NORTHWESTERN UNIVERSITY

THE **sense organs** [organa sensuum] of the body are divisible into two categories. One is the group of endings of general sensibility which mediate such sensations as touch, pressure, muscle and tendon sensibility, temperature and pain. They are distributed in the skin of the body and occur also in muscles, tendons, joints and the internal viscera. The other set, designated as special sense organs, includes the peripheral instruments of the senses of smell, taste, vision and hearing. These latter structures are found only in certain localized areas of the head (fig. 864 B) where they have become specialized to



A B C

Fig. 864.—The Olfactory Organ.

A. Right nasal cavity, with the nasal septum turned up along its superior border. The olfactory area is indicated in black. (After Read.)

B. Vertical section of the olfactory mucous membrane prepared by the silver technique. The olfactory cells and fibers are in black. × 550.

C. Isolated elements of the olfactory epithelium. The olfactory cells bear cilia. × 735. (After Brunn.)

respond to particular forms of stimulation to which the other sensory endings are insensitive. The organs of smell, vision and hearing convey information concerning objects and events at some distance from the body. Hence these three organs have been called 'distance receptors' to distinguish them from the other sensory neurones which collect information from the organism itself and especially from the skin.

The essential difference between what is termed general sensibility and the special senses lies in the fact that the organs of special sense are each attuned to a specific stimulus which does not affect any other part of the body. Thus the waves of light or sound and the chemical substances which excite a consciousness of taste or stimulate the olfactory epithelium—all these varied stimuli create no impression whatever when they come into contact with the sensitive general surface of the body or even with sense organs other than those especially adapted to each kind of stimulus. This difference in function between the ordinary and the special senses, as well as the differences between the individual organs

of special sense, is also associated with a specificity of structure. In other words, each special sense organ has a characteristic receptive mechanism of cells, highly specialized in form, structure and function, which receives the stimuli coming from without and transmits their effects to the nerve-endings, whence an appropriate impulse is relayed to the brain. These cells are all derived directly or indirectly from the surface of the body. The mechanisms of smell and taste are relatively simple and consist of little more than the special sensory cells without any accessory apparatus. On the other hand, the eye and ear are highly complex in structure; this is because an elaborate mechanical arrangement is necessary for receiving the original external stimulus and converting it into a form appropriate to affect the sensory cells proper.

It must, nevertheless, always be borne in mind that sensation itself is a function of the brain alone—it is the response in consciousness to the afferent impressions transmitted to the brain by the sensory nerves and profoundly modified during their passage through the central nervous system. Further, the quality of the sensation does not arise in the sense organ but in the brain itself. Thus it is that artificial stimulation of the trunk of a sensory nerve can produce sensations similar to those obtained normally through the related sensory end-organ.

THE OLFACTORY ORGAN

There are no complicated accessory structures forming a distinct **olfactory organ** [organon olfactus] corresponding, for example, to the eye and ear. The nose

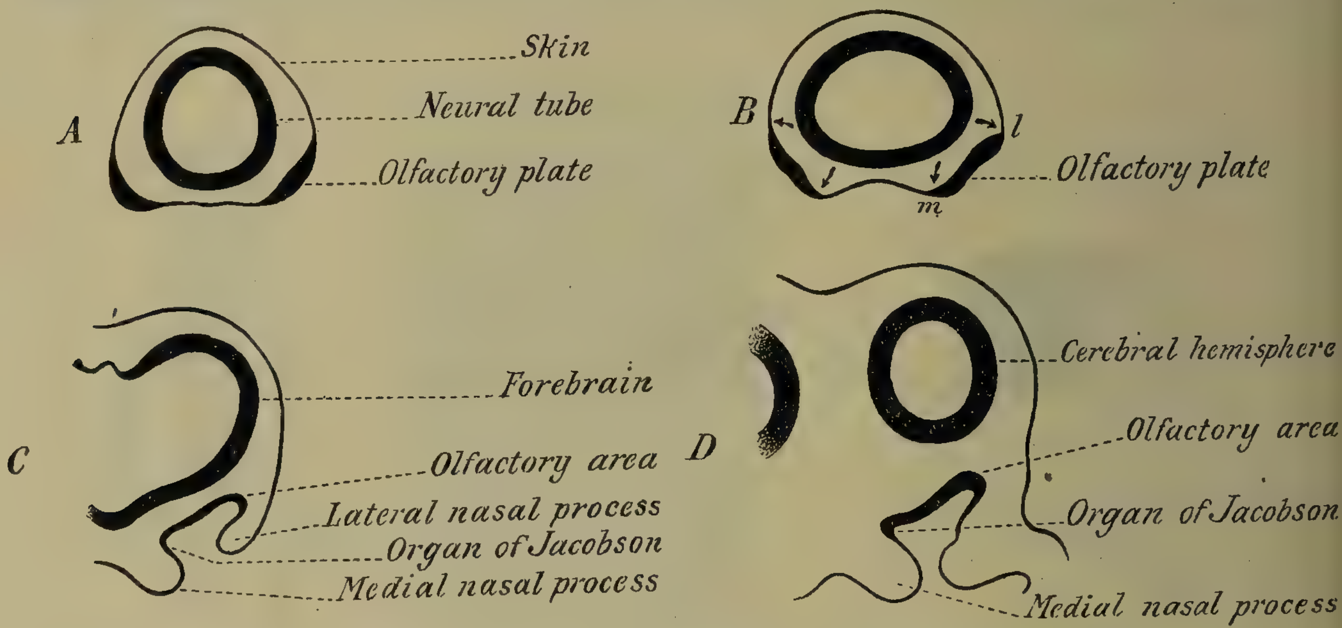


Fig. 865.—Development of the Olfactory Organ, as Illustrated by Transverse Sections through the Head. × about 15.

A. At 5 mm., with early olfactory placodes.
B. At 6.5 mm., with nasal processes (*m* and *l*) appearing.
C. At 9 mm., with olfactory fossa present.
D. At 10 mm., with olfactory fossa differentiating further.

is the peripheral organ of smell, but only a small part is directly olfactory in nature while the remainder is primarily for respiratory purposes. The morphology of the nose as a whole is described on pp. 1295–1299.

The **olfactory region** [regio olfactoria] comprises but a minor portion of each nasal cavity (fig. 864 A). On the lateral wall it is limited chiefly to a field over the superior and supreme conchæ, but it also invades slightly the middle concha; the adjacent septum bears a similar olfactory territory. The total area is about that of a one-cent piece. The olfactory mucous membrane, yellowish and less vascular than the respiratory mucosa, is chiefly characterized by its epithelium (fig. 864 B, C). Besides tall, non-ciliated *sustentacular cells* and small *basal cells* there are the specific *olfactory cells.* These are bipolar, spindle-shaped elements whose blunt peripheral process ends in several fine olfactory hairs and whose central process continues brainward as an olfactory nerve-fiber.

The olfactory cell corresponds to a ganglion cell of the dorsal spinal roots, but in this instance the cell body has retained its primitive location in the surface epithelium. In this regard the olfactory neurone is unique among the primary neuroepithelial cells of vertebrates, although a similar condition is well known among invertebrates. The nerve-fibers, lacking myelin sheaths,

collect in small bundles and course through the cribriform plate of the ethmoid bone to enter the olfactory bulb of the brain (figs. 762, 801).

The **vomeronasal organ** (of Jacobson) [organon vomeronasale] is a tiny, tubular epithelial sac situated on each anteroinferior surface of the nasal septum. Although rudimentary in man, it is homologous with a similar organ of certain quadrupeds where it apparently serves as an accessory organ of olfaction.

Development of the olfactory organ.—The *olfactory placodes* are paired thickenings of the primitive epidermis, appearing first on the under surface of the head of embryos 4 mm. long and in the fifth week of development (figs. 12 B, 865 A). Specimens twice this size show these plates depressed into pits, known as *olfactory fossæ* (fig. 865 B–D), about which the nose soon develops from the nasal processes of the primitive face (fig. 17). The lining epithelium of each fossa differentiates into olfactory and respiratory regions, while from the medial wall a separate pocket foreshadows the vestigial vomeronasal organ (fig. 865 D). Additional details of the development of the nose are given on pp. 52, 1311.

THE GUSTATORY ORGAN

The **taste-organ** [organon gustus] consists of an aggregate of minute epithelial bodies, the *taste-buds* [caliculi gustatorii], situated mostly in the epithelial covering of the tongue. The commonest location is on the walls of the vallate papillæ (fig. 941), but they are also plentiful on the foliate papillæ and occur sparingly on the fungiform papillæ, soft palate and epiglottis. They are more numerous and wide-spread in the newborn than in the adult.

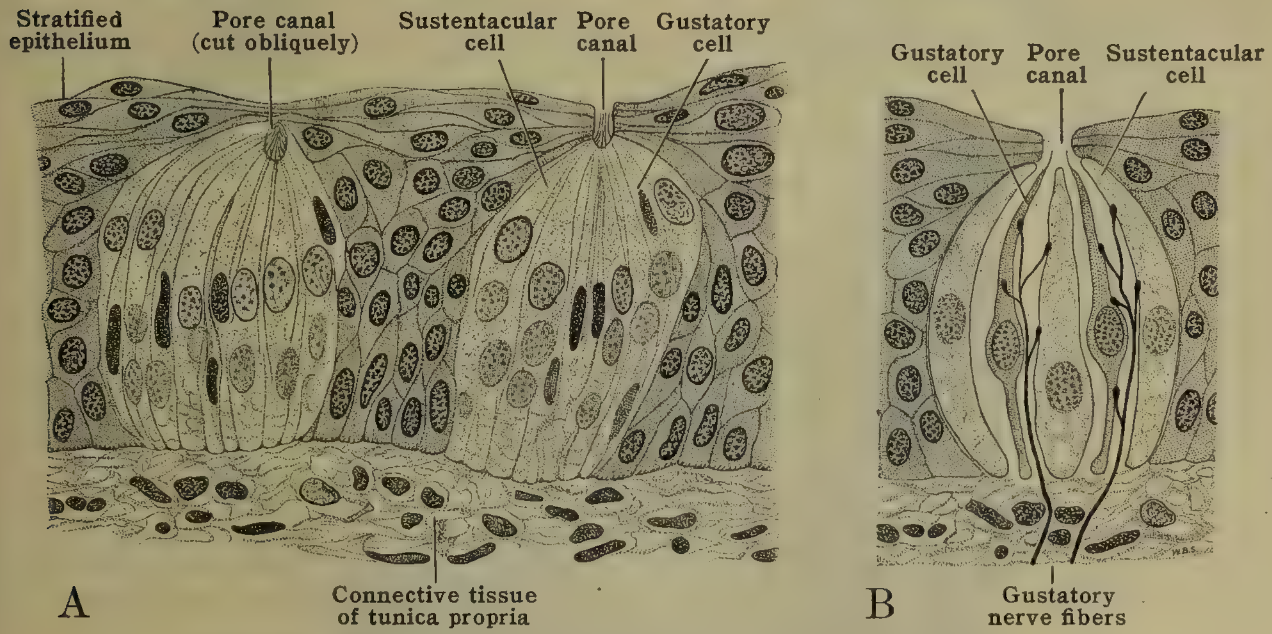


Fig. 866.—Taste-Buds in Vertical Section.
A. From a vallate papilla. × 475.
B. Diagram of the structure of a taste-bud. × 475.

The chorda tympani division of the sensory root of the facial nerve is the nerve of taste for the anterior two-thirds of the tongue; the glossopharyngeal nerve supplies the posterior third (figs. 812, 945). The entire region of mucous membrane innervated by these nerves seems to be sensitive to taste stimuli, rather than the taste-bud areas alone.

A taste-bud is ovoid or conical in shape, measuring about 0.07 mm. in length and somewhat less in greatest breadth. It is a specialized part of the oral stratified epithelium, extending through the entire thickness of this membrane and opening at the free surface through a small channel termed the *pore-canal* (fig. 866 A).

1. Structure of the taste-buds.—A taste-bud consists of gustatory cells and supporting cells (fig. 866 B). The *gustatory cells* are slender, fusiform elements which have been appropriated from the general epithelium and set apart as specialized secondary sense cells. About their sides fine nerve branches ramify for the purpose of receiving the impulses generated by the contact of such cells with sapid particles in solution. The free end of each gustatory cell ends in a stiff, hair-like process which projects into the pore-canal. The *sustentacular cells* are thick, elongate elements arranged chiefly about the periphery of the taste-bud, like the staves of a barrel. Nevertheless, transitional stages between gustatory and so-called sustentacular cells are demonstrable and it is not certain that two distinct cell types exist.

2. Development of the gustatory organ.—The taste-buds begin to organize within the oral epithelium at the end of the second fetal month. A local thickening of the entoderm differentiates into both sensory taste-cells and inert supporting cells. For a time taste buds occur rather generally throughout the oral cavity, but in late fetuses and after birth many degenerate.

THE EYE

The **visual organ** [organon visus] consists of the **eye** [oculus] and various **accessory organs** [organa oculi accessoria], such as the extrinsic muscles, the eyelids and the tear apparatus. The eye, properly speaking, includes merely the **bulb of the eye** [bulbus oculi], or eyeball, and the **optic nerve** [nervus opticus] connecting it with the brain; this system constitutes the essential part of the organ of vision.

The eyeball occupies the front half of the cavity of the orbit where it is embedded in fat and connective tissue (fig. 867). Attached to the bulb and also contained in the orbital cavity are the *optic nerve, ocular muscles* and certain other nerves and vessels. The anterior or exposed third of the bulb is covered by a soft mucous membrane, the *conjunctiva*, which is reflected onto the inner surfaces of the protective *eyelids*. In close association with the eyeball is the *lacrimal apparatus*.

1. THE EYEBALL

The two ocular bulbs, or **eyeballs**, are situated where the upper and middle thirds of the face meet. They lie right and left of the root of the nose, at a distance of about 3 cm. from the midplane of the face. The eyeball is almost spherical, but not perfectly so. A side view of the eye in a living subject will

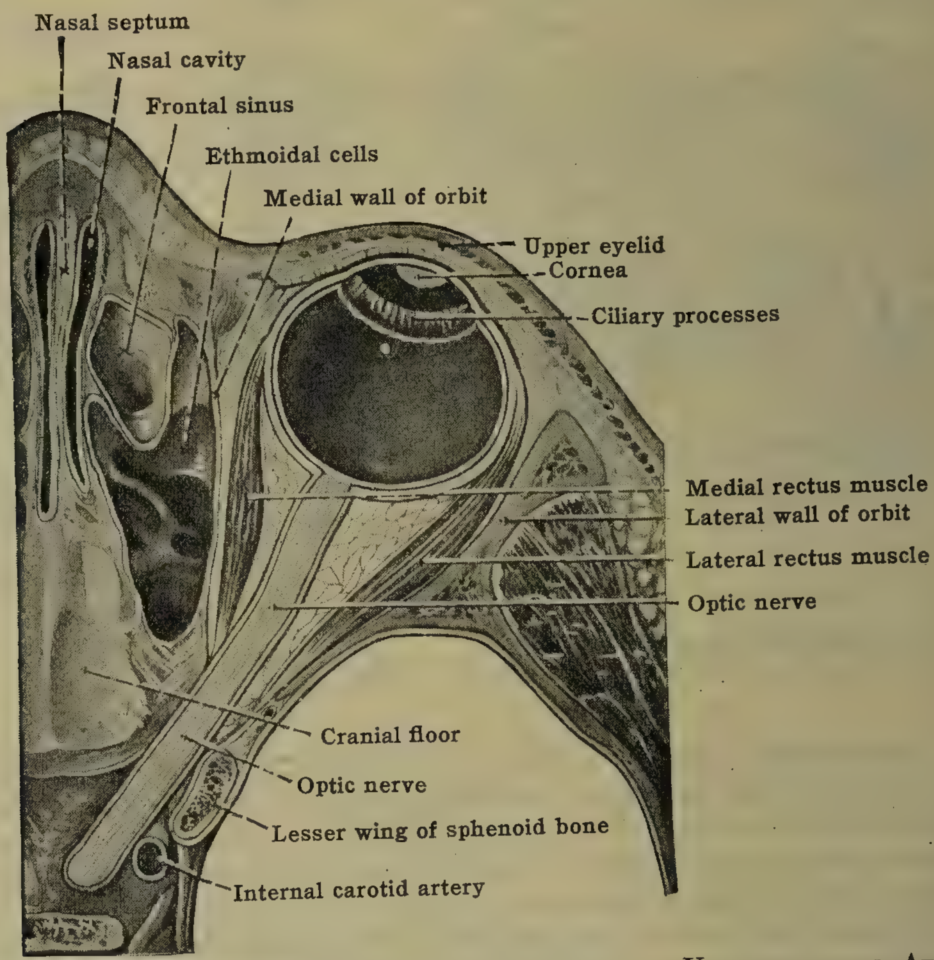


Fig. 867.—Horizontal Section of the Right Orbital Region, Viewed from Above. Natural Size.

show that the anterior, clear front (the *cornea*) bulges beyond the curvature of the larger, white remainder (the *sclera*). Thus the bulb may be said to be composed of parts of two spheres, an anterior portion (one-sixth of the whole), of smaller radius, being superposed upon a larger posterior segment of greater radius (fig. 868). The junction of the two is marked by a shallow circular groove, the *scleral sulcus* [sulcus scleræ].

For ease in description certain topographical terms have been given (fig. 869). The *anterior pole* [polus anterior] designates the center of the corneal curvature; the *posterior pole* [polus posterior] similarly marks the center of the posterior curvature. An imaginary line connecting these two poles constitutes the *axis of the eye* [axis oculi]. The *equator* [æquator] encircles the bulb midway between

the two poles. The various *meridians* [meridiani] are circles which in their circumferential circuits intersect both poles.

The diameter of the bulb is about 24 mm., but the shape is in reality an ellipsoid, flattened slightly from above downward and with the anteroposterior axis longest. In the female the eyeball is 0.5 mm. smaller in all diameters. Bisection of the bulb through its axis in a sagittal plane proves that the medial, or nasal half is slightly smaller than the lateral, or temporal half. The size of the bulb is quite constant in each sex; an apparently large eye is due wholly to protrusion of the bulb and wider opened lids.

The eyeball may be considered as a hollow sphere, whose wall consists of three concentric coats and whose cavity is filled with three transparent refracting media (fig. 868). The three coats are: (1) an outer, **fibrous tunic** [tunica fibrosa oculi], made up of the sclera behind and the cornea in front; (2) an intermediate, pigmented **vascular tunic** [tunica vasculosa oculi], comprised from behind forward

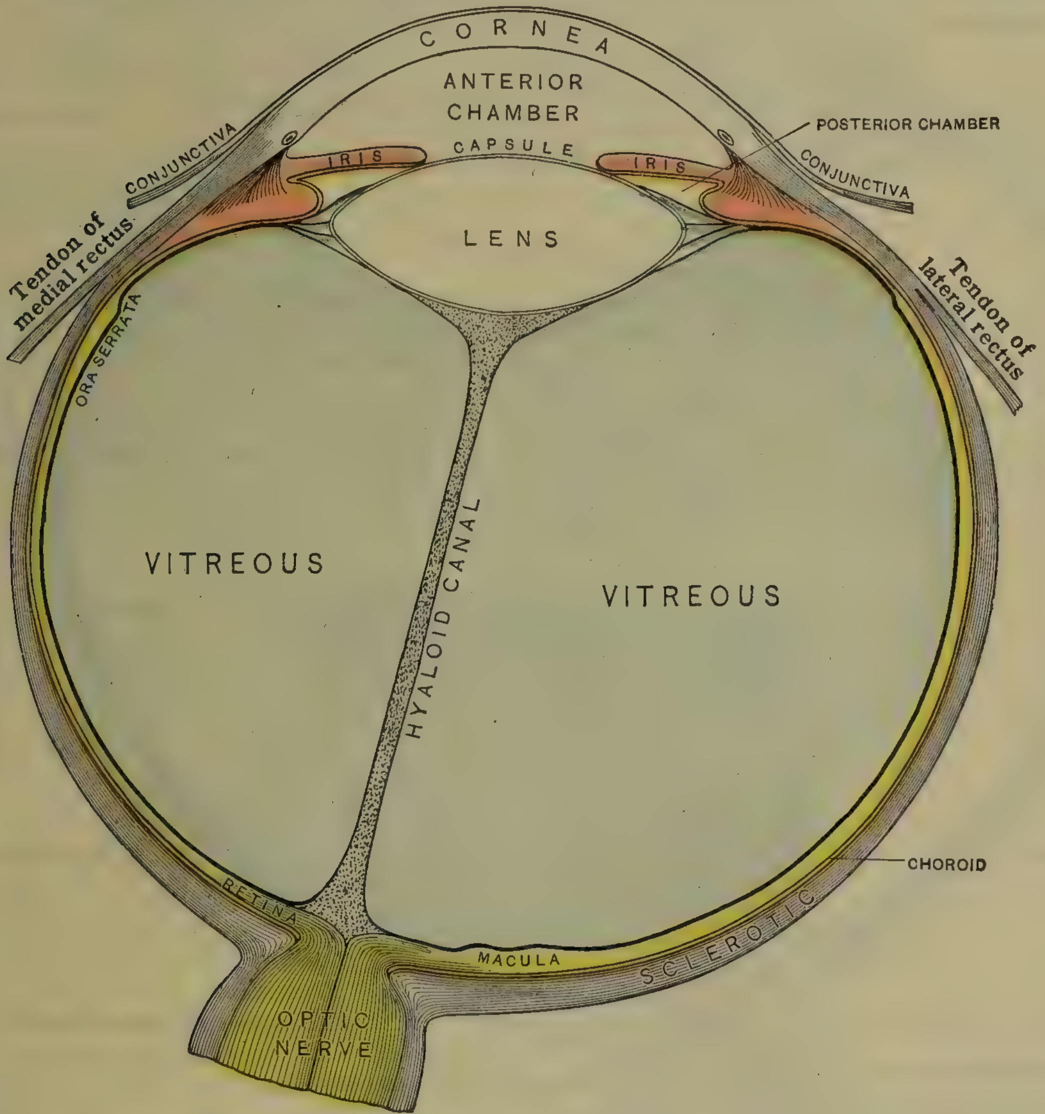


FIG. 868.—THE RIGHT EYEBALL IN HORIZONTAL SECTION, VIEWED FROM ABOVE. × 3.5. (From Testut in Gerrish's 'Anatomy,' Lea & Febiger.)

of the chorioid, ciliary body and iris; and (3) an internal, **nervous tunic** [retina], continuous with the optic nerve. The three refractive media are: (1) the **vitreous body,** behind; (2) the **crystalline lens,** intermediate; and (3) the **aqueous humor,** in front.

A. THE TUNICA FIBROSA OCULI

The **fibrous tunic** (tunica externa NK) consists of the **sclera,** which is the white, opaque portion, and the **cornea,** which is the transparent, anterior remainder through which the pupil and colored iris are seen. At their junction is the shallow groove named the *sulcus scleræ* (fig. 869). Both the sclera and cornea are firm and dense; formed of interlacing fibers, they furnish considerable rigidity to the eyeball.

1. The sclera.—This portion of the fibrous tunic encloses the posterior five-sixths of the bulb. It constitutes the so-called 'white' of the eye, that on the front, exposed surface being covered with the conjunctiva through which small superficial blood-vessels can be seen in life. The *sclera* is in close connection behind with the sheaths of the optic nerve, and is there perforated by the

entering optic nerve fibers; this leaves a sieve-like circular area, called the *cribriform plate* [lamina cribrosa scleræ] (area cribriformis scleræ NK), partially bridged across by fibers from the inner scleral layers (fig. 869). The sclera is thickest (about 1 mm.) posteriorly where it is strengthened by the outer sheath of the optic nerve and by the tissue surrounding the ciliary vessels and nerves; thinning toward the equator (0.4 mm.), it is reinforced by the tendinous insertions of the rectus muscles so that its thickness anteriorly increases to 0.6 mm. (fig. 869).

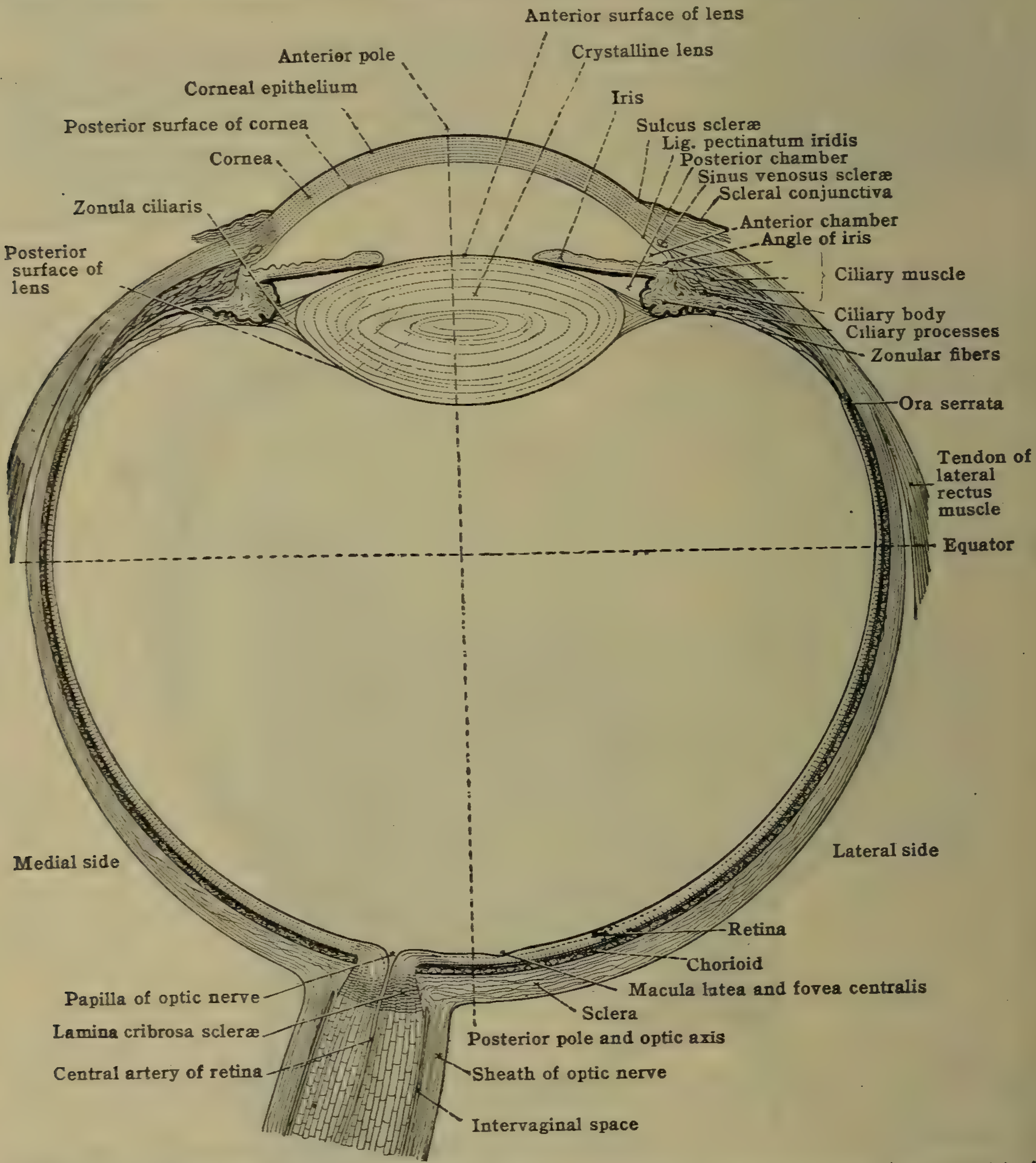


Fig. 869.—Horizontal Section of the Right Eyeball, Viewed from Above. × 4.

In children the sclera is often so thin that the underlying chorioidal pigment shows through and gives it a bluish cast; in the aged it may be yellowish. The sclera is smooth externally except where it receives the rectus and oblique muscles. Around the entrance of the optic nerve numerous small apertures provide for the passage of the long and short ciliary arteries and nerves; near the equator four large apertures transmit the vorticose veins, while close to the corneal junction the sclera is pierced by the anterior ciliary arteries (fig. 875).

Structure of the sclera.—Densely arranged, flattened bundles of white fibers, with a sparse intermingling of elastic fibers, make up the substance of the sclera. The fibers interlace complexly and the whole sclera becomes a firm, inelastic capsule. It is customary to recognize three layers (fig. 870): (*a*) externally is the *episcleral tissue*, looser in texture and grading outward into the spongy tissue of the interfascial space (of Tenon); (*b*) the dense *sclera proper* comprises the main bulk of the sclera; and (*c*) the *lamina fusca* is a thin, pigmented, internal stratum transitional into the lamellated suprachorioidal tissue.

Vessels and nerves.—Sparse *arteries* come from the anterior and short posterior ciliary arteries (fig. 875). *Veins* are tributary to the vorticose and anterior and posterior ciliary vessels (fig. 876). Close to the sclerocorneal junction the sinus venosus scleræ (canal of

Schlemm) runs circularly around the periphery of the cornea and gives rise to the anterior ciliary veins. The *nerves* are branches of the ciliary nerves (see pp. 1010, 1153).

Clinical aspects.—Violent rupture of the eyeball commonly causes the sclera, rather than the cornea, to give way; the bursting point is usually quite close to the corneal border where the sclera is thinnest. It is the firm, unyielding nature of the sclera that produces pressure on nerves, and hence pain, in those affections of the eye characterized by increased intraocular tension. Nevertheless, the eyeball of children may enlarge under these conditions (*buphthalmos*).

FIG. 870.—VERTICAL SECTION OF THE SCLERA AND CHORIOID. × 225. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

The numerous episcleral branches of the anterior ciliary arteries are normally invisible, but when inflamed they appear as a narrow, pink band about the corneal border which is then known as the zone of ciliary congestion.

2. The cornea.—The clear front of the eyball is a fibrous but perfectly transparent and nonvascular portion of the tunica fibrosa. It constitutes the anterior one-sixth of the whole coat. The *cornea* is nearly circular in peripheral outline and has a diameter of approximately 12 mm. Its stronger curvature

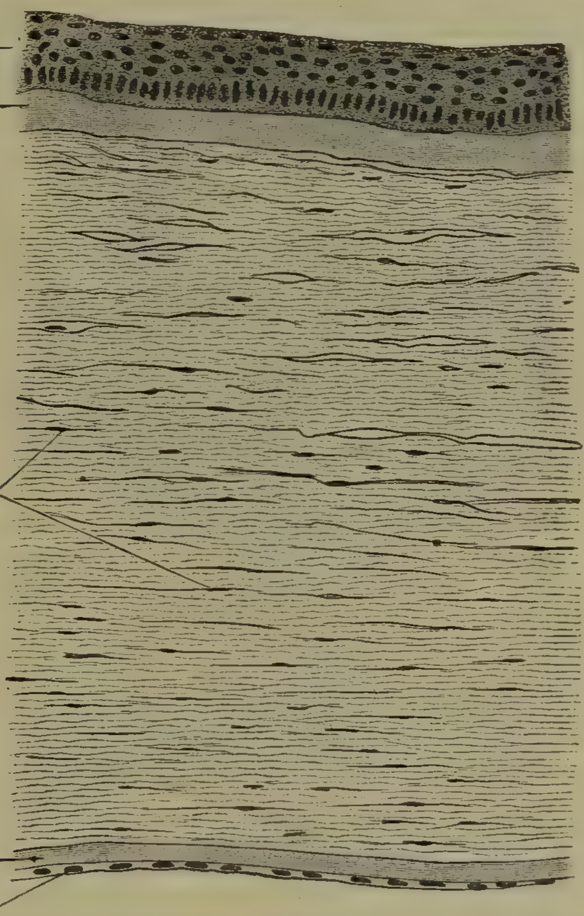


FIG. 871.—VERTICAL SECTION OF THE CORNEA. × 100. (Stöhr.)

makes it bulge prominently as a protruding dome (figs. 869, 875). The degree of curvature varies in individuals and diminishes somewhat with age. At the *corneal border* [limbus corneæ] occurs the scleral sulcus, already mentioned. The cornea is covered with corneal epithelium externally, continuous with that of the general conjunctiva, and bounds the anterior chamber internally. These free surfaces are the *anterior surface* [facies anterior] and *posterior surface* [facies

posterior], respectively. The cornea is thicker than the sclera but diminishes from the margin toward the center, which latter is designated the *vertex corneæ.*

Structure of the cornea.—Five layers can be distinguished (fig. 871): (*a*) The external *corneal epithelium* [epithelium corneæ] is stratified yet contains only about five layers which change quickly from basal, low columnar cells to superficial, flattened elements. (*b*) The *anterior elastic lamina* (of Bowman) [lamina elastica anterior] furnishes an almost homogeneous basement membrane to the corneal epithelium; it may be regarded as a condensed outer portion of the layer next beneath. (*c*) The *substantia propria* comprises the main mass of the cornea; its modified connective tissue is arranged in about sixty dense, thin lamellæ, all of which are cemented into a homogeneous matrix; fine elastic networks are also present, especially at the deeper levels. (*d*) The *posterior elastic lamina* (of Descemet) [lamina elastica posterior] (lamina basialis NK) is a thin, homogeneous lamella of a special elastic nature; it serves as a basement membrane to the endothelium next inside. (*e*) The *endothelium of the anterior chamber* [endothelium cameræ anterioris] covers the posterior surface of the cornea; it is a single layer of relatively thick squamous cells.

The sclerocorneal junction.—At the margin of the cornea there is a transition into the scleral tissue. The corneal epithelium elevates to the more highly stratified type of the conjunctiva. Vascular loops are prominent in the stroma. Besides the changing character of the general fibrous tissue, there is an important modification of the posterior elastic lamina (of Descemet). This splits up into a trabecular meshwork which passes to the iris, serves for the attachment of the ciliary muscle, and constitutes the outer wall of the ring-shaped *scleral venous sinus* [sinus venosus scleræ], or canal of Schlemm. Collectively the mesh is known as the *pectinate ligament of the iris* [ligamentum pectinatum iridis] (spongium anguli iridocornealis NK) (fig. 873). Enclosed between the loose trabecular meshes are the *spaces of the iridial angle* (of Fontana) [spatia anguli iridis] (fig. 883). Both the spaces and the sinus are commonly held to participate in the drainage of aqueous humor from the anterior chamber.

Vessels and nerves.—Except at the extreme periphery, the adult cornea is devoid of blood-vessels and lymphatics. Numerous sensory nerve fibers come from the long and short ciliary nerves (see pp. 1010, 1153, 1154) and are distributed both to the substantia propria and to the corneal epithelium (fig. 888).

Clinical aspects.—The lack of vascularity renders the cornea subject to infection after slight injury (*keratitis*) or to necrosis during malnutrition (*keratomalacia*). In interstitial keratitis the vascular loops at the corneal periphery penetrate the fibrous substance of the cornea for a short distance. Due to a deeper location their color is less bright than usual; large aggregates of such vessels produce characteristic '*salmon patches.*' In the complication of trachoma known as '*pannus*' continued irritation leads to the ingrowth of vessels from neighboring conjunctival arteries; these, however, merely underlie the corneal epithelium and do not invade the deeper substantia propria. Fatty degeneration of corneal tissue, especially in the aged, produces two white crescents near the margin of the cornea, both above and below; these often unite into a ring (*arcus senilis*). Corneal wounds heal readily despite the lack of a direct blood-supply, but any destruction of the fibrous components is repaired by opaque scar tissue. The profusion of free nerve-endings accounts for the high sensitivity of the cornea.

B. The Tunica Vasculosa Oculi

The **middle coat** of the eyeball (tunica media oculi NK) is chiefly vascular, but it also contains anteriorly the intraocular muscles which effect accommodation. For these reasons connective tissue is relatively sparse, yet there are present abundant pigmented cells which color the tunic brown. The soft vascular tunic is intimately connected to the internal retinal layer but it is attached firmly to the sclera in two regions only. Both are ring-shaped zones of fusion, one about the optic nerve, the other at the sclerocorneal junction. Elsewhere there is a narrow perichorioidal space bridged by extremely delicate connective-tissue lamellæ. Most anteriorly the middle coat is continued into the iris which is a flattened ring-shaped plate, separated from the cornea by the large 'anterior chamber.' The vascular coat has two prominent openings: the larger one, in front, is the pupillary opening of the iris; the smaller, behind, permits the passage of the optic nerve toward the brain.

Three regional subdivisions, differing structurally, may be recognized (fig. 868, in red). From behind forward they are, in order: (1) the **chorioid** [chorioidea]; (2) the **ciliary body** [corpus ciliare]; and (3) the **iris.**

1. **The chorioid** (chorioides NK).—This is a soft, thin membrane which comprises the posterior two-thirds of the vascular coat. It lies between the sclera and retina and extends as far forward as the visual limit (ora serrata) of the latter (fig. 869). The chief function of the chorioid is to maintain the nutrition of the retina, and to this end its blood-vessels constitute the most striking structural feature of the layer. When normally filled with blood, the chorioid has a maximum thickness of about 0.25 mm. posteriorly, but this diminishes by one-half at the anterior limit. The chorioid is pierced by the optic nerve and receives the short ciliary arteries and the vorticose veins. Its external surface is rough because of the connecting lamellæ which traverse the peri-

chorioidal space in passing to the sclera; the internal surface is smooth through an intimate attachment to the flat pigment layer of the retina.

Structure of the chorioid.—Four layers are present, which when enumerated from without inward are as follows (fig. 870): (*a*) The *suprachorioid* [lamina suprachorioidea] (stratum perichorioideum NK) consists of series of slanting lamellæ which connect chorioid with sclera. The sum total of the cleft-like spaces between lamellæ comprises the *perichorioidal space* [spatium perichorioideale]. Each lamella consists of so-called endothelium, structureless except for scattering nuclei; it bears chromatophores and is supported by elastic fibers. (*b*) The *vascular layer* [lamina vasculosa] (l. crassivasculosa NK) is a stratum composed of larger vessels externally and smaller ones internally. Its connective-tissue stroma is characterized by stellate pigmented cells. Most internally there is a thin zone, containing peculiar stromal cells, intermediate in position between the blood-vessels and the still deeper capillaries of the next stratum; it is sometimes recognized as a separate layer and in it is found the specialized, iridescent tapetum of some animals. (*c*) The *capillary layer* [lamina choriocapillaris] (l. capillarium NK) is a single-layered network of large capillaries embedded in fine fibrous tissue; the surface of the capillaries toward the retina lies directly against the basal membrane of the pigmented epithelium. (*d*) The *basal membrane* (of Bruch) [lamina basalis] is a double mem-

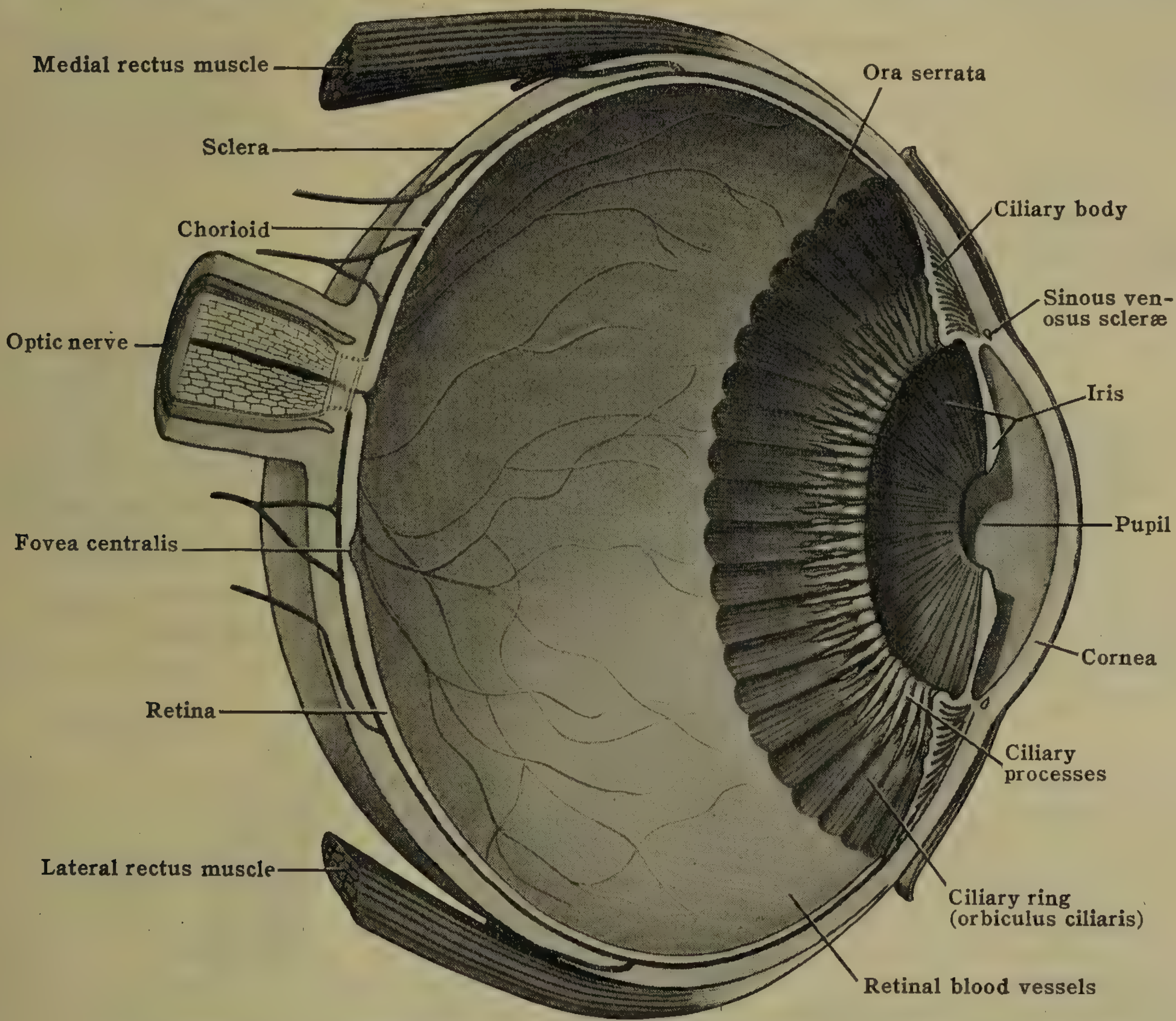


Fig. 872.—Horizontal Hemisection of the Right Eyeball, Viewed from Above and Behind. × 4.

brane, 1 to 2μ thick. Its outer lamella is apparently a compact, elastic feltwork continuous with fibers in the capillary interstices. The inner component is homogeneous and is believed to be a cuticular derivative of the pigmented epithelial cells.

Clinical aspects.—Congenital *coloboma* of the chorioid is a deficiency of chorioidal tissue inferiorly along the course of the fetal cleft in the optic cup. It allows the pearly sclera to show through at ophthalmoscopic examination, even though the defect be covered internally with thin, atypical retina. It is to be expected from the vascular nature of the chorioid that its disturbances are mostly inflammatory (*chorioiditis*). Inflammatory foci sometimes convert into fibrous areas, binding the chorioid to the retina and terminating in the atrophy of both. Injuries to the eyeball, or even sudden decrease of intraocular tension at operation, may lead to extensive bleeding into the perichorioidal space. Also hemorrhages between the chorioid and retina must originate from chorioidal vessels since the outer layers of the retina are entirely nonvascular. Pigmented sarcomatous tumors develop from the pigmented cells of the chorioidal stroma.

2. The ciliary body.—The thickened middle portion of the vascular tunic extends from the level of the ora serrata to the iris. The entire *ciliary body* is a wedge-shaped, flattened ring which is triangular in meridional section (fig.

873). The outer surface is in apposition with the sclera; the short anterior side, at right angles to the outer, extends from the pectinate ligament toward the lens; the inner, free surface is lined by an insensitive extension of the retina. The ciliary body consists of three parts (figs. 872, 873): (*a*) The **ciliary ring** [orbiculus ciliaris]; (*b*) the **ciliary crown** [corona ciliaris]; and (*c*) the **ciliary muscle** [musculus ciliaris].

A view of the internal surface of an eyeball shows a wavy line about midway between the equator and the lens (fig. 872); this ora serrata of the retina marks the transition between the light-sensitive retina proper, posteriorly, and the blind extension which continues anteriorly even to the pupillary border of the iris. Directly anterior to the ora serrata is a girdle-shaped zone, 3 to 4 mm. wide, known as the *orbiculus ciliaris*, or ciliary ring; it has a relatively smooth surface, yet bears narrow radial grooves. Directly adjoining the orbiculus, still in an anterior direction, is a narrower circular zone, the *corona ciliaris;* this ciliary crown takes its name from the prominent meridional ridges, or *ciliary processes*

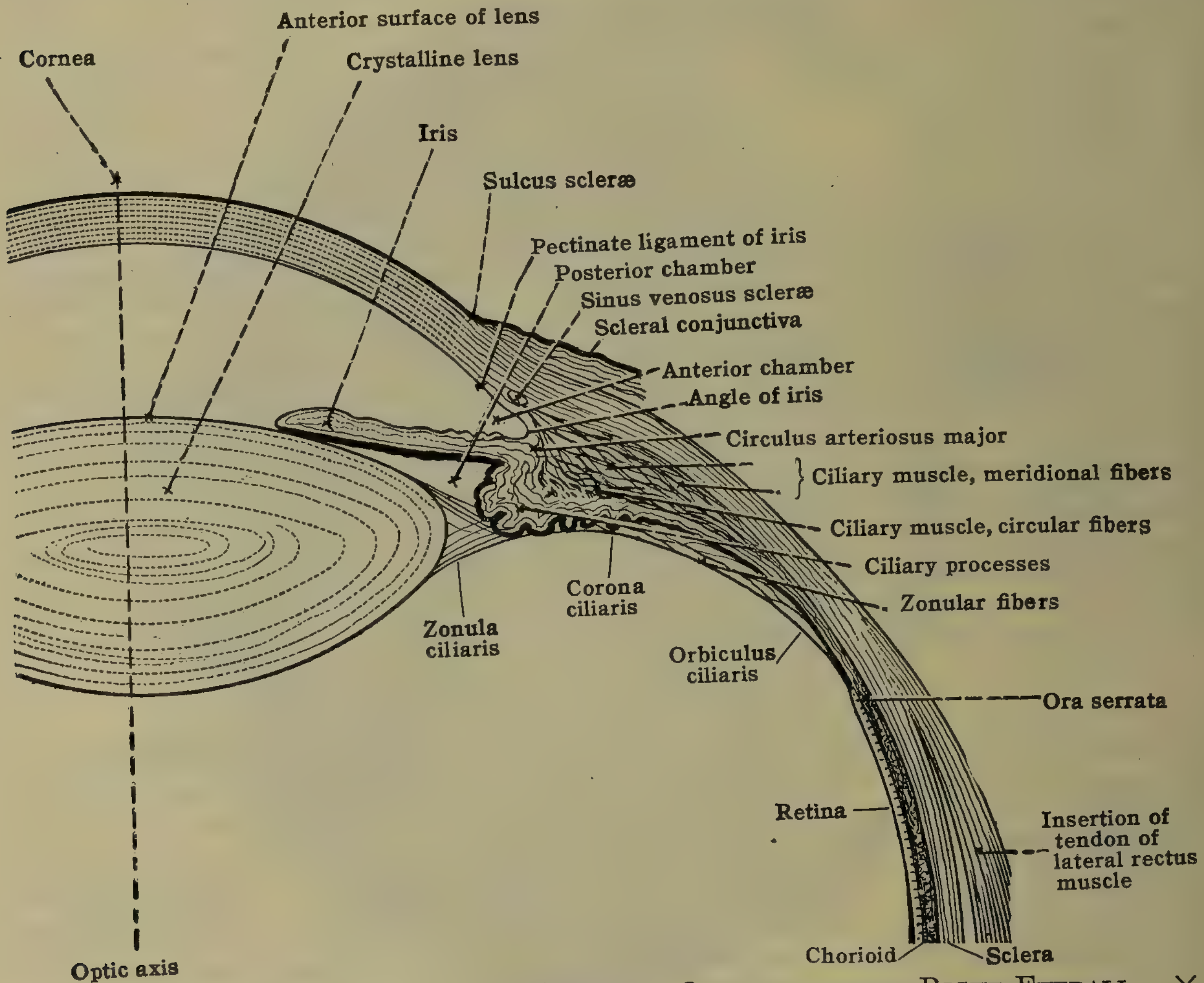


FIG. 873.—HORIZONTAL SECTION OF AN ANTERIOR QUARTER OF THE RIGHT EYEBALL. × 6.

[processus ciliares] (plicæ ciliares NK), about 70 in number, which characterize its folded internal surface and serve as points of attachment for the fibers of the suspensory ligament of the lens. The outer portion of the ciliary body, chiefly between the sclera and the corona, is occupied by the *ciliary muscle* (fig. 873). This is a mass of smooth fibers, thick anteriorly but tapering off posteriorly; it more or less repeats the triangular shape of the ciliary body in meridional section.

Structure of the ciliary body.—The chorioid passes insensibly into the *orbiculus ciliaris* which is the least modified part of the ciliary body; here, as elsewhere in the ciliary body, the choriocapillaris is absent. The *ciliary processes* of the *corona ciliaris* are elevated meridional folds, or ridges, about 2 mm. long and 0.8 mm. high; toward the orbiculus they taper, but their ends next the lens are more free and rounded (fig. 872). Similar smaller elevations in the intervening furrows are the *ciliary folds* [plicæ ciliares]. The ciliary processes consist of a rich vascular plexus embedded in a pigmented stroma. Superficially, next the cavity of the eyeball, is an epithelial covering of modified retina. It consists of an outer, pigmented layer [stratum pigmenti corporis ciliaris] and an inner, unpigmented layer [pars ciliaris retinæ]; both sheets are of simple, single-layered epithelium. The *ciliary muscle* is an elaboration within the suprachorioid layer (fig. 873). For the most part it is made up of *meridional fibers* [fibræ meridionales] which course toward the ciliary processes, orbiculus and chorioid. The *circular*

fibers [fibræ circulares] comprise a band located internally, near the base of the iris. The ciliary muscle is the chief agent in changing the shape of the lens during accommodation.

Clinical aspects.—Penetrating wounds of the cornea or sclera are most serious when in the immediate region of the ciliary body. This territory is the 'danger zone' of the eye. Here occur the most important vascular and nervous anastomoses of the eyeball, and from this zone inflammation (*cyclitis*) can spread rather directly to almost all parts of the eye. Of special seriousness is *sympathetic ophthalmia* which by an uncertain route induces destructive inflammation in the sound eye.

3. The iris.—The most anterior portion of the vascular tunic is the colored *iris*, a circular plate, 12 mm. in diameter and 0.5 mm. thick (fig. 872). It is pierced centrally by an aperture of changeable width, the *pupil* [pupilla], which is useful in regulating the amount of light admitted to the eye. The iris is suspended free in the aqueous space between the cornea and lens and divides it into an anterior and a posterior chamber (fig. 873). At its peripheral border the iris is continuous with the ciliary body and it is also connected to the cornea by the *pectinate ligament*, already mentioned.

Viewed through the transparent cornea, certain details may be observed in the living subject. Since the iris occupies a frontal plane with respect to the body, the *anterior surface* [facies anterior] (f. cornealis NK) is seen. The actual *ciliary border* [margo ciliaris], at the periphery, is hidden by the opaque sclera, but the *pupillary border* [margo pupillaris] is apparent, edged by a finely notched

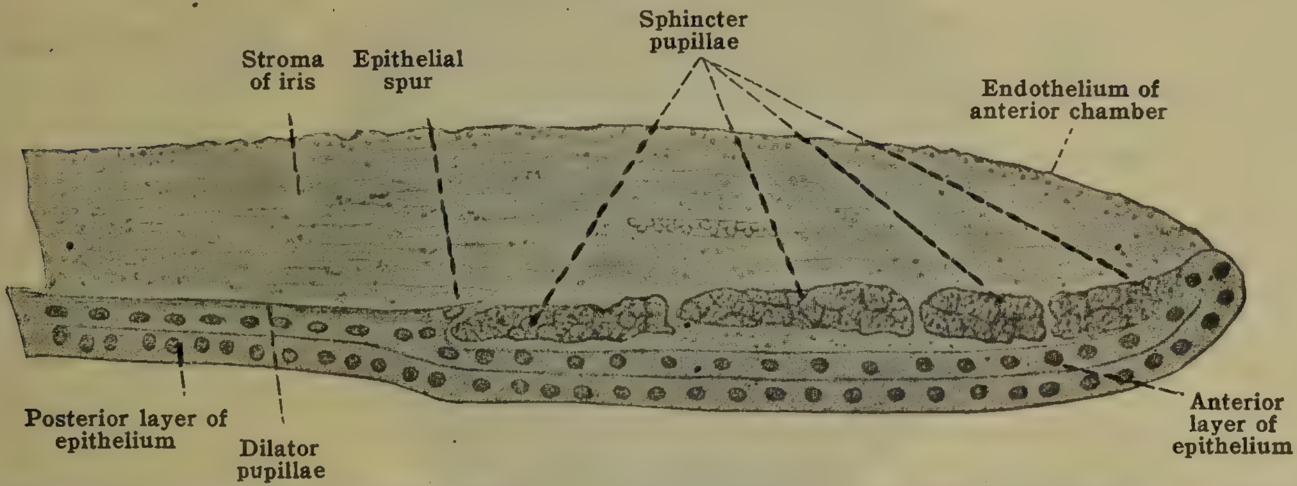


FIG. 874.—RADIAL SECTION OF THE PUPILLARY BORDER OF THE IRIS. × about 75. (After v. Szily, from Franz.)

dark seam. About 1.5 mm. from the pupil, where the arterioles form an anastomosing circle, occurs a zigzag line which marks the iris into two concentric zones; the inner is the more delicately striated *annulus iridis minor*, the outer, the coarser *annulus iridis major*. The anterior surface of the iris shows delicate, tortuous radiations caused by the blood-vessels shining through. The darkness of the iris color depends on the amount of pigment present in the more anterior levels in addition to that of the posterior surface, which when present alone is responsible for blueness. The *posterior surface* [facies posterior] (f. retinalis NK) is studded with radiating *iridial folds* [plicæ iridis] (rugæ iridis NK).

Structure of the iris.—The anterior surface of the iris is covered with endothelium which lies upon a condensed, nonvascular boundary layer, chiefly made up of chromatophores (fig. 874). Still deeper is the general *stroma of the iris* [stroma iridis], containing numerous blood-vessels intermingled with spongy connective tissue and chromatophores. On the posterior surface of the iris are the epithelial representatives of the two retinal layers of the primitive optic cup; these single-layered epithelia become continuous at the pupillary border. The more anterior layer [stratum pigmenti iridis] (primitively, the pigmented epithelium) differentiates into the smooth muscle of the iris which occurs in two distinct masses. The *m. sphincter pupillæ* is a flat ring, about 0.9 mm. wide, encircling the free border of the pupil and separated from the parent epithelium by connective tissue. The *m. dilator pupillæ* consists of myoepithelial cells, partly pigmented, extending in a radial direction from the sphincter almost to the root of the iris. The remaining, or posterior layer of epithelium [pars iridica retinæ] (potentially, nervous retina) is highly pigmented and abuts upon the posterior chamber.

Clinical aspects.—A congenital gap in the iris may pass from the pupil inferiorly and medially; this constitutes one type of *coloboma*. Strands of the fetal pupillary membrane sometimes persist and stretch across the pupil. High vascularity renders the iris subject to inflammation (*iritis*). Some disturbances reach it from the sclera and cornea, while the iris, in turn, spreads inflammation to the ciliary body and, less often, to the chorioid. Both pathways depend on the nature of the intimate vascular relations between these parts. Weak attachment at the insertion of the iris allows it to be torn away with relative ease. The iris is a delicate and

yielding membrane that derives much support from contact with the lens, but this very contact predisposes toward inflammatory adhesions (*synechiæ*).

4. Vessels and nerves of the tunica vasculosa.—The arteries are all derived from the ophthalmic division of the internal carotid (figs. 875, 876, 887). The chorioid is supplied by numerous branches of the short posterior ciliary vessels which pierce the retina around the entrance of the optic nerve and form a rich plexus in the vascular layer. The arterial supply of both the ciliary body and iris is from the long posterior ciliary and anterior ciliary vessels. The long posterior ciliary arteries, two in number, pierce the sclera and run forward, one medially and one laterally, in the perichorioidal space to the ciliary body where they enter into anastomoses with the anterior ciliary arteries which accompany the rectus muscles. At the root of the iris an arterial ring is formed, the *circulus arteriosus major* (c. arteriosus NK), and near the pupil there is another ring, the *circulus arteriosus minor*.

The veins of the vascular tunic are almost all tributary to the vorticose veins (figs. 875, 876), which in turn reach the cavernous sinus by way of the posterior ciliary and superior ophthalmic vessels (fig. 887). The anterior ciliary veins drain a part of the ciliary muscle and, following back in the rectus muscles, find the superior ophthalmic vein.

Lymphatic vessels are lacking. The perichorioidal space possibly serves for the movement of lymph.

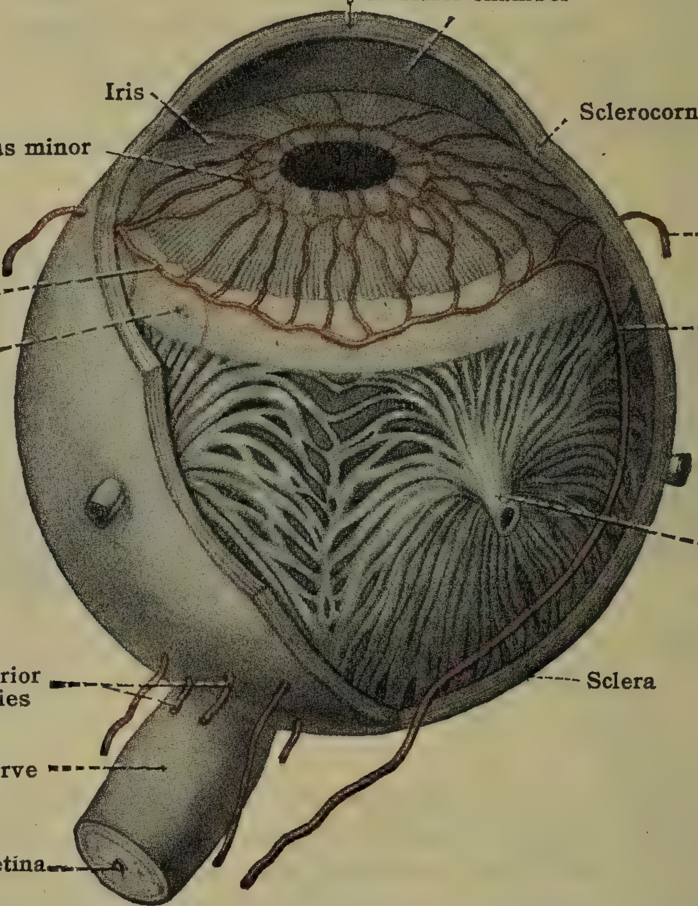


FIG. 875.—LATERAL DISSECTION OF THE BLOOD-VESSELS OF THE EYEBALL. × 3.

The nerves are the long and short ciliary (fig. 888). The former are branches of the nasociliary from the ophthalmic division of the trigeminus; the latter are from the ciliary ganglion. Entering the eyeball near the optic nerve they course in the perichorioidal space, giving off twigs to the sclera and chorioid, and enter the ciliary muscle where a plexus is formed. From this plexus branches proceed to the ciliary muscle, ciliary processes and the iris. Fibers derived from the oculomotor nerve through the ciliary ganglion supply the sphincter pupillæ, while the dilator pupillæ is innervated by sympathetic fibres from the superior cervical ganglion.

C. THE TUNICA NERVOSA OCULI, OR RETINA

The **retina** (tunica interna NK) is a soft and delicate membrane which is everywhere in contact with the tunica vasculosa and comprises the innermost of the three coats of the eyeball (fig. 868, in yellow). It represents developmentally a bulbous extension of the brain wall which infolded to produce a double-layered cup. The line where the two resulting lamellæ are continuous (*i.e.*, the rim of the primitive cup) has already been noted at the pupillary border of the iris. The outer lamella is an insensitive **pigment layer** [stratum pigmenti]; the inner is the **retina proper** (retina NK), characteristically nervous for the reception of visual impressions but much simplified toward the front of the eye.

The retina as a whole can be divided into three concentric zones (fig. 869): (1) Extending from the posterior pole to a level well forward of the equator is the truly nervous portion, the **pars optica retinæ**. Its anterior extent is marked

by a wavy line, the *ora serrata*, a short distance behind the ciliary processes (fig. 872). Here the nervous elements cease and the retina suddenly becomes much thinner. (2) Lining the internal surface of the ciliary body is the insensitive **pars ciliaris retinæ.** (3) Continued still farther upon the posterior surface of the iris, even to the margin of the pupil, is the **pars iridica retinæ**. The ciliary and iridial regions have already been described along with the ciliary body and iris, of which they are important components; the pars optica must now be examined in detail.

The **pars optica retinæ** consists of the *pigment layer*, a simple, low columnar epithelium containing abundant pigment, and the much thicker *retina proper*,

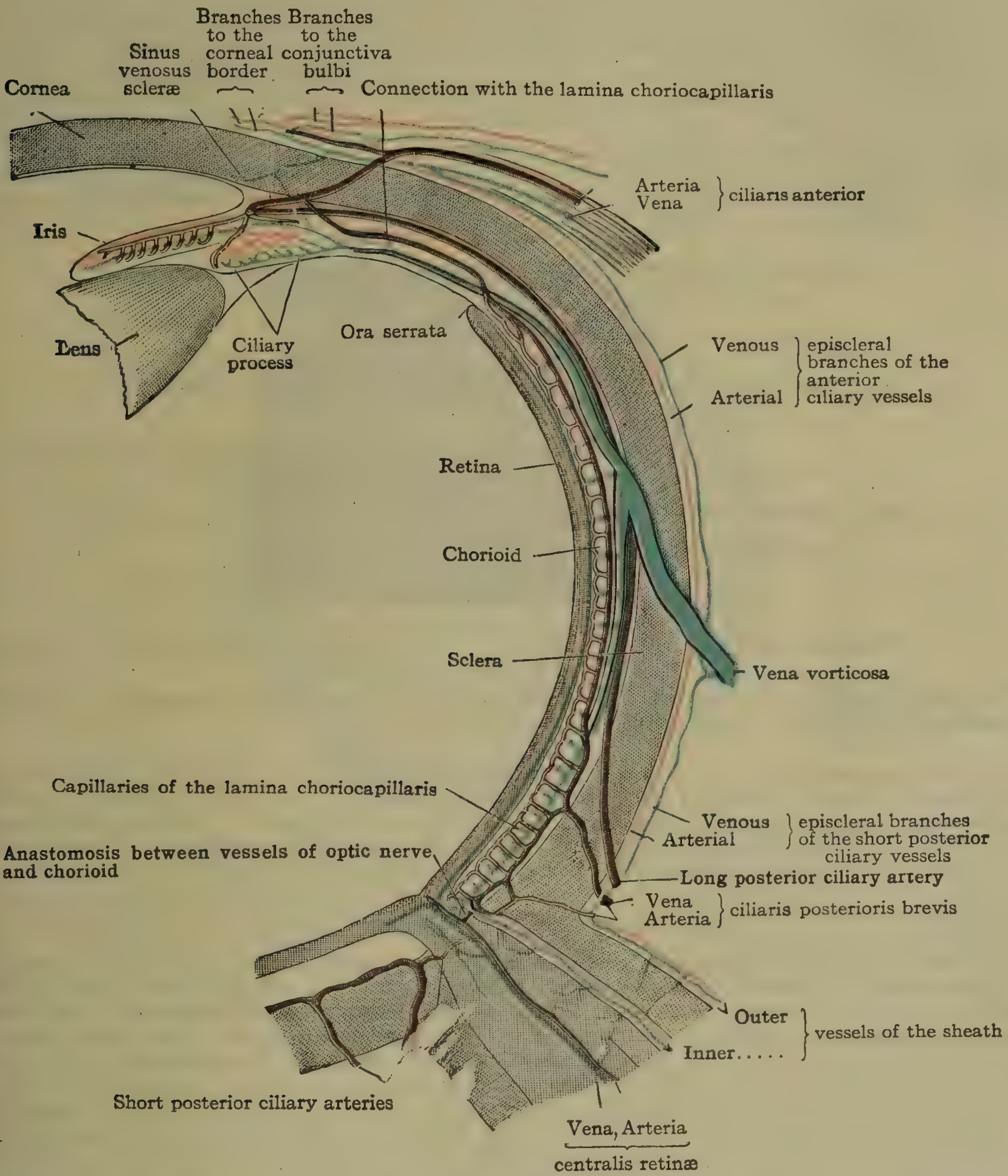


FIG. 876.—DIAGRAM OF THE OCULAR BLOOD-VESSELS DRAWN INTO A HORIZONTAL SECTION OF THE LEFT EYE. (From Stöhr, after Leber.)

a transparent, stratified nervous layer. The pars optica is a smooth membrane diminishing in thickness from 0.4 mm. near the optic nerve to about 0.15 mm. at the ora serrata. In a surface view of a fresh retina one sees at the intersection point of the visual line an ill-defined yellowish spot, the *macula lutea*, which bears a saucer-shaped pit known as the *fovea centralis* (cf. fig. 869). The fovea measures 1.7 mm. in horizontal diameter and represents a modified portion of the retina best suited for acute vision. About 3.5 mm. nasally from the fovea centralis the point of entrance of the optic nerve shows as a whitish circular *optic papilla* [papilla n. optici], or optic disc. This insensitive 'blind spot' of the retina is a slightly elevated hillock which measures about 1.5 mm. in diameter and bears a

central depression, or *excavation* [excavatio papillæ n. optici], from which the retinal vessels emerge (fig. 869).

1. General structure of the retina.—The two layers of the retinal tunic, pigmented and nervous, are quite unlike histologically, although both started from the same outgrowth of the brain wall. The pigmented epithelium remains relatively undifferentiated, while the primitive nervous layer becomes stratified and highly specialized into neuroepithelium, neurones and neuroglia. Except at the optic papilla and the ora serrata, where union is firm, these two layers are scarcely more than in apposition, so that pathological detachment is easy.

When the nervous tunic is stained by ordinary histological methods ten layers are seen. These are (fig. 877): (1) *pigmented epithelium;* (2) *rod* and *cone layer;* (3) *external limiting membrane;* (4) *outer nuclear layer;* (5) *outer plexiform layer;* (6) *inner nuclear layer;* (7) *inner plexiform layer;* (8) *ganglion cell layer;* (9) *nerve fiber layer;* (10) *internal limiting membrane.* On the other hand, from the general structural and functional standpoint there are three zonal levels in the retina, as follows: (*a*) the pigmented epithelium (layer 1); (*b*) the photoreceptive, neuroepithelial visual cells (layers 2, 4 and a part of 5); (*c*) the nerve cell layer, belonging to a displaced portion of the brain wall (layers 5, in part, and 6 to 9). In addition, there is a supporting framework (layers 2 and 10, and also a scattering of neuroglial cells and fibers between these levels), all of which corresponds to the neuroglia tissue in the gray substance of the brain. From the standpoint of neurone chains alone, there are three superimposed links in the nervous retina. The first neurone begins with layer 1 and extends into 5; the second neurone includes layer 6 and parts of 5 and 7; the third neurone is found in layers 7 to 9.

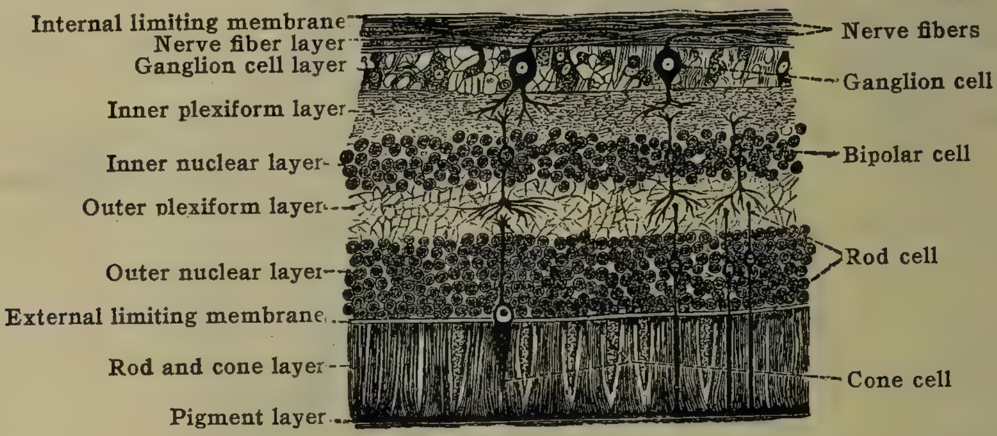


Fig. 877.—Vertical Section of the Retina. × 200. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

The chief neurone types (in black), as demonstrated by metallic impregnation, have been superposed upon the layers shown by ordinary stains.

2. The pigment layer.—The *pigmented epithelium* is a single layer of low, columnar cells which take the shape of regular hexagonal prisms. The basal, nucleated, pigment-free end is firmly attached to the chorioid through the *basal membrane* (of Bruch). The free end contains crystalline pigment needles which extend into short, fringe-like processes. In some lower vertebrates these processes continue to a considerable height, fitting around the rods and cones and presumably giving them optical isolation. The inward and outward migration of pigment in darkness and light respectively, exhibited so strikingly in many vertebrates, is not demonstrable in mammals.

3. The visual cells.—Specialized neuroepithelial cells serve as the photosensitive receptors of light stimuli. However, only their outer portions, which are highly differentiated for this purpose, are actually sensitive to light. The visual cells are of two kinds, the *rod* and *cone visual cells* (fig. 877). Although comparable in general organization, each type has its distinctive characteristics. They extend through pores in the external limiting membrane which serves to divide them into two functionally different segments. Above the level of the membrane is the specialized photoreceptive portion, the *rod* and *cone*, respectively. Below the membrane are the nuclear and filamentous regions. Each cell consists of the following parts: (*a*) outer segment; (*b*) inner segment; (*c*) nucleus; (*d*) fiber; and (*e*) termination. The first two divisions comprise the rod or cone; the third part and some of the fourth make up the outer nuclear layer of the retina, while the fifth (terminal) portion is found in the outer plexiform layer where it enters into synaptic relation with neurones of the second order.

The complexly organized rods and cones rise vertically, palisade fashion, into the space beneath the pigmented epithelium. The rods are long (60 μ) and slender (2 μ) cylinders, the cones shorter (32 μ) and thicker (7 μ) flasks. Except in the fovea the rods far outnumber the cones, the totals being estimated at 130 million as against 7 million. There is reason to believe that the cones are adapted to bright-light, acute vision and the perception of colors, while the rods are much more sensitive for dim-light vision, yet are color blind. An unstable colored substance, *visual purple*, can be seen in the fresh retina after a period of dark adaptation, but it bleaches quickly in the light. Visual purple occurs at least chiefly in the outer segments of the rods and apparently plays an important rôle in the physiology of vision.

4. The bipolar cells.—These elements comprise the second link in the neurone pathway to the optic centers. Like the rod and cone cells, the bipolar neurones are arranged vertically to the retina as a whole (fig. 877). *Cone bipolars* and *rod bipolars* are distinguished on the basis of the synaptic connection made with particular visual cells in the stratum above. The central, nucleated region of these elements lies in the inner nuclear layer and accounts for

the granular appearance of this stratum under low magnification. One of the bipolar processes extends into the outer plexiform layer, the other in the opposite direction descends into the inner plexiform layer. At these two levels synaptic relations exist between the bipolars and the first and the third neurones, respectively. Less numerous are the *horizontal* and *amacrine cells* of this same general level; they are association neurones, linking functionally other nearby nervous elements.

5. The ganglion cells.—The third neurone link is composed of elements whose cell bodies are arranged in a single layer near the internal surface of the retina (fig. 877). They are large, multipolar *ganglion cells* that communicate with cells of the bipolar level in the inner plexiform layer. In the opposite direction unmyelinated axons bend into the nerve fiber layer, whence they make their way convergingly toward the optic nerve; here they continue uninterruptedly to the brain.

6. The supporting tissue.—As in the brain, neuroglial supporting elements are present. Most prominent are the columnar *fibers of Müller* which stretch vertically between the two limiting membranes. The cells are slender pillars of very irregular contour, whose recesses and projections shelter and fit about neighboring nerve cells. Associated with their extremities are the two limiting membranes—the outer one fenestrated, the inner not. Structurally they are of a cuticular or terminal-bar nature. In the inner strata of the retina occur *neuroglial cells* of the more common types.

7. Modified regions of the retina.—Abruptly next the optic nerve, but more gradually toward the ora serrata, there is a tapering off of the retina and a successive loss of its component layers. The extreme periphery of the sensitive retina is characterized by a richer supporting tissue, a reduction of nervous elements, and a gradual disappearance of visual cells.

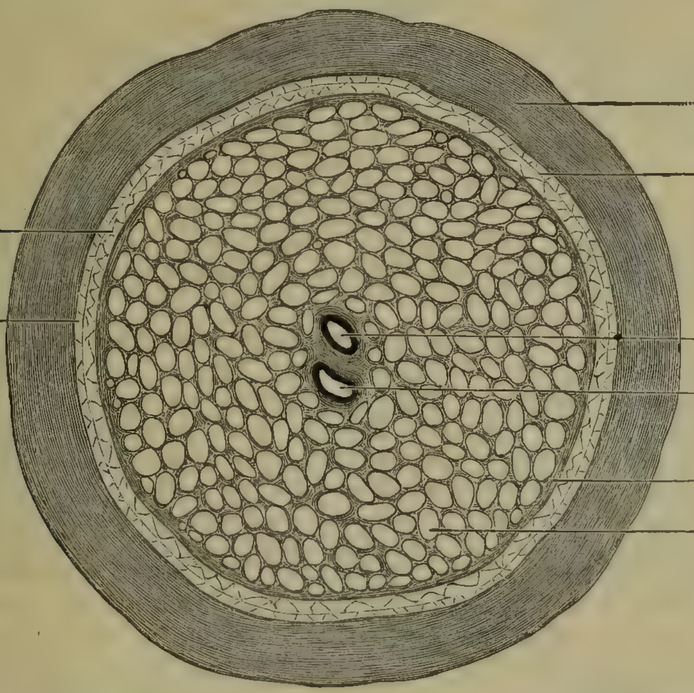


FIG. 878.—TRANSVERSE SECTION THROUGH THE OPTIC NERVE, SHOWING THE RELATIONS OF ITS SHEATHS AND THE CONNECTIVE-TISSUE FRAMEWORK. × 12.

In the **foveal region** the retina undergoes important simplification to adapt it better as the site of keenest and clearest vision. It is a thinned area (0.1 mm. thick at the center) designed to permit in so far as possible the direct and unhampered stimulation of cones, which is the only kind of visual cell present. To this end the inner layers spread aside so that the cone fibers take oblique courses toward the periphery of the fovea where the usual connections occur. The foveal cones are long, slender and very numerous, all of which is favorable for visual acuity (*i.e.*, the ability to detect tiny objects as separate points).

8. The optic nerve.—The full course of the *optic nerve* and its connections have been described elsewhere (pp. 924, 1004). Nevertheless, certain features are appropriately considered along with the ocular bulb and its retinal coat, since the nerve not only is a direct continuation of the fibers already mentioned as constituting the nerve fiber layer, but its coverings also unite with those of the eyeball.

The segment of the optic nerve lying within the orbit (pars orbitalis tractus optici NK) is about 25 mm. long and 3.5 mm. in diameter. It runs a slightly sinuous course between the optic foramen at the apex of the orbit and the point of union with the eyeball about 3 mm. to the nasal side of the posterior pole (fig. 889). In the orbit the nerve is enveloped by protective *sheaths* [vaginæ n. optici]. These comprise an outer fibrous sheath, continuous with the dura mater of the brain, and an inner vascular covering derived from the pia mater (fig. 878). The space between the dural and pial sheaths is subdivided by a fine prolongation of the arachnoid into two parts, named the *intervaginal spaces* [spatia intervaginalia]. These are, respectively, an outer, narrow *subdural space* and an inner, wider *subarachnoid space;* communication is effected with the corresponding intracranial cavities and also with the perichorioidal space of the orbit. The arachnoidal sheath is connected with the sheath on each side of it by numerous fine processes which bridge across the intervening spaces (fig. 879). The pial sheath sends processes inward to form a septal system which subdivides the nerve into bundles of nerve fibers; the nerve fibers themselves, so enclosed, are bound together by neuroglial tissue. The nerve fibers are myelinated but have no cellular neurilemma sheath. About 1 cm. behind the eyeball the central retinal vessels enter the nerve obliquely and then run forward in its axis

(fig. 879). They are accompanied throughout by a special extension of the pial sheath, which forms a fibrous cord in the center of the nerve (figs. 878, 879). The general appearance of the optic nerve in transverse section is like that of a large nerve funiculus, surrounded by perineurium (pial sheath) and with endoneurial septa (pial extensions) dividing groups of component nerve fibers into polygonal fields.

On reaching the eyeball the dural sheath is joined by the arachnoid, after which it turns away from the nerve and is continued into the outer two-thirds of the sclera (fig. 880). The pial sheath similarly leaves the nerve, its greater part passing into the inner third of the sclera while a few fibers join the chorioid. The intervaginal spaces consequently end abruptly in the

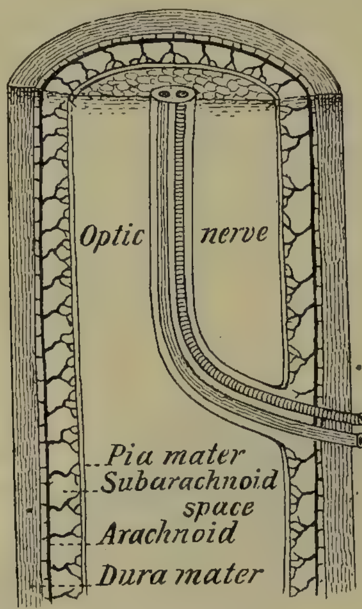


FIG. 879.—STEREOGRAM OF THE OPTIC NERVE, HEMISECTED TO SHOW THE RELATIONS OF ITS SHEATHS AND THE CENTRAL RETINAL BLOOD-VESSELS. (Wolff.)

sclera around the nerve entrance. In this locality the connective-tissue framework of the nerve becomes a thicker and closer mesh, and has already been mentioned as the *lamina cribrosa scleræ* (fig. 880). It arises by processes passing out from the termination of the axial fibrous cord and by trabeculæ passing inward from the pial sheath, sclera and chorioid. The lamina follows the curve of the surrounding sclera and is therefore slightly convex backward. The nerve trunk at this level quickly becomes reduced to one-half its former diameter through the fibers losing their myelin sheaths (fig. 880). Apart from the consequent loss of bulk, this histological change may readily be recognized with the unaided eye in a longitudinal section of a fresh nerve, its aspect here changing from opaque white to semitranslucent gray. The *optic papilla*, its *excavation*, and the emerging blood-vessels have all been described in a previous paragraph.

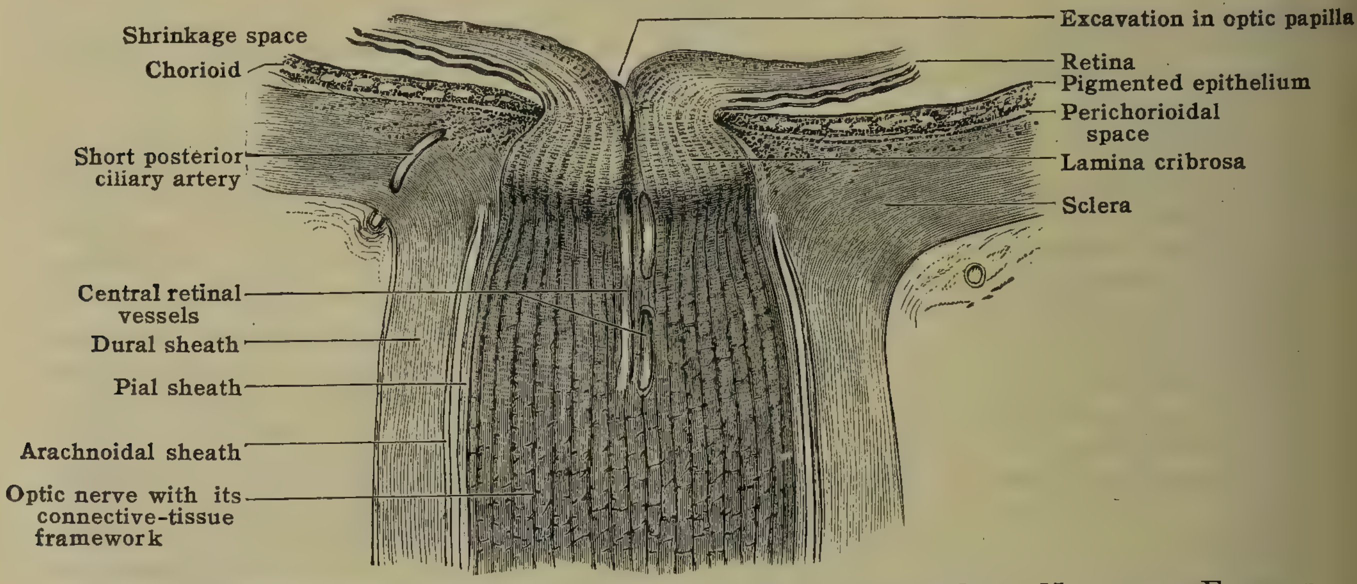


FIG. 880.—LONGITUDINAL SECTION THROUGH THE JUNCTION OF THE OPTIC NERVE AND EYEBALL. × 10.

The optic nerve is mainly nourished by fine vessels, derived from those of the pial sheath, which run into the substance of the nerve in the connective-tissue septa, already mentioned (fig. 876). In front of its point of entrance, the central retinal artery aids to some extent in the blood supply of the axial part of the nerve.

9. Vessels.—The *arterial* supply of the retina is derived solely from the single central artery of the retina. This is a branch of the ophthalmic artery (fig. 887) which enters the optic nerve about 1 cm. behind the eyeball (fig. 879). Pursuing an axial course it reaches the optic papilla and there divides into an upper and lower branch, each of which divides again into

nasal and temporal branches. These course superficially in the nerve fiber layer of the retina and proceed toward the ora serrata, branching dichotomously as they advance (figs. 872, 876). The central foveal region is not invaded by blood-vessels. Capillary plexuses penetrate from the nerve fiber layer through the inner nuclear layer, but no farther. The visual cells and pigmented epithelium are dependent on the choriocapillaris for nourishment. The retinal arteries are all end-arteries, which do not anastomose except through capillary plexuses. Nevertheless, an indirect communication with the ciliary vessels through anastomoses with the short posterior ciliary arteries (*circulosus vasculosus nervi optici*) is effected at the optic nerve entrance (fig. 876). Sometimes a branch from the ciliary-vessel system supplies a smaller or larger territory of the retina.

The *veins* of the retina are nonmuscular vessels which accompany their arteries and unite into a central vein, also situated axially in the optic nerve (fig. 876), which emerges to join the superior ophthalmic vein (fig. 887).

Lymphatics are limited to perivascular channels around the capillaries and veins.

10. Clinical aspects.—The attachment between the nervous and pigmented layers of the retina is so weak that mutual separation is readily effected by effusions of hemorraghic or other nature, or even by a blow upon the eyeball. However, even extensive detachment does not usually free the retina from the optic papilla and ora serrata. Inflammatory affections of the meninges of the brain spread easily along the continuous subdural and subarachnoid spaces of the optic nerve. Intracranial disease, except meningitis, can also extend through the optic nerve itself. In enucleation of the eye there is little bleeding because the small-sized central artery is the only one divided. Sudden blindness follows the plugging of the central artery because of a nearly complete elimination of the retinal blood-supply; the small anastomoses with chorioidal vessels at the main stem of the optic nerve are quite unable to effect a prompt, adequate, collateral circulation. If a sub-branch be embolized, only the area supplied by that particular system of end-arteries is affected. Hemorrhage into the vitreous body frequently accompanies trauma and may come either from the retinal vessels which course in the inner layers of that membrane or from vessels in the ciliary region. Due to the partial crossing of the two optic nerves at the chiasm, fibers from the right or left half of each retina are recombined into the right or left optic tract, respectively (fig. 748). Hence a lesion of the optic pathway posterior to the chiasm will produce blindness in one-half of each retina on the same side as the injury (*hemianopia*). If an entire optic nerve anterior to the chiasm be involved, total blindness follows in the eye supplied; when but part of the nerve is concerned there is a correspondingly partial involvement of the retina (*unilateral hemianopia*).

D. The Refracting Media

The interior of the optic bulb, bounded by the wall already considered, is a potential cavity only, for in life it is fully occupied by certain contents which are divided into three parts, named according to their consistency and anatomical form (fig. 868). Of these, the one that is most sharply and independently outlined is the **crystalline lens** [lens crystallina], which is suspended just behind the iris and lies between the other two components. In front of the lens is a space (camera oculi) filled with a watery fluid, the **aqueous humor.** Behind the lens is a much larger cavity, occupied by the jelly-like **vitreous body** [corpus vitreum]. All three media are transparent, since the light rays must pass through the contents of the eyeball before gaining the retina where an optical image is brought to focus. In fact, these refractive media are of direct use in forming such images.

1. The vitreous body.—This material, formerly called the vitreous humor, is a transparent jelly, filling out the space between the lens and the retina and constituting about four-fifths of the volume of the eyeball. It is in close contact with the pars optica retinæ and serves as a support to it as far forward as the ora serrata. Here the adherence between the two reaches a maximum, but over the pars ciliaris the vitreous separates from the surface of the retina and passes to the posterior surface of the lens where adherence with the lens capsule again occurs. The bulging lens causes a deep concavity, the *hyaloid fossa* [fossa hyaloidea], in the anterior surface of the vitreous body.

Structure of the vitreous body.—In the fresh condition the *vitreous body* [corpus vitreum] is a completely transparent, firm jelly; it then contains 98.6 per cent water and appears both colorless and structureless. After fixation a delicate fibrillar mesh, the *vitreous stroma* [stroma vitreum] (s. corporis vitrei NK), can be demonstrated, whose interstices are filled with clear, watery *vitreous humor* [humor vitreus] (humor corporis vitrei NK). This structural appearance, however, is suspected to be partly an artefact. A *hyaloid membrane* [membrana hyaloidea] at the free surface is commonly described; although there is a peripheral condensation of the fibrillar framework into a boundary layer, an independent capsular membrane can not be demonstrated. The axis of the vitreous body is occupied by a lymph channel, the *hyaloid canal* [canalis hyaloideus], which extends from the optic papilla to the posterior pole of the lens (fig. 882). It has a diameter of 1 mm. and corresponds to the position of the former hyaloid artery which assists in the vascularization of the fetal lens. Certain free cells, apparently lymphocytic in nature, occur in the peripheral layers of the vitreous.

Clinical aspects.—The vitreous body is not actively concerned with ocular pathology. It may harbor the products of inflammation or of hemorrhage located elsewhere. Such hemorrhages are commonly resorbed with relative difficulty. Foreign bodies usually arouse serious

neighboring inflammation but sometimes they remain inertly lodged in the vitreous substance. Many individuals are bothered by floating specks known as *muscæ volitantes;* some of these are caused by opacities in the vitreous jelly. The vitreous body separates readily from the retina except at the region of the optic papilla where the branch of the central artery for the lens emerged in the fetus. This artery may persist even into adult life.

2. The crystalline lens.—The lens is a slightly yellowish, transparent, biconvex disc, situated between the iris in front and the vitreous body behind (figs. 869, 881 A). Its *anterior surface* [facies anterior lentis] (f. iridica NK) faces the anterior chamber of the eye and is in light contact with the pupillary margin of the iris which it presses forward slightly. The *posterior surface* [facies posterior lentis] (f. hyaloidea NK), considerably more convex, occupies the hyaloid fossa of the vitreous (fig. 882). These two surfaces meet at the rounded-off edge, or *equator*, [æquator lentis], which is everywhere directed toward the nearby ciliary processes. The central point of the anterior and posterior surface is called the *anterior pole* [polus anterior lentis] (p. pupillaris NK) and *posterior pole* [polus posterior lentis] (p. hyaloideus NK), respectively, while the line joining these poles is the *axis of the lens* [axis lentis]. The lens is closely encased in a hyaline, elastic *capsule* and is held in position by its suspensory ligament (*zonula ciliaris*) which radiates from the equatorial region to the ciliary body.

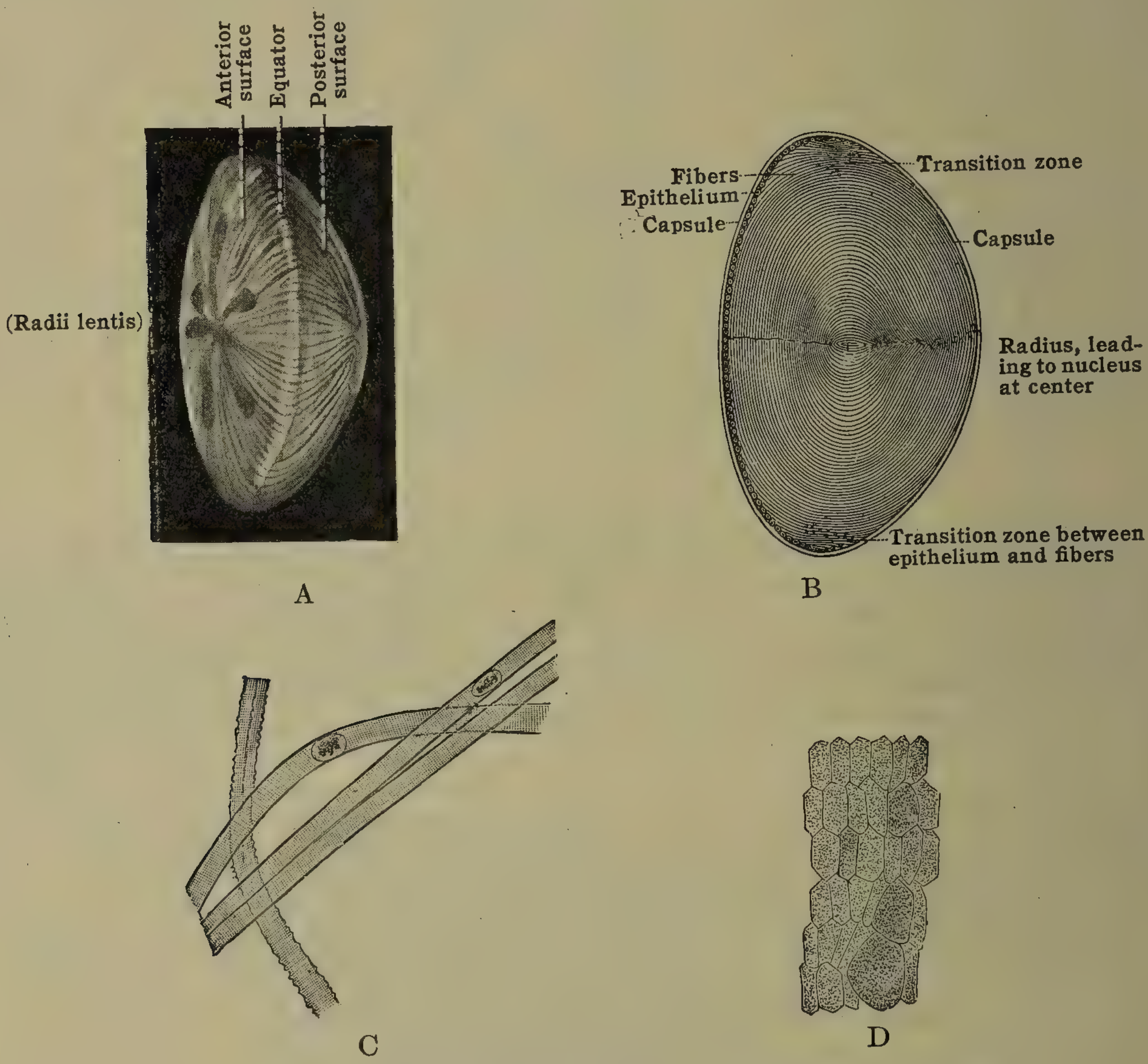


FIG. 881.—THE STRUCTURE OF THE CRYSTALLINE LENS.

A. Entire lens, viewed from the side. × 4.
B. Meridional section of lens. × 5. (After Babuchin.)
C. Isolated lens fibers from a newborn. × 240. (Stöhr.)
D. Transverse section through lens fibers. × 560. (Stöhr.)

The size of the lens increases by continued growth throughout life; at middle age the equatorial diameter is 9 mm., while the axial thickness averages nearly 4 mm. The shape also changes with age; in a fetus the lens is nearly spherical, in the adult fairly convex, and in old age considerably flattened. Besides this, the shape is temporarily modified from moment to moment during near and far accommodation.

Structure of the crystalline lens.—The lens consists of the fibrous *lens substance*, an anterior covering of *lens epithelium*, and the *lens capsule* enclosing the whole (fig. 881 B).

The surface of the lens is bounded by a homogeneous, elastic *capsule* [capsula lentis]. It has the character of a cuticular membrane and is derived from the epithelium of the lens primordium. It is thickest on the anterior surface (10–20 μ) and thinnest at the posterior pole (3 μ). The capsule is elastic in nature and when cut or torn rolls outward.

The single-layered *lens epithelium* [epithelium lentis] lies beneath the capsule, extending over the anterior surface of the lens and as far back as the equator. It is composed of somewhat flattened cells near the anterior pole, but toward the equator they become progressively cuboidal and finally columnar. At the equator the cells are arranged in slanting meridional rows and gradually pass over into the elongated, so-called lens fibers which form the substance of the lens proper (fig. 881 B). The transitional stages seen about the equatorial circumference of the lens reflect a progressively slowing growth and transformation process that continues throughout life.

The *lens substance* [substantia lentis] is soft at the periphery [*substantia corticalis*] (cortex lentis NK) but has a harder consistency centrally [*nucleus lentis*]. The unit of structure throughout is the *lens fiber* [fibræ lentis] (fig. 881 C, D). These fibers are cells which assume the form of flat ribbons, 7–10 mm. long, 8–12 μ wide, and 2 μ thick; in transverse section each is a flattened hexagon cemented to its neighbors. Only those fibers close to the periphery show a nucleus; in older, and therefore more deeply located fibers the nucleus shrinks and disappears (fig. 881 B). The arrangement of lens fibers is orderly yet intricate. On both the anterior and the posterior surface there are nine to twelve faint lines, or sutures (*radii lentis*), which diverge radially from the poles toward the equator (fig. 881 A). The two systems are also called lens stars. They are so oriented on the anterior and posterior surfaces that the rays of one are placed over the interspaces of the other. At successive depths in the lens each suture system becomes progressively simpler until it is finally reduced to a three-rayed star, the posterior one oriented like an erect Y while the anterior is inverted. These sutures mark the lines where the ends of lens fibers abut. The fibers themselves extend in a curved course between the anterior and posterior set of rays. However, no fiber extends from pole to pole; those that begin near one pole end near the equator on the opposite surface, while the intervening fibers assume intermediate positions. A section through the equator of a lens shows that, except centrally, the lens fibers are arranged in regular radial lamellæ, over 2000 in number. The short interdigitating sides of the fibers effect a stronger coherence between adjacent lamellæ than between the flat surfaces of fibers in the same lamella. For this reason, the simultaneously formed fibers of different generations can be separated rather easily into concentric layers like an onion.

Clinical aspects.—The lens may be congenitally absent (*aphakia*) or of abnormal size and shape. Partial rupture of its suspensory ligament leads easily to displacement of the lens either forward or, more commonly, backward into the vitreous body. When disturbed the lens tends to swell and injure adjacent delicate structures. The capsule is brittle and elastic, and on tearing, as at operation or by external violence to the eyeball, it curls outward. A broken capsule permits the entrance of aqueous humor which swells the lens fibers and produces one type of cataract. The condition of *cataract*, in general, is characterized by the opacity of part or all of the lens or its capsule. It often begins in the nucleus lentis but may be confined to certain cortical lamellæ.

3. The zonula ciliaris.—The lens is held in position by a system of fibers stretching between the equator of the lens and the ciliary body (fig. 873). Collectively these fibers are designated as the *suspensory ligament* of the lens (apparatus suspensorius lentis NK) or the *ciliary zonule* (of Zinn) [zonula ciliaris]. They are also important since through them the ciliary muscle effects changes in the curvature of the lens during accommodation.

The *zonular fibers* [fibræ zonulares] are fine, shiny filaments, the largest having a thickness of 35 μ, the smallest being not easily measured with accuracy. They arise from the surface of the epithelium of the ciliary body, even as far back as the ora serrata, where they cause the fine surface striation of the orbiculus. In the region of the corona the fibers are coarser, through fusion, and in addition new fine ones are recruited from the surface of the ciliary process. The fibers as a whole collect into flat bundles in the valleys between adjacent ciliary processes. From here the bundles pass in convergent radial courses to the lens where they attach to the capsule in two layers, one in front and the other behind the equator (fig. 873). The cleft bounded by these two lamellæ and the lens border constitutes the *zonular spaces* (or canal of Petit) [spatia zonularia].

4. The aqueous chamber.—The *aqueous humor* is a clear, colorless, watery fluid which fills the space between the cornea and the vitreous body. This general chamber is incompletely subdivided by the iris into two parts (fig. 873). The *anterior chamber* [camera oculi anterior] (c. o. major NK) is bounded in front by the cornea, behind by the iris and lens, and peripherally by the structures of the *iridial angle* [angulus iridis]. Its maximum depth at the center is 2.8 mm. The *posterior chamber* [camera oculi posterior] (c.o. minor NK) is a small ring-shaped space, triangular in section, bounded in front by the iris, peripherally by the ciliary processes, posteriorly by the vitreous body, and centrally by the lens. The spatia zonularia and the system of ciliary valleys are component parts of this chamber.

Clinical aspects.—The absorptive power of the aqueous humor is great, due apparently to the peculiar drainage channels at the iridial angle. Pus or bloody extravasations into the anterior chamber are speedily removed. Soft cataracts are sometimes broken up *in situ* with a needle after entry has been made through the lens capsule; following such treatment the opaque debris is efficiently removed by the aqueous humor. *Glaucoma* is a malady occasioned by increased intraocular tension; this latter condition, in turn, is produced by swelling of the intraocular contents or by the accumulation of excess fluid within the eyeball. The

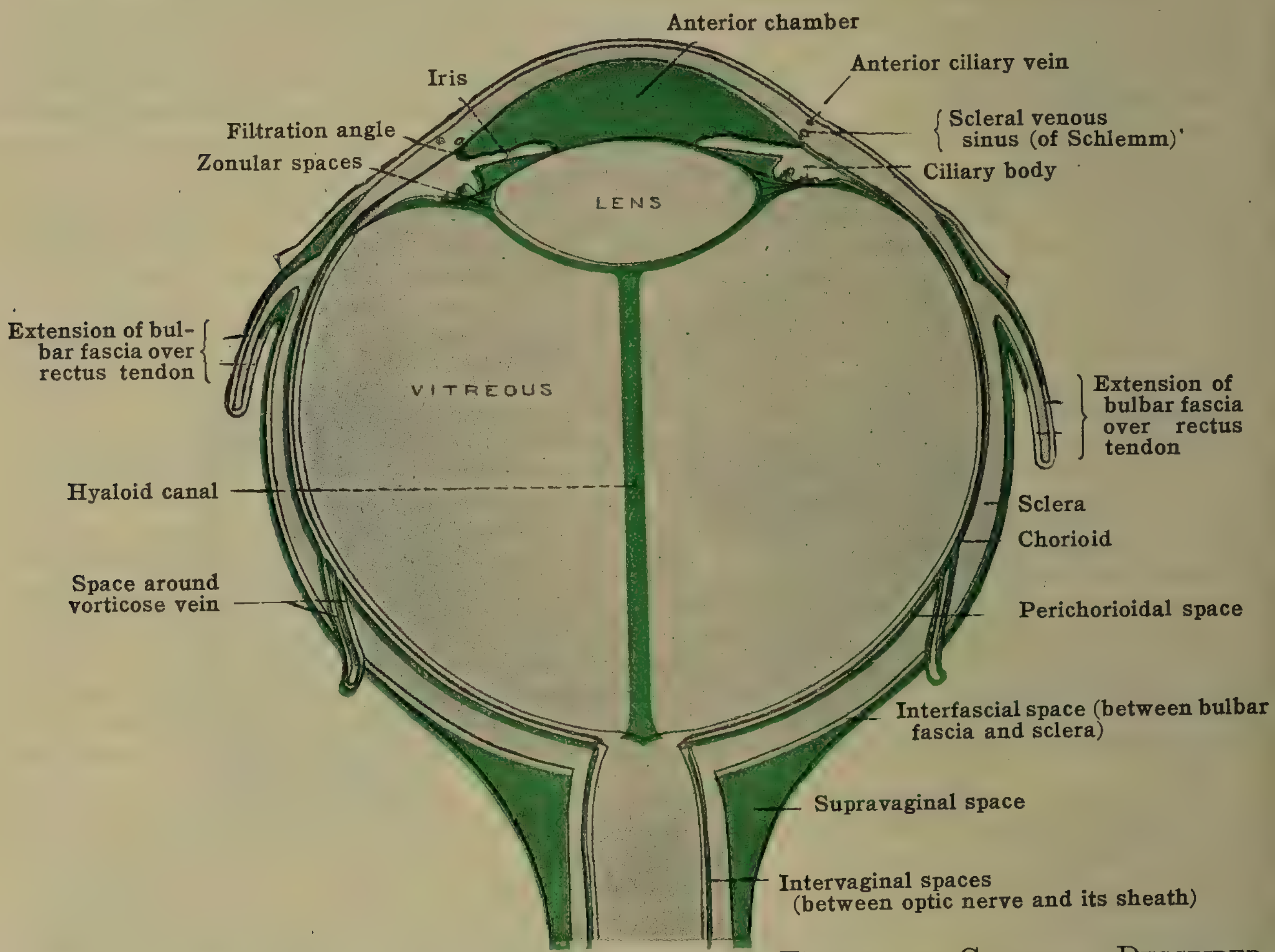


Fig. 882.—Diagram of the Lymphatic Spaces of the Eyeball, as Commonly Described.

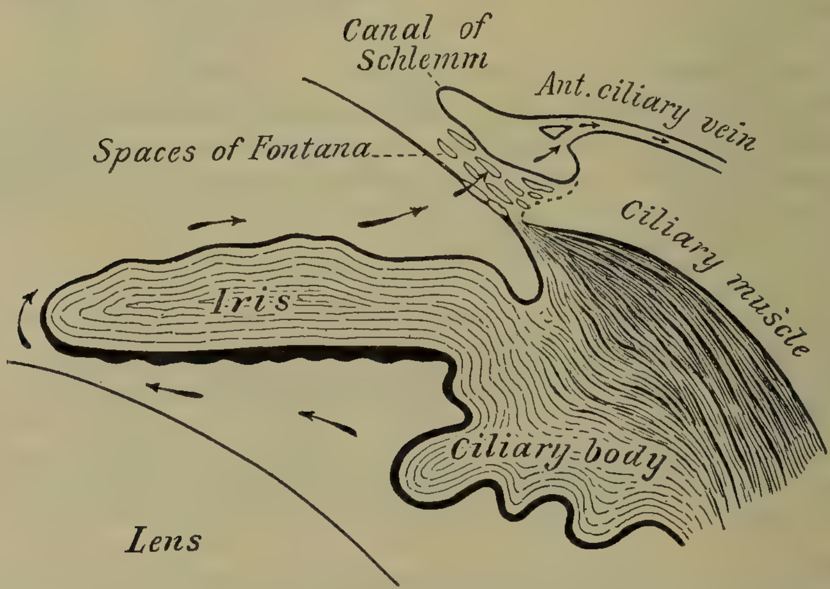


Fig. 883.—Diagram to Illustrate the Filtration Angle and the Reputed Path of Lymph Secreted from the Ciliary Body. (After Thomson.)

augmented internal tension causes pain by pressing the ciliary nerves against the unyielding sclera; at the same time, interference with the normal functioning of these nerves is manifested by a fixed and dilated pupil and an anesthetic cornea. Compression of the retinal blood-vessels or of the nerve fibers produces a progressive narrowing of the visual field, beginning at the retinal periphery. Pressure on the optic nerve elicits the characteristic subjective flashes of light, while the weakest part of the sclera, at the lamina cribrosa of the optic papilla, yields to produce the evaginated 'cupped disc.' In the opposite direction the lens is forced forward toward the cornea and makes the anterior chamber abnormally shallow.

5. Lymph-spaces of the eye.—Apart from the conjunctiva no true lymphatic vessels occur in the eyeball. There are, nevertheless, various spaces through which artificial injections can

find or, perhaps in part, force their way (fig. 882). The intervaginal spaces of the optic nerve communicate with the intracranial cavities, and injections can be made to enter the perichorioidal space. Also an injection into the perichorioidal space may pass along the walls of the vorticose veins to the interfascial space (of Tenon) and thence along the suppositious supravaginal spaces of the optic nerve. Yet some of these, at least, probably do not belong to the lymphatic system (*e.g.*, the interfascial space appears to be more after the nature of a bursa, and perhaps the same is true for the perichorioidal space). Again, there are the hyaloid canal and perivascular channels of the retina which are said to drain into the intervaginal spaces of the optic nerve.

The aqueous humor of the posterior chamber is commonly believed to arise from the ciliary processes, permeate the vitreous body, and pass through the pupil into the anterior chamber where drainage is accomplished through the spaces of the iridial angle (of Fontana) and the sinus venosus scleræ (of Schlemm). For this reason, the periphery of the anterior chamber has been designated the 'filtration angle' (fig. 883). However, the idea of the filtration of a continuous stream of lymph is now held to be doubtful, and even the drainage function of the canal of Schlemm is questioned.

II. ACCESSORY ORGANS

There are various accessory organs [organa oculi accessoria], not a part of the eye proper but in close association with it and necessary for its efficient functioning. Such accessory structures include the **fasciæ, ocular muscles, eyebrows, eyelids, conjunctiva** and **lacrimal apparatus.**

A. The Orbit and Orbital Fasciæ

The anterior, wider half of the pyramidal-shaped orbit is mainly occupied by the eyeball which, nevertheless, projects slightly beyond the orbital opening. The posterior two-thirds of the eyeball is in relation with soft parts, chiefly muscles [musculi] and fat [corpus adiposum orbitæ], which fill up the remainder of the cavity (fig. 889). The structure and relations of the bony orbit itself have been described sufficiently on pp. 127–128, but the membranous structures associated with the orbit demand special consideration at this time. Such fibrous tissues, binding together and supporting the oribital contents, constitute the **orbital fasciæ** [fasciæ orbitales]. Although these interconnect they may be regarded as belonging to four systems (figs. 884, 885): (1) the **periorbita,** lining the bony walls; (2) the **orbital septum,** helping close the entrance to the orbit; (3) the **bulbar fascia,** partially encapsulating the eyeball; and (4) the **muscular fasciæ,** ensheathing the orbital muscles.

1. The **periorbita,** or orbital periosteum, is applied closely to the bony walls of the orbit but is not attached very firmly. Posteriorly it becomes continuous with the dura mater at the optic foramen and the superior orbital fissure, while at the optic foramen it connects also with the dural sheath of the optic nerve. Where the periorbita covers the inferior orbital fissure the periosteal fibers are interwoven with smooth muscle to constitute the *orbital muscle.* From the inner surface of the orbital periosteum, septa pass into the orbital cavity and separate the fat lobules there. One important process arises midway on the roof of the orbit and runs forward to the superior lacrimal gland (fig. 885). From its surface next the bone the periorbita sends out fibrous processes which help keep in position the pulley, or trochlea, of the superior oblique tendon. On arriving at the fossa of the lacrimal sac the periorbita divides into two layers, the thin posterior one continuing onward to line the floor of the lacrimal fossa while the thicker anterior layer bridges over this groove and its contained lacrimal sac (fig. 884). At the rim of the orbit the periorbita goes over into the periosteum of the bones of the face.

2. The **orbital septum** [septum orbitale], also called the palpebral fascia, is a fibrous sheet which is stretched across the entrance to the orbit and bears a direct fascial relation to the posterior surface of the palpebral portion of the orbicularis oculi muscle (fig. 885). It attaches to the margin of the orbit and there becomes continuous with the periosteum (figs. 885, 889). It prevents the fat of the orbit from encroaching on the eyelids and, as a strengthening component of the lids, assists them in closing the orbital entrance. In the upper lid the orbital septum unites with the anterior lamella of the aponeurosis of the levator palpebræ superioris muscle (fig. 889). On the sides it blends with the deeper surfaces of the medial palpebral ligament and the lateral palpebral raphe. In the lower lid the septum unites with the sheath of the inferior rectus and then passes to the anterior surface of the tarsus (figs. 885, 899). Vessels and nerves destined for the face and scalp perforate the septum.

3. The **bulbar fascia** [fascia bulbi] (capsula bulbi NK), or capsule of Tenon, is a firm, fibrous tunic which ensheathes all but the corneal portion of the eyeball, separating it from the fat and other orbital contents and furnishing a socket in which limited motion is possible (figs. 884, 885). The fascia is perforated behind by the optic nerve and the ciliary vessels and nerves; near the equator the vorticose veins pierce it, and still farther forward the tendons of the ocular muscles pass through slits in its capsule. A direct extension of the fascia bulbi backward over the optic nerve is commonly described (fig. 885), but this is scarcely demonstrable; tube-like fascial continuations furnish sheaths for the ocular muscles. The inner surface of the bulbar fascia is relatively smooth, yet is everywhere connected with the sclera by loose, wide-meshed areolar tissue. This interval between sclera and fascia, known as the *interfascial space* (of Tenon) [spatium interfasciale] (s. circumbulbare NK), is a bursa which permits

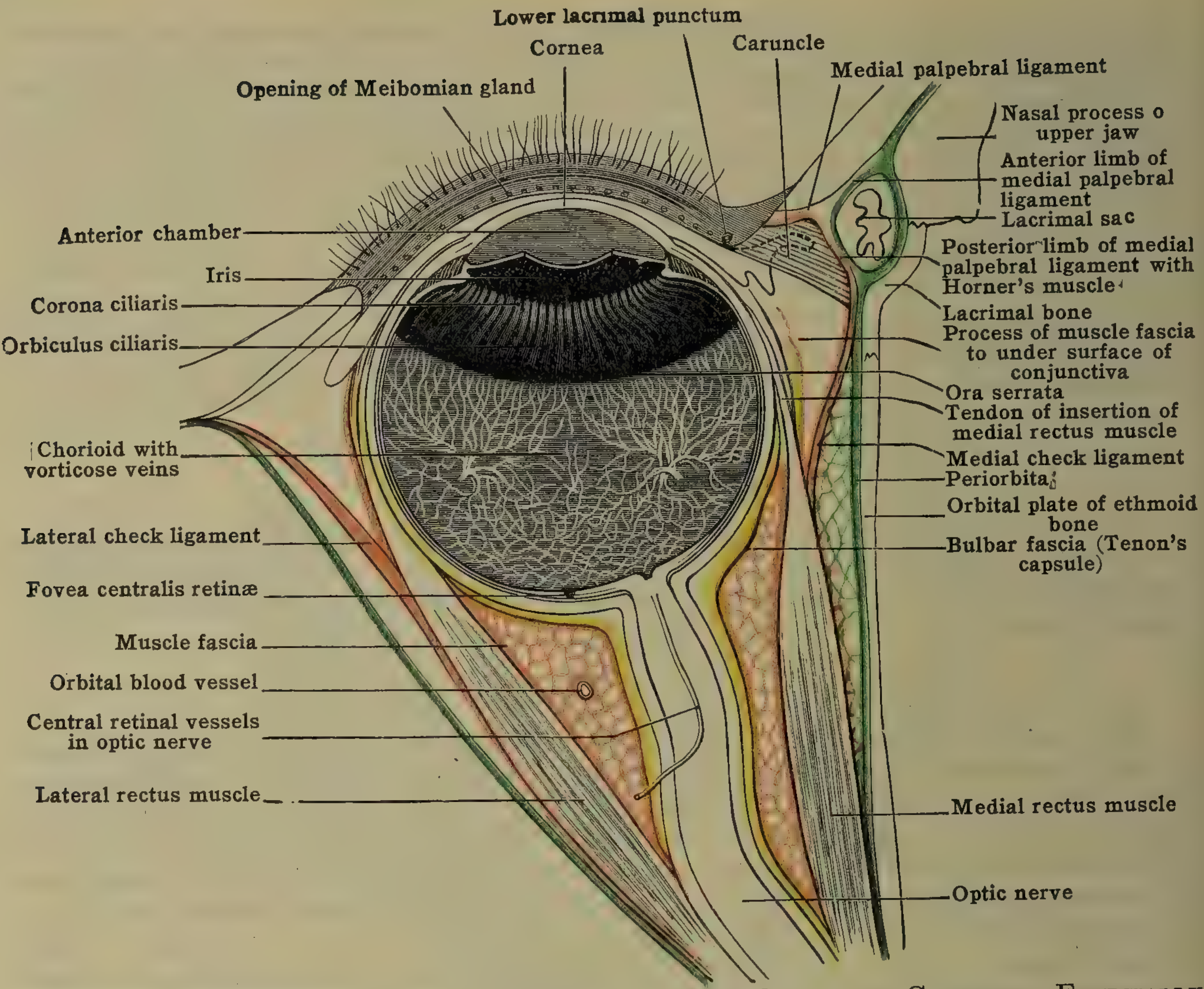


Fig. 884.—Diagrammatic Horizontal Section of the Orbit and Contents, Especially to Show the Orbital Fasciæ. × 2. (Modified after Fuchs.)

Periorbita, green; bulbar and muscular fasciæ, red; interfascial and supravaginal spaces, yellow.

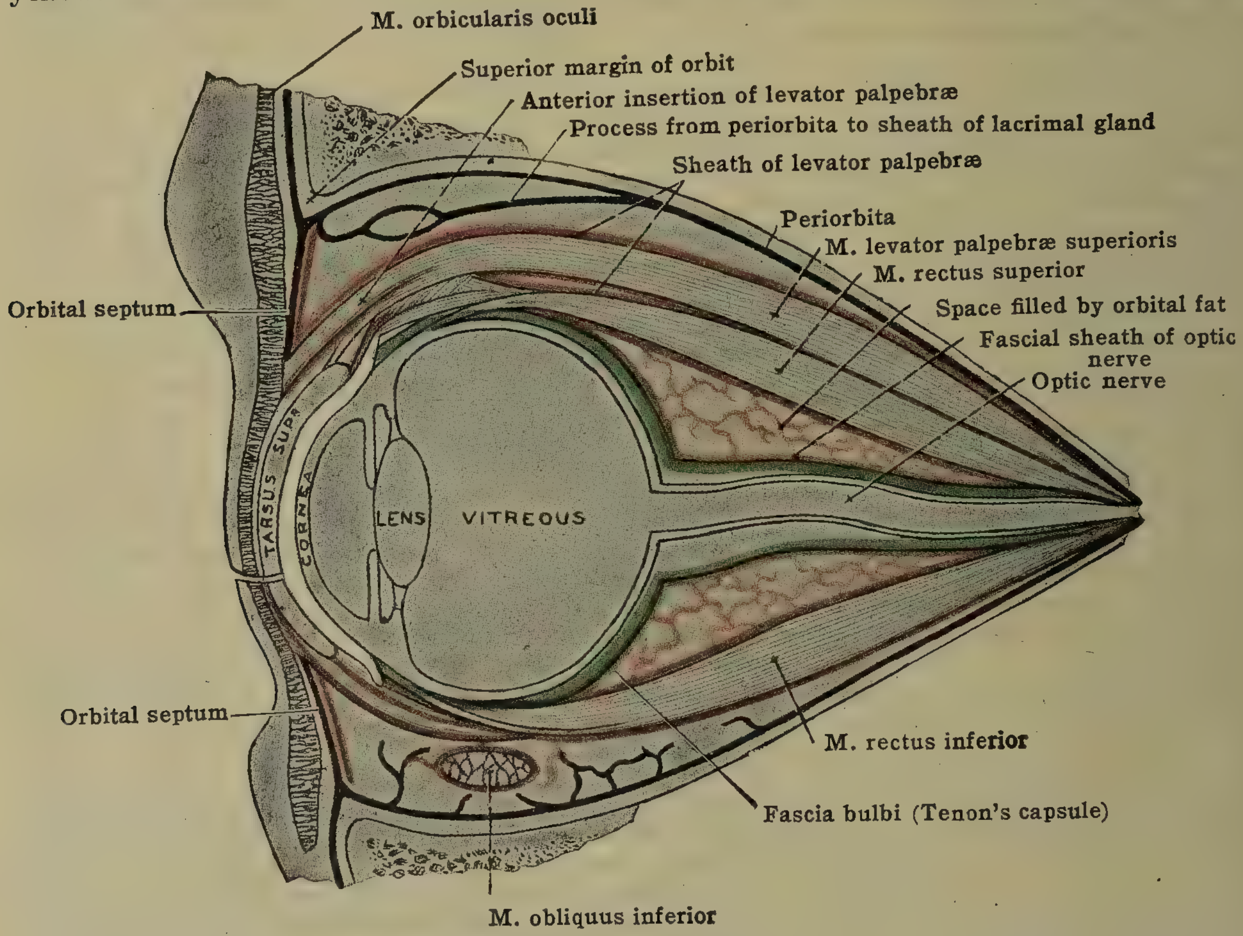


Fig. 885.—Diagrammatic Vertical Section of the Orbit and Contents, Especially to Show the Orbital Fasciæ. × 1.5.

Periorbita, black; bulbar and muscular fasciæ, red; interfascial and supravaginal spaces, green.

some movement of the eyeball within the encapsulating fascia (fig. 884, in yellow; fig. 885, in green). It extends forward to the level where the fascia fuses with the ocular conjunctiva, just in front of the insertions of the rectus muscles. Posteriorly it is reputed to connect with a supravaginal space about the optic nerve, but even the existence of such a space is doubtful.

4. Fibrous sheaths, or **muscular fasciæ** [fasciæ musculares], for the ocular muscles are thin posteriorly but strengthen near the eyeball to appear like tubular extensions of the bulbar fascia (figs. 884, 885). At the junction of the muscular and bulbar fasciæ, processes pass to the orbital wall. These are especially robust in relation to the medial and lateral recti and are called *check ligaments*, since they appear to restrain excessive muscular action (figs. 884, 886). There is considerable blending of the fascial extensions just mentioned and also of the bases of the muscle sheaths; the margins of the sheaths of the medial, inferior and lateral recti, together with the medial and lateral check ligaments, form a continuous hammock-like band (the suspensory ligament of Lockwood) slung beneath the eyeball for its support.

5. **Clinical aspects.**—Dermoid tumors occur in the orbital region, and most frequently at the lateral angle of the eye. The interior of the orbit is most easily reached by incisions lateral to the eyeball (although the line of the eyebrow is commonly utilized to conceal the scar); this is both because of the slope of the lateral wall toward the midplane and because the lateral

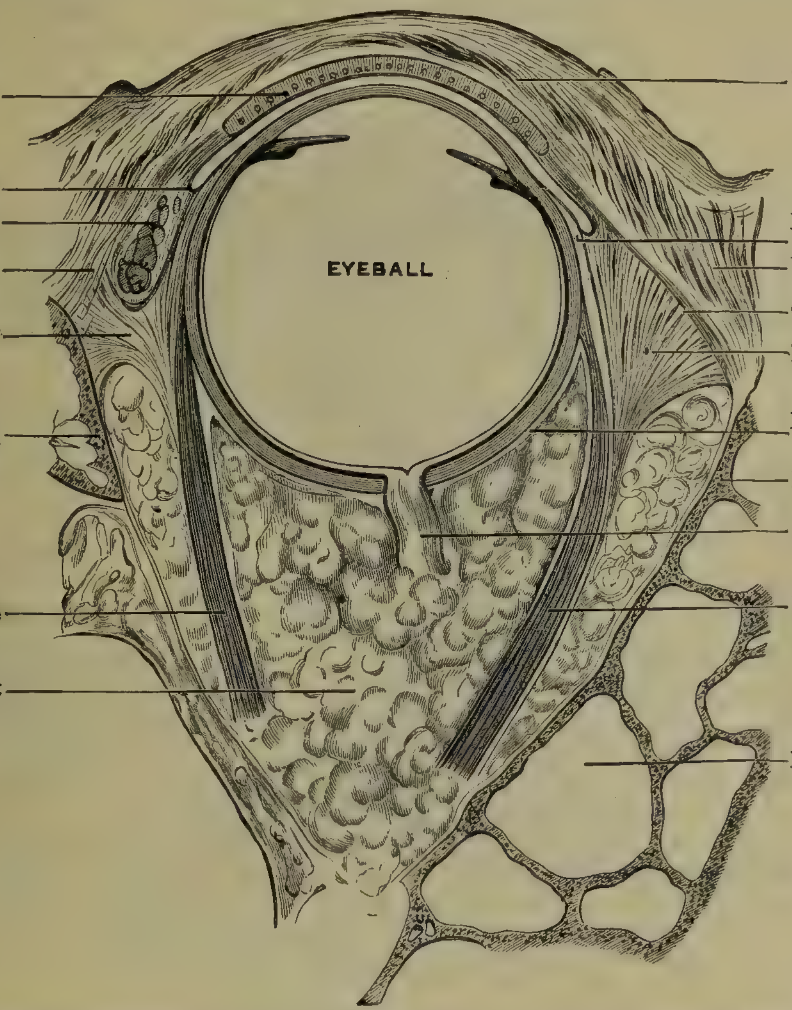


FIG. 886.—HORIZONTAL SECTION THROUGH THE LEFT ORBIT, VIEWED FROM ABOVE. × 1.5. (After von Gerlach.)

orbital border recedes more than the others. The bones of the roof, floor and especially of the medial wall are very thin and may be penetrated by foreign bodies thrust into the orbit from without, as well as by invading tumors which destroy the intervening bone. Protrusion of the eyeball (*exophthalmos*) is produced by tumors and abscesses in the orbit or by enlargement of the eyeball in disease. Absorption of the abundant, loose orbital fat is responsible for the characteristic sunken appearance of the eyes in emaciation or severe illness (*enophthalmos*). This adipose tissue furnishes a favorable bed for the growth of tumors or for the spread of abscesses, the pus from which may come to occupy the entire cavity. Since the orbital septum constitutes a barrier to the escape of pus, abscesses of the orbit need to be opened early in order to prevent interference with sight. Such tumors and abscesses may originate within the orbit or result from invasion. Tumors tend to enter by destroying the thin intervening walls rather than by utilizing natural openings. Pus usually comes from suppurations in the frontal sinus and ethmoidal cells. Hemorrhage results either from direct injury to the local vessels or by entry through the orbital plate of the frontal bone after fracture of the base of the skull. Air in the orbit is a diagnostic sign of a fracture that has established a communication with the nasal cavities or sinuses.

Both the conjunctiva and the bulbar fascia must be opened in the operation of *tenotomy* to correct squint. After division of the tendon of the proper eye muscle (usually the medial or lateral rectus) the muscle still retains an indirect attachment to the eyeball and conjunctiva through its fascial sheath and also connects with the orbital wall by the check ligament. Hence it can still exert a restraining action on the eyeball before a new muscular insertion is effected. After enucleation of the eyeball the bulbar fascia and the ocular muscles attached indirectly to it are still able to control the movement of an artificial eye.

B. The Orbital Vessels and Nerves

1. Arteries.—The main blood-supply to the orbit is afforded by the *ophthalmic artery*, a branch of the internal carotid, which enters through the optic foramen and quickly gives off most of its branches (fig. 887). These vessels vary greatly in their manner of origin and also in their course; they are further remarkable for their tortuosity, their delicate walls and their loose attachment to the surrounding tissues. The ophthalmic artery gives off special branches in the orbit to the lacrimal gland, ocular muscles, retina (through the optic nerve) and eyeball, as well as extraorbital branches to the meninges, ethmoidal cells and nasal mucous membrane. Twigs from these several sources supply the fat, fasciæ and ordinary nerves of the orbit. Branches which leave the orbit anteriorly ramify on the forehead and nose, and also supply the eyelids and the tear passages. The ophthalmic artery has many anastomoses with derivatives of the external carotid. The contents of the orbit are also supplied in part by the *infraorbital artery*, a branch of the internal maxillary division of the external carotid (fig. 531); in particular this artery supplies part of the inferior rectus and inferior oblique muscles, and also gives branches to the lacrimal sac and lower eyelid.

2. Veins.—Tributaries, corresponding generally to those of the ophthalmic artery, unite to form the superior and inferior ophthalmic veins (fig. 887). Either separately or as one trunk, they ultimately pass through the superior orbital fissure and empty into the cavernous

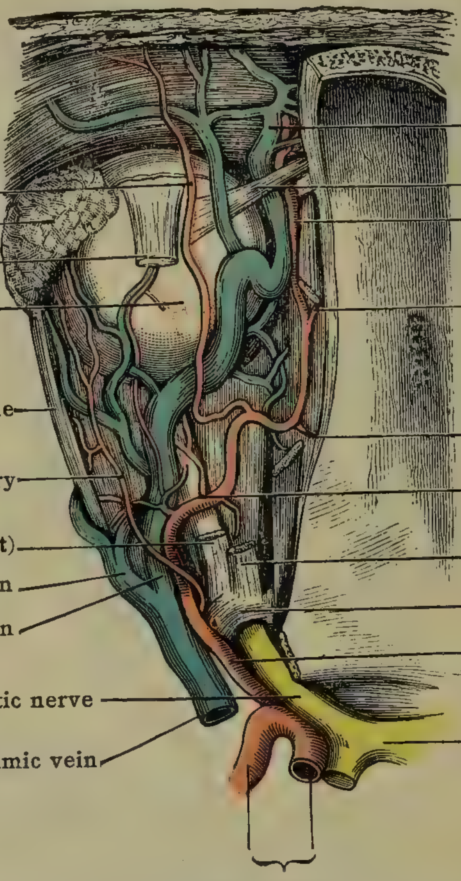


Fig. 887.—The Blood Vessels of the Left Orbit, Viewed from Above. Natural Size.

sinus. The inferior vein may connect with the pterygoid plexus by a branch which leaves the orbit through the inferior orbital fissure.

3. Lymphatics.—Definite lymphatic vessels have never been demonstrated, although there doubtless are perivascular and other channels to provide for lymph drainage. Lymph glands are not represented in the orbit.

4. Nerves.—The nerves of the orbit are *motor*, *sensory* and *sympathetic*. All enter the orbit by the superior orbital fissure, with the exception of one small sensory branch which passes through the inferior orbital fissure and the optic nerve, previously described, which utilizes the optic foramen (fig. 888).

A. The **motor nerves** are the oculomotorius, trochlearis and abducens, all of which are intended primarily for the extrinsic eye muscles (fig. 888). The trochlear nerve alone enters the orbit outside the common tendinous ring.

a. The *oculomotor nerve* gains the orbit in two parts. Of these, the *superior ramus* further splits into two branches. One supplies the superior rectus muscle, entering its lower surface far posteriorly; the other branch enters the levator palpebræ muscle on the posterior third of its lower surface. The *inferior ramus* divides into three branches, of which one supplies the inferior rectus muscle, entering its upper surface far back, and another enters the medial surface of the medial rectus muscle, a little behind its middle. The third branch of the inferior ramus furnishes the short (motor) root to the ciliary ganglion and one or more twigs to the inferior rectus muscle, after which the remainder then enters the lower surface of the inferior oblique muscle at about its middle.

b. The *trochlear nerve* supplies the superior oblique muscle, entering its upper surface about midway in its course.

c. The *abducens nerve* innervates the lateral rectus muscle, entering its medial surface at about the junction of the posterior and middle thirds.

As regards the manner of termination of these motor nerves in the ocular muscles, it is found that the nerve on entry breaks up into numerous bundles of fibers; these form first coarse and then fine plexuses, the latter ultimately sending off fine twigs that supply the muscle throughout with nerve endings. The posterior third of these muscles is, however, comparatively poorly supplied with both plexuses and nerve endings.

B. The **sensory nerves** are furnished by the ophthalmic and maxillary division of the trigeminal nerve. The ophthalmic division is chiefly orbital, while the maxillary sends only a small branch to the orbit.

a. The *ophthalmic division* of the trigeminal nerve enters the orbit in three parts, of which the nasociliary alone passes inside the common annulus (fig. 888).

α. The *frontal nerve* splits subsequently into *supratrochlear* and *supraorbital nerves*, both of which pass out of the orbit. These are distributed to the upper eyelid, and to the skin over the root of the nose, the forehead and the hairy scalp as far back as the coronal suture. The periosteum in this region and the frontal sinus also receive branches.

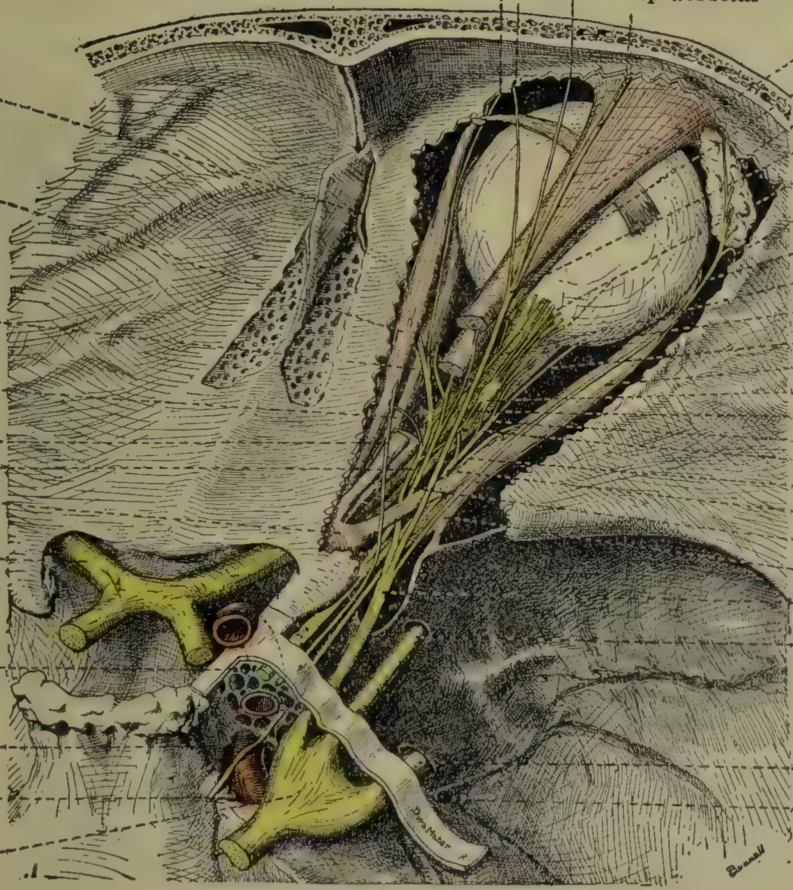


FIG. 888.—THE NERVES OF THE RIGHT ORBIT, VIEWED FROM ABOVE AND BEHIND. NATURAL SIZE.

β. The *lacrimal nerve* supplies the lacrimal gland, anastomoses with a branch of the maxillary nerve in the orbit, and finally pierces the upper eyelid. Outside the orbit it is distributed to the lateral part of the upper lid, the conjunctiva at the lateral angle, and the adjacent skin.

γ. The *nasociliary nerve* gives off: (a) a branch to the ciliary ganglion, constituting its long root; (b) two or three *long ciliary nerves* to the eyeball; and (c) the *infratrochlear nerve* passing out of the orbit and supplying the eyelids, the skin of the side of the nose near the medial angle of the eye, the lacrimal sac, caruncle and plica semilunaris. The remainder then leaves the orbit as the *anterior ethmoidal nerve* and is finally distributed to the nose.

b. The *maxillary division* of the trigeminal nerve has a branch, called the *zygomatic nerve*, which passes into the orbit through the inferior orbital fissure, anastomoses with the lacrimal nerve, and leaves the orbit in two parts (fig. 804). These are distributed to the skin of the temple and cheek.

A few minute twigs from the sphenopalatine ganglion, and sometimes from the maxillary division of the trigeminal nerve, also pass through the inferior orbital fissure to supply the periorbita in this neighborhood.

C. The **sympathetic nerves** of the orbit are mainly derived from the plexus on the internal carotid artery. With the exception of branches accompanying the ophthalmic artery, and of the distinct sympathetic root of the ciliary ganglion, they enter the orbit in the substance of the other nerve cords. The connections between the ocular nerves and the carotid plexus are recognizable as fibers passing to the oculomotor, abducens and ophthalmic nerves; as a rule, the comparatively large twigs going to the abducens join it farthest back, and those to the oculomotor farthest forward. Sympathetic connections with the trochlear nerve are very doubtful.

The *ciliary ganglion* is situated far back in the orbit between the optic nerve and the lateral rectus muscle (fig. 888). Its three roots (motor, sensory and sympathetic) have been mentioned in earlier paragraphs (fig. 810). Anteriorly it gives off three to six small trunks; these subdivide to form the *short ciliary nerves*, about twenty in number, which pierce the sclera around the entrance of the optic nerve.

Preganglionic fibers in the oculomotor nerve end in the ciliary ganglion; from the cells of this ganglion arise the postganglionic fibers that innervate the ciliary and sphincter pupillæ muscles (fig. 783). Sympathetic fibers, whose preganglionic components emerge from the spinal cord in the motor roots of the first two or three thoracic nerves, enter the sympathetic trunk and ascend without interruption to cell stations in the superior cervical ganglion (fig. 783). Thence continuing onward through the carotid canal and superior orbital fissure, they supply: (1) the dilator muscle of the iris; (2) the smooth muscle fibers in the eyelids; and (3) possibly smooth muscle elements alleged to occur in the check ligaments and bulbar fascia. Paralysis of the cervical sympathetic nerve in the neck by trauma or the pressure of a malignant growth, causes, therefore: (1) narrowing of the pupil; (2) narrowing of the palpebral fissure (*ptosis*); and (3) retraction of the eyeball (*enophthalmos*). These symptoms may be observed in fractures of the spinal column involving the lower cervical vertebræ.

C. The Ocular Muscles

There are seven voluntary muscles in the cavity of the orbit; six attach to the eyeball and control its movements, while the seventh serves to elevate the

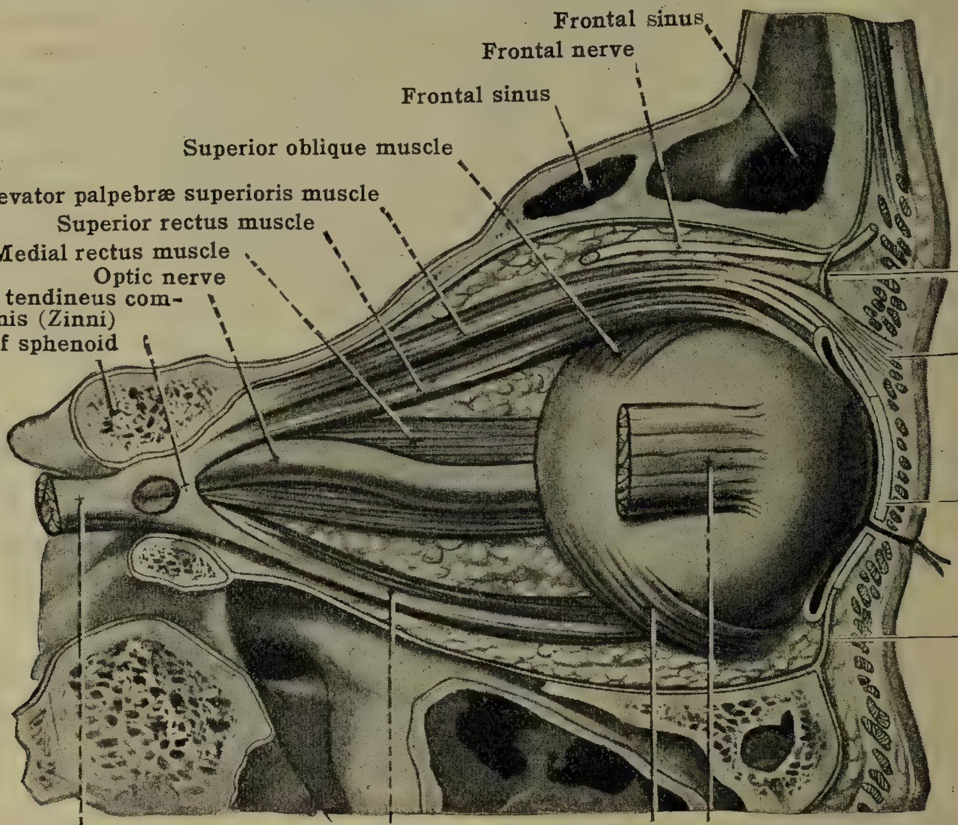


Fig. 889.—Dissection of the Muscles of the Right Orbit, in Lateral View. × 1.5.

upper eyelid. Besides these, a layer of involuntary muscle fibers, the *orbital muscle* [musculus orbitalis], bridges the inferior orbital fissure; it is the vestigial remnant of a muscle that causes tension of the orbital wall and protrudes the eyeball in lower animals. Collectively, these several muscles are designated as **ocular muscles** [musculi oculi]. All the voluntary muscles, except the inferior oblique, arise at the apex of the orbit and diverge as they pass forward (fig. 889). The actual site of origin is the immediate vicinity of the optic foramen—either from bone or from a fibrous ring which encircles the optic nerve (fig. 890). Four of the muscles to the eyeball bear the name 'rectus' (*i.e.*, straight), while their relation to the eyeball and their positions of insertion in front of the equator are correctly indicated by descriptive adjectives (superior, inferior, medial and lateral) given them. Two oblique muscles, superior and inferior, attach behind the equator of the eyeball after pursuing courses which do not run in a straight, forward direction (fig. 892). All six muscles are arranged in opponent pairs, namely, the superior and inferior recti, the medial and lateral recti, and the superior and inferior obliques. (The NK recommends *bulbi tegmentalis* instead of superior and *bulbi maxillaris* instead of inferior.)

1. The four **rectus muscles** [m. rectus superior, inferior, medialis et lateralis] arise from a fibrous ring, the *annulus tendineus communis*, which attaches around the upper and inner edges of the optic foramen and then bridges across the superior orbital fissure (figs. 889, 890). It is also firmly united to the dural sheath of the optic nerve. The origins of the recti may be said to begin with a short, common tendinous tube, from which the muscles soon separate, taking positions close to the orbit as indicated by their respective names. From the upper, inner and lower parts of the ring arise the superior, medial and inferior rectus, respectively. The lateral rectus is often said to have two heads, one on each side of the superior orbital fissure where it is pierced by nerves emerging through that fissure, but bridging fibrous tissue really makes a continuous origin from the lateral side of the tendinous ring to the spine bordering the fissure. The recti are all oblong, flat muscles, broader in front than behind; their length is about 40 mm. After following the orbital wall for the first half of their course they leave it and continue toward the eyeball, running through the orbital fat, and are finally inserted by broad, thin tendons into the sclera about 6 mm. behind the corneal margin (figs. 889, 891, 892). Sometimes these tendinous insertions can be seen in the living subject as series of whitish parallel lines. Because of their respective positions in the orbit, the axis of this cone of ocular muscles is somewhat oblique to the anteroposterior axis of the eyeball. The strongest of these muscles is the medial rectus; the weakest but longest (as to muscle content) is the superior rectus. The

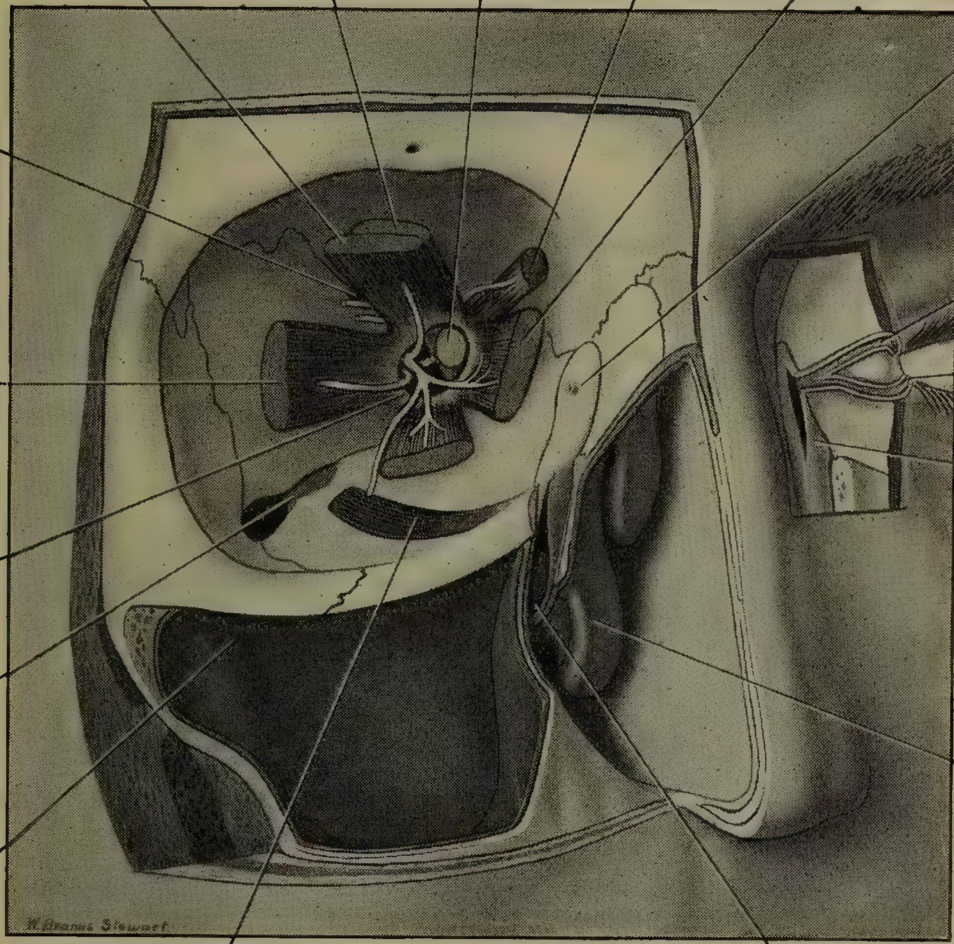


FIG. 890.—DISSECTION OF THE ORBITAL REGION, SHOWING THE ORIGIN OF THE OCULAR MUSCLES AND THE RELATIONS OF THE LACRIMAL PASSAGES. NATURAL SIZE.

innervation of the lateral rectus is from the abducens nerve while the other three recti are supplied by the n. oculomotorius.

2. The fusiform **superior oblique muscle** [m. obliquus superior] is the longest and thinnest eye muscle. It arises from the periosteum of the body of the sphenoid bone, medially and a little in front of the optic foramen and the origin of the medial rectus (figs. 890, 891). The muscle runs forward close to the medial margin of the orbital roof until the fibrous loop (the *trochlea*) on the frontal bone is reached. Here it becomes tendinous, passes through the pulley-like trochlea, and then bends at an angle of 50 degrees to run posteriorly and laterally under the superior rectus to its insertion behind the equator and between the superior and lateral recti (figs. 891, 892). The nerve-supply is furnished by the trochlear nerve.

3. The **inferior oblique muscle** [m. obliquus inferior] is the shortest of all voluntary ocular muscles. It takes origin from the medial margin of the floor of the orbit, near the front and just lateral to the beginning of the lacrimal fossa (fig. 890). The muscle curls laterally, upward, and backward, between the inferior rectus tendon and the floor of the orbit, and then continuing to a position behind the equator inserts under cover of the lateral rectus (figs. 889, 891). The innervation is through the oculomotor nerve.

4. The **m. levator palpebræ superioris** (m.l.p. frontalis NK) is a muscle which lifts the upper eyelid. It originates at the back of the orbit just above and in front of the optic foramen,

from which it is separated by the origin of the superior rectus (fig. 890). Coursing forward and expanding beneath the roof of the orbit, it partially overlies the superior rectus and then descends through the orbital fat to be inserted into the root of the upper lid (figs. 889, 891). In addition, the aponeurosis spreads into a medial and a lateral horn that attach to the corresponding orbital margins. This aponeurosis may be considered as occurring in two distinct layers (figs. 889, 898). The upper, or anterior layer (lamina superficialis NK) of insertion is fibrous and passes in front of the tarsal supporting plate of the lid where it comes into relation

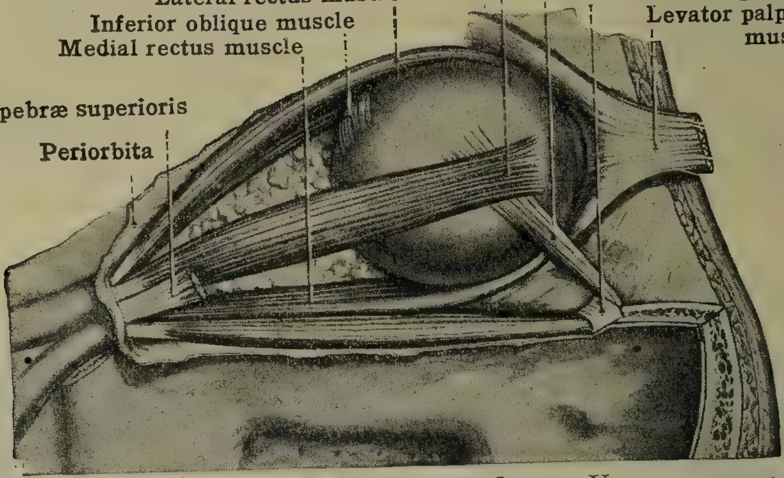


FIG. 891.—DISSECTION OF THE MUSCLES OF THE LEFT ORBIT, VIEWED FROM ABOVE. NATURAL SIZE.

with fibers of the orbicularis muscle and with the skin; this attachment is primary in importance. The lower, or posterior lamella (lamina profunda NK) contains smooth muscle (the superior tarsal muscle) and is inserted along the upper border of the tarsus. In addition there is a third set of connections between the fused fascial sheaths of the levator and superior rectus muscles and the conjunctiva at its line of reflection from eyelid to eyeball. The nerve-supply is from the oculomotor nerve.

The muscles of the eyebrow and eyelids are considered on pp. 402 and 1160.

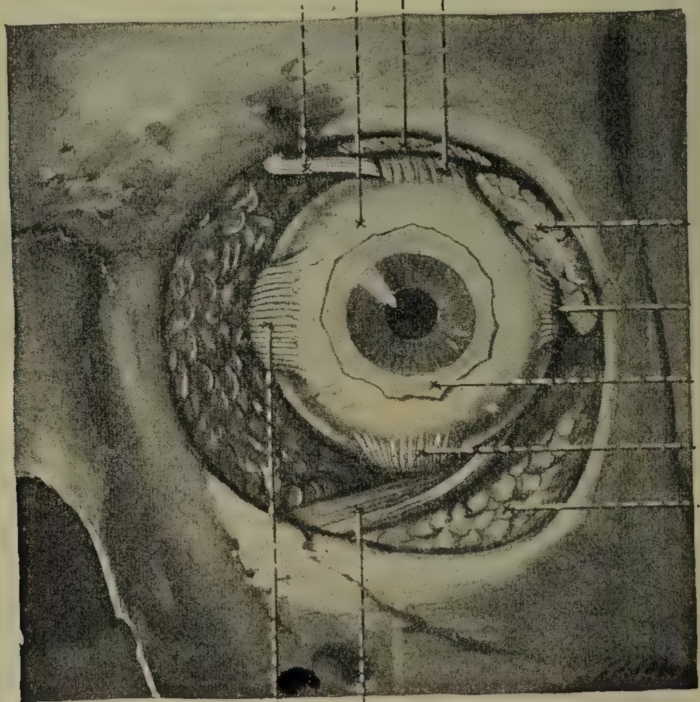


FIG. 892.—SUPERFICIAL DISSECTION OF THE LEFT ORBIT, VIEWED FROM IN FRONT. NATURAL SIZE.

5. Action of the ocular muscles.—The bulbar fascia forms a socket in which the eyeball moves slightly, while eyeball and fascia move together as a unit on the bed of orbital fat. The position of this socket (and of the contained eyeball) in the orbit is not subject to gross alteration; it is merely the direction and not the situation of the eye that changes. The movements that take place can be described in reference to three principal axes passing through the center of the roughly spherical eyeball. These axes are: (*a*) vertical, through the equator; (*b*) horizontal,

through the equator; and (*c*) anteroposterior, in the ocular axis. The movements that occur may be analyzed into upward and downward (*i.e.*, a rocking about the horizontal diameter of the equator), medial and lateral (*i.e.*, a side-to-side shifting about the vertical diameter of the equator), and rotation (*i.e.*, a wheel rotation around the anteroposterior axis). Taking the upper pole of the eyeball as the moving point, rotation may be described as medial (nasalward)

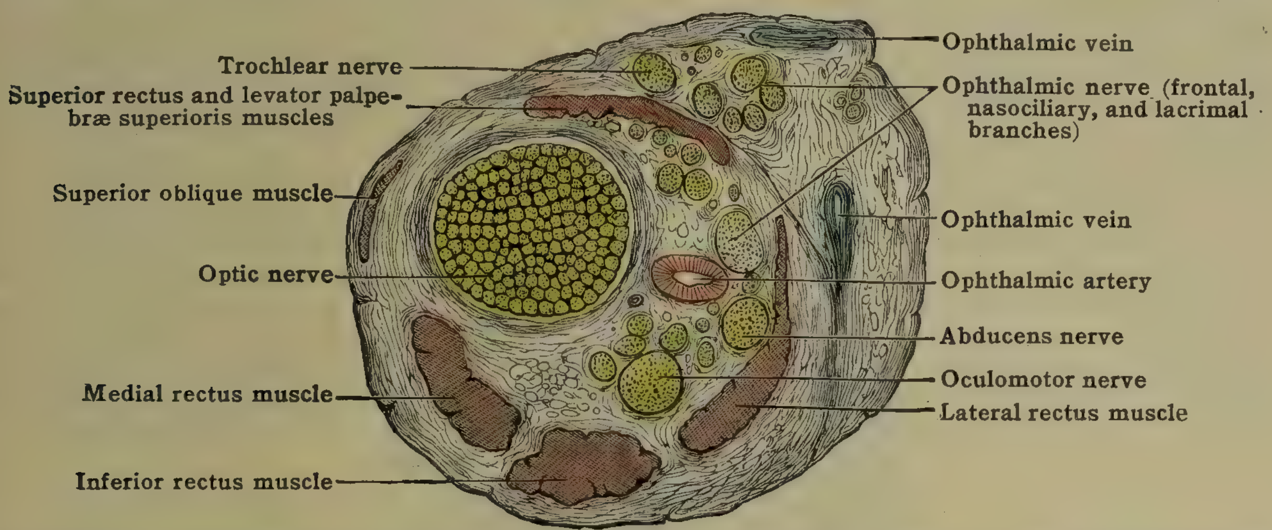


FIG. 893.—TRANSVERSE SECTION THROUGH THE RIGHT ORBIT CLOSE TO THE OPTIC FORAMEN, VIEWED FROM BEHIND. × 5. (After Lange.)

or lateral (temporalward). The term 'rotation' should be applied only in the sense just defined; the other primary movements are all radial.

The only two muscles that move the eyeball on one axis alone are the *lateral rectus* and the *medial rectus;* their names, 'lateral' and 'medial,' describe the side-to-side displacing effects on the cornea.

The actions of the superior and inferior recti are complicated by the obliquity of the axes of muscles and eyeball previously mentioned. Contraction of the *superior rectus* makes the eye

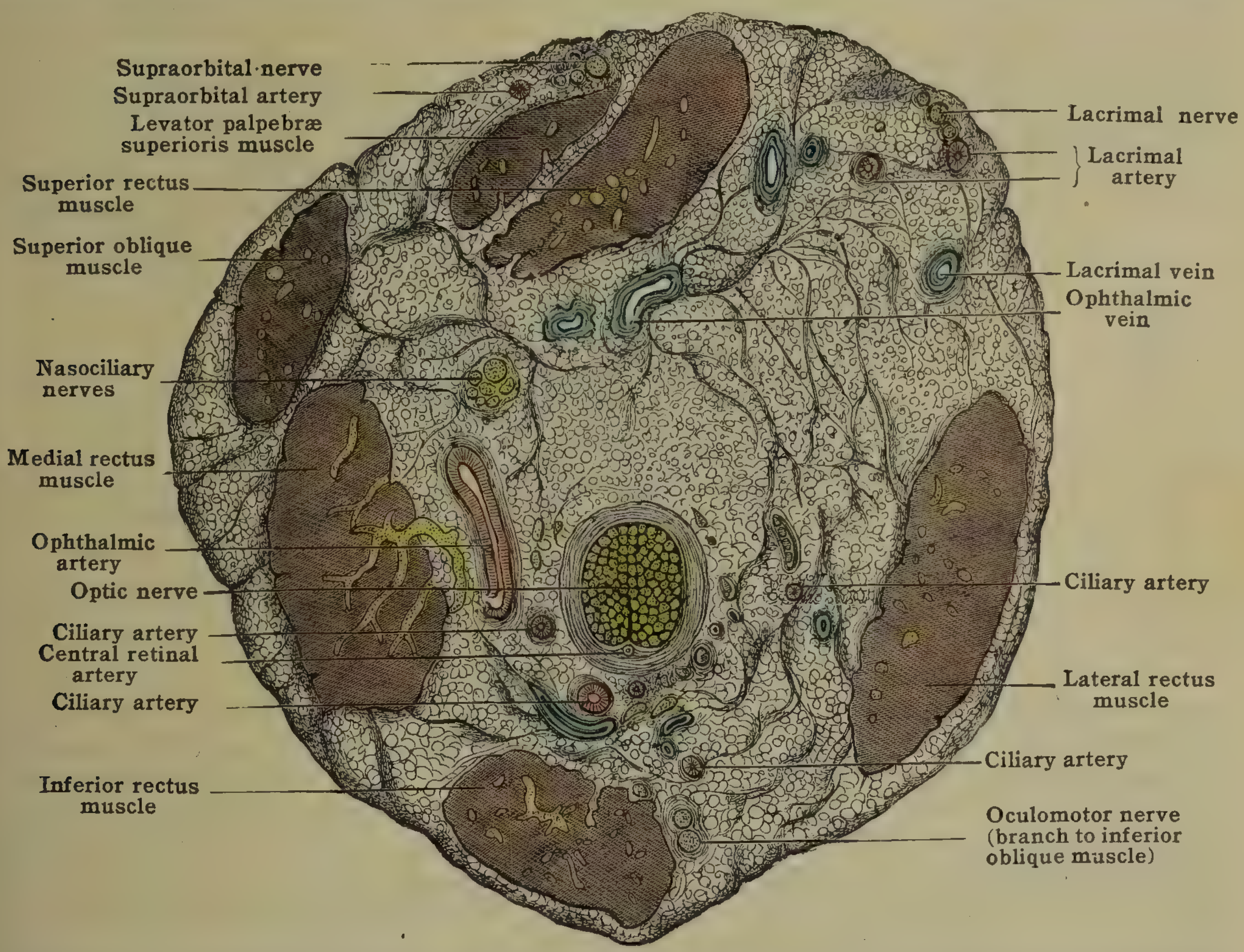


FIG. 894.—TRANSVERSE SECTION THROUGH THE RIGHT ORBIT 10 MM. BEHIND THE EYEBALL, VIEWED FROM BEHIND. × 5. (After Lange.)

look upward and somewhat medially; at the same time there is a slight rotation of the upper pole medially. The *inferior rectus* directs the eye downward and medially, and rotates the upper pole laterally.

The *superior oblique* moves the eye so that it looks downward and laterally, at the same time rotating it medially. The *inferior oblique* turns the eye upward and laterally, meanwhile rotating it laterally.

When the pupil looks directly downward the superior oblique and inferior rectus act together. Similarly, the inferior oblique and superior rectus coöperate in turning the eye directly upward. Oblique movements demand a coördination of two rectus muscles and one of the obliques.

6. **Clinical aspects.**—*Strabismus*, or squint, is produced by a functional inequality of the opposing muscles. It is more common toward the medial side. Any such disturbance of the eye-muscle balance occurring in later life causes double vision (*diplopia*), whereas children learn to use one eye and ignore the other. To correct strabismus the proper rectus tendon is severed, after which reattachment is effected more posteriorly on the sclera. The important nerves passing through the orbit may be injured by wounds and by fracture of the orbit, or become pressed upon by tumors, aneurisms, hemorrhages or inflammatory effusions. Paralysis of the oculomotor nerve leads to fixation of the pupil in a dilated condition (because the sphincter pupillæ is rendered inactive) and drooping of the upper lid (*ptosis;* because of paralysis to the levator palpebræ superioris), while the eyeball becomes relatively fixed with a divergent squint (due to the unopposed action of the lateral rectus). In complete paralysis movement can be made only in a combined outward and downward direction. Paralysis of the trochlear nerve is without marked effect on the position of the eye since most of the muscular actions of the superior oblique are taken over by other muscles; diplopia enters, however, and is most pronounced when the eye is directed downward (because the superior oblique can no longer correct the tendency of the inferior rectus to impart a medial as well as downward direction to the eye). Paralysis of the abducens nerve is accompanied by convergent squint (due to the unopposed action of the medial rectus) and the consequent inability to turn the eye directly outward.

D. The Eyebrow

The **eyebrow** [supercilium] is an arching prominence of skin which covers the upper border of the orbit and bears numerous short hairs directly obliquely. It consists of thickened integument, connected deeply with the frontalis, corrugator and orbicularis oculi muscles (figs. 403, 406).

E. The Eyelids

Each eye has two loose, movable folds of integument placed in front for protection. These **eyelids** [palpebræ], even when opened widest, overlap part of

Fig. 895.—The Right Eye with Eyelids Closed, Viewed from in Front. Natural Size.

the eyeball that projects beyond the orbit; when closed they cover completely the eyeball and the entrance to the orbit (fig. 895). The *upper lid* [palpebra superior] (p. frontalis NK) is larger and more mobile than the *lower lid* [palpebra inferior] (p. malaris NK); it is supplied by an *elevator muscle* [m. levator palpebræ superioris] (m.l.p. frontalis NK). The upper lid extends upward as far as the eyebrow; the lower lid has no precise inferior limit, although the lower margin of the orbit may be taken as its boundary. The superficial covering of skin is attached more tightly nearer the free palpebral margin where it overlies a firm fibrous plate named the *tarsus* [tarsus superior et inferior] (tarsi palpebrarum NK), readily demonstrated by pinching the eyelid horizontally. These relations furnish the basis for dividing each lid into an orbital and a tarsal region. The boundary between the two is marked by a fold of skin which is much plainer in the upper lid (fig. 895).

The space between the free margins of the two lids is the *palpebral fissure* [rima palpebrarum]. This is a mere slit when the lids are closed, but when they

are open its shape is much like that of an almond, some 30 mm. long. *Medial* and *lateral angles* [angulus oculi medialis et lateralis] (a.o. nasalis et temporalis NK), or canthi, are formed by the meeting of the lids at each end of the palpebral aperture, while the unions themselves constitute the corresponding *palpebral commissures* [commissura palpebrarum medialis et lateralis] (c.p. nasalis et temporalis NK) (figs. 895, 896). The lateral commissure subtends a sharp angle, but the medial angle is extended and more rounded, the margins of the lids for

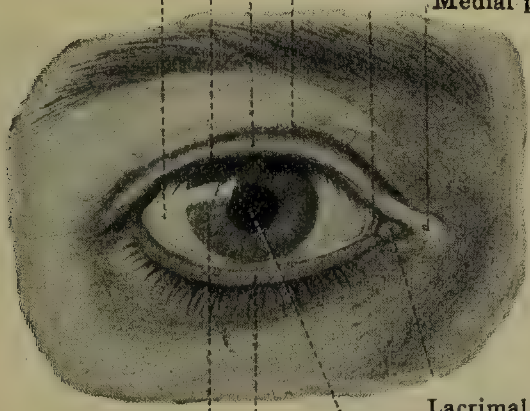


FIG. 896.—THE RIGHT EYE WITH EYELIDS OPEN, VIEWED FROM IN FRONT. NATURAL SIZE.

the last 5 mm. running an almost parallel course and lacking lashes. Here the eyelids are not in contact with the eyeball and bound a small bluntly triangular space, the *lacrimal lake* [lacus lacrimalis], which is largely occupied by a fleshy protuberance, the *caruncula lacrimalis* (fig. 897). At the base of the triangle, on the margin of each lid, is a prominence, the *lacrimal papilla* [papilla lacrimalis], whose summit is pierced by an orifice, the *punctum lacrimale,* which marks the beginning of a lacrimal duct (fig. 897). The lower punctum is rather larger than the upper and is placed farther out from the medial angle of the eye; both are

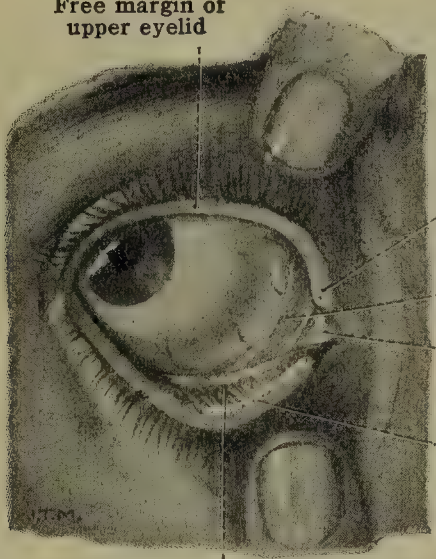


FIG. 897.—THE RIGHT EYE, WITH THE EYEBALL TURNED LATERALLY AND THE EYELIDS EVERTED TO SHOW THE CONJUNCTIVA AND THE STRUCTURES OF THE MEDIAL ANGLE. NATURAL SIZE.

applied against the surface of the eyeball and are not visible unless the eyelids are everted slightly.

Each eyelid presents an *anterior* and a *posterior surface* [facies anterior et posterior] (f. cutanea et conjunctivalis NK), separated by a free margin. The margin has a sharp *posterior edge* [limbus palpebralis posterior] (l.p. conjunctivalis NK) which is applied to the surface of the eyeball; here occurs the region of transition of skin into the conjunctival mucous membrane which both lines the

posterior surface of the lid and is reflected over the exposed front of the eyeball. Along the posterior edge may be seen a single row of minute apertures where the *tarsal glands* (of Meibom) [glandulæ tarsales] open; examination of the everted eyelid reveals the glands themselves showing through as a series of yellow lines arranged perpendicularly to the free margin (fig. 897). The *anterior edge* [limbus palpebralis anterior] (l.p. cutanei NK) is somewhat more rounded and bears a double or triple row of stiff *cilia*, or eyelashes. Those of the upper lid are longer and stronger, but both have their points curved away from the palpebral fissure so that there is no interlacing when the lids close.

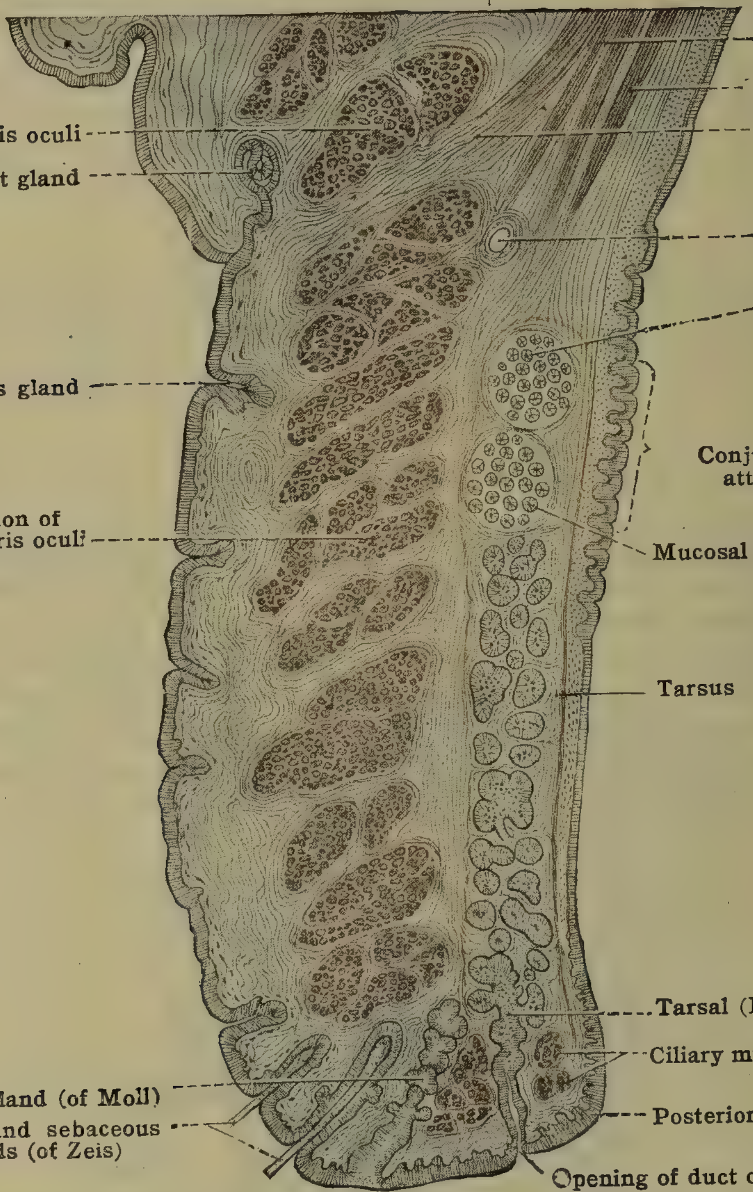


FIG. 898.—SAGITTAL SECTION OF THE UPPER EYELID. × 12. (After Waldeyer and Fuchs.)

1. **Structure of the eyelids.**—The eyelids contain the following structures from without inward (fig. 898): (*a*) *integument;* (*b*) *subcutaneous tissue;* (*c*) *muscular layer;* (*d*) *orbital septum;* (*e*) *tarsus* and *tarsal glands;* and (*f*) *conjunctiva.* In addition, the upper lid has the aponeurotic insertion of the levator palpebræ superioris muscle (p. 1155). Connected to the extremities of the tarsi are the medial and lateral palpebral ligaments (figs. 899, 900). Each eyelid may be regarded as consisting of two layers of skin, the posterior having been folded back upon the anterior at the margin of the lid; thus the epidermis and corium of the outer skin component are represented respectively by the conjunctival epithelium and tarsus of the inner layer.

The external covering of **skin** is thin, bearing small sweat glands and sparse, downy hairs provided with sebaceous glands. The *cilia*, already described, possess large sebaceous glands (of Zeis), while nearby on the margin are peculiar, modified sweat glands (of Moll).

The **subcutaneous tissue** is remarkably loose in texture and contains no fat.

The **muscular layer** is intermingled largely with the subcutaneous tissue (fig. 898). It consists mostly of the palpebral portion of the *m. orbicularis oculi*, whose fibers arise from the medial orbital margin and course over the whole upper and lower eyelid in a succession of arches, to meet again beyond the lateral angle. There they interlace and join, thereby giving rise to the *lateral palpebral raphe* [raphe palpebralis lateralis] (fig. 899). The portion of the orbicularis muscle that overlies the orbital septum originates medially at the medial palpebral ligament. On the other hand, the pretarsal portion begins at the posterior lacrimal crest; the muscle mass that lies behind the lacrimal sac is known as the *pars lacrimalis*, or muscle of Horner.

The muscle fibers of the eyelids are arranged in loose bundles, separated by connective tissue. One strong bundle of orbicularis fibers, called the *ciliary muscle* (of Riolan), is found near the edge of the lid, in front of and behind the ducts of the tarsal glands (fig. 898).

A **connective-tissue layer** separates the orbicularis muscle from the tarsus in the tarsal division of the lids. In the upper lid this is to be regarded as mainly the anterior aponeurotic expansion of the tendon of the levator palpebræ, which sends connective-tissue septa between the bundles of the overlying orbicularis and even to the skin (figs. 898, 899). Into the upper anterior border of the upper tarsus is attached the posterior layer of the levator palpebræ expansion; this consists of smooth muscle fibers and constitutes the *superior tarsal muscle* [m. tarsalis superior] (figs. 898, 899). In the orbital part of the upper lid the central connective tissue includes also the orbital septum (fig. 899), lying here immediately behind the orbicularis muscle, but this soon thins and fades into the continuation of the levator expansion (fig. 889). The latter is strengthened by an extension of the sheath of the superior rectus, through which this

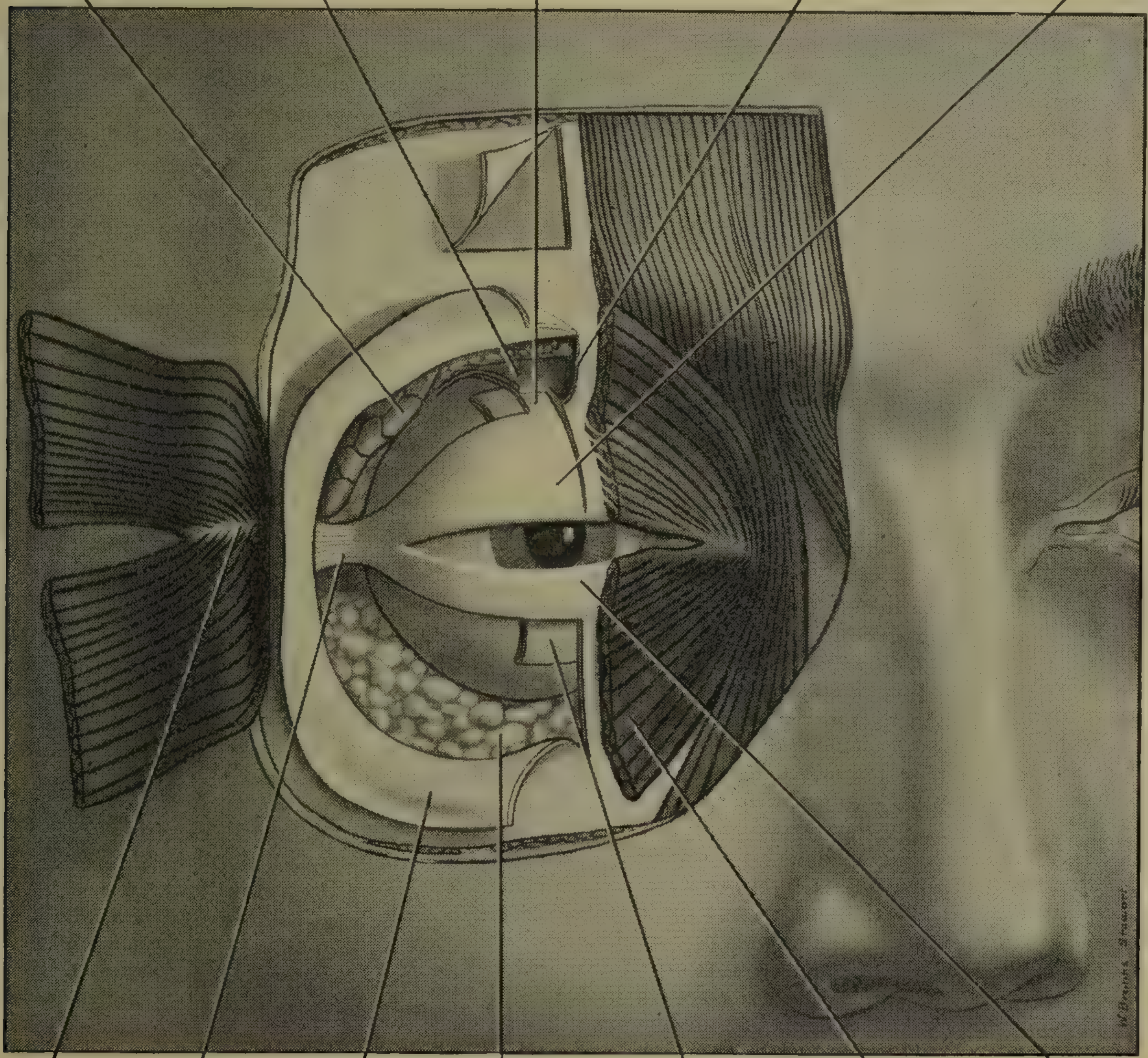


FIG. 899.—SUPERFICIAL DISSECTION OF THE RIGHT ORBIT, IN FRONT VIEW. × 2.

muscle is enabled indirectly to influence the elevation of the lid. In the lower eyelid the central connective tissue similarly consists of the orbital septum blended with a thin fibrous extension of the sheath of the inferior rectus (fig. 885); bundles of smooth muscle occur in this sheath extension and, as the *inferior tarsal muscle* [m. tarsalis inferior], become inserted at the inferior border of the lower tarsus. Immediately in front of each tarsus is a little loose connective tissue which contains the large blood-vessels and nerves of the lids.

The **tarsus** is a stiff plate of dense fibrous tissue which largely maintains the form of each lid and gives lodging to the tarsal glands (fig. 899). The free borders of the tarsi are straight; the attached borders are convex, especially in the upper lid. The length of each tarsus is about 20 mm. and its width and thickness are greatest midway of the lid; the width of the upper tarsus (10 mm.) is about twice that of the lower. The relations of tarsus to orbital septum have been described in a previous paragraph. Two ligamentous formations fix the two ends of the tarsi to the orbital wall (figs. 899, 900): (*a*) the *medial palpebral ligament* [lig. palpebrale mediale]; and (*b*) the *lateral palpebral ligament*, often confused with the overlying lateral palpebral raphe. The *medial palpebral ligament* is a strong, fibrous band running toward the root of the nose, easily demonstrable in life by drawing the lateral angle of the eye outward. The ligament is U-shaped, its anterior and posterior limbs embracing the lacrimal sac. Arising from the frontal process of the maxilla, the stronger anterior limb extends over the front wall

of the entire upper half of the lacrimal sac and attaches to the tarsi; a thin continuation bends around the lateral wall of the sac and then passes behind it to the posterior crest of the lacrimal bone. Superiorly the medial ligament is thin and blends with the periosteum; inferiorly it is thicker and terminates in a prominent free margin (fig. 899). The palpebral fibers of the orbicularis muscle are inserted into the anterior surfaces of both limbs, those attached to the posterior limb constituting the pars lacrimalis (*i.e.*, Horner's muscle) of the orbicularis oculi (fig. 884). The *lateral palpebral raphe* designates an interlacing of the orbicularis muscle fibers at the lateral angle of the eye, somewhat strengthened deeply by connective tissue of the orbital septum; it attaches to the frontosphenoidal process of the zygomatic bone. At a still deeper level there is a quite separate stronger band of fibrous tissue which may be appropriately called the *lateral palpebral ligament* (fig. 851); it attaches to the tarsi and to the zygomatic bone just within the orbital margin, and is overlaid by the lateral horn of the levator aponeurosis (just as is the tarsal plate itself).

Within the substance of the tarsi are embedded the slender **tarsal glands** (of Meibom), 30–40 in the upper lid, 20–30 in the lower lid (figs. 897, 898). They occur in a closely crowded series, all parallel to each other and perpendicular to the margins of the lids. Each has a long axial duct, which throughout its length receives short side ducts from the individual saccules. The openings of the main excretory ducts form a single row of minute apertures visible along the free margins of the lids (fig. 897). The secretion of the tarsal glands is sebaceous, and through it the palpebral margins are lubricated to serve as a barrier against overflow of tears.

The **conjunctival layer** will be described in the next section.

2. Vessels and nerves.—The *arteries* of the eyelids are derived chiefly from the ophthalmic division of the internal carotid through the small palpebral branches (fig. 887). The medial palpebral arteries, superior and inferior, enter from the nasal side and run across the lids near their free margins. On nearing the lateral commissure these vessels join branches from the lacrimal arteries (besides receiving twigs from the external carotid through the superficial temporal and transverse facial branches; fig. 524). In this manner a primary arterial arch is formed in each eyelid (fig. 537). A smaller secondary arch occurs along the convex, attached tarsal border.

The *veins* of the eyelids are more numerous and larger than the arteries. Those from the palpebral conjunctiva reach the internal jugular through tributaries of the ophthalmic vein (fig. 596). The venous drainage of the pretarsal tissues escapes more superficially into the angular vein medially and into the superficial temporal laterally (fig. 588).

The *lymphatics* also present a pretarsal and post-tarsal network, which like the veins communicate through the tarsal plates. Most of them pass lymph to the anterior auricular and the parotid lymph glands, but the vessels at the inner angle and the medial half of the lower lid find their way to the submaxillary lymph glands (fig. 630).

The *sensory nerves* are branches of the ophthalmic division of the trigeminus (fig. 888). The upper lid is chiefly supplied by the supraorbital nerve, the lower lid by the infraorbital (fig. 809). At the medial angle the supratrochlear and infratrochlear nerves also aid in the supply, and at the lateral angle the lacrimal does the same. The *motor nerve* to the levator palpebræ muscle is from the oculomotorius while the orbicularis oculi is supplied by the facial nerve. The involuntary fibers of the lids are innervated by the sympathetic system.

3. Clinical aspects.—The laxity of the subcutaneous tissue of the eyelids leads to marked swelling when the lids become edematous, inflamed or hemorrhagic. The prominence of a 'black eye' thus depends upon the ease with which blood spreads through these tissues and upon the thinness of the overlying skin. Inflammation of hair-follicles or of the several kinds of glands at the border of the lids is common, while the whole border of the lid is frequently the seat of chronic inflammation (*blepharitis*). The slow, terminal circulation of this region, its moistness and liability to local irritation, and the readiness with which its glands participate in any inflammation are all contributary factors to these conditions. 'Stye' (*hordeolum*) is a suppuration occurring in one or more of the glands of Zeis or Moll. Shrinking of the skin in the aged or contraction of scar tissue from burns easily draws the lower lid away from the eyeball; such eversion is designated *ectropion*. Nodules in the tarsus (*chalazion*) result from the retention of secretion in tarsal (Meibomian) glands; to avoid scarring they are preferably opened from the conjunctival surface of the lid.

F. The Conjunctiva

At the free margins of the eyelids the skin assumes the characteristics of a mucous membrane that clothes the inner surfaces of the lids as the **palpebral conjunctiva** [tunica conjunctiva palpebrarum]. This mucosal lining is then reflected back upon itself at the base of each eyelid where the arching folds are designated, respectively, the *superior* and *inferior fornix* [fornix conjunctivæ superior et inferior] (f.c. frontalis et malaris). Continuing over the surface of the eyeball as the **bulbar conjunctiva** [tunica conjunctiva bulbi] as far as the edge of the cornea, its epithelium alone (the corneal epithelium) is carried across the transparent front of the eye. Thus there is formed a *conjunctival sac* whose anterior wall is supplied by the inner surfaces of the two eyelids and whose posterior wall lies upon the front third of the eyeball (figs. 889, 899). The *lacrimal lake* [lacus lacrimalis] is the shallow bay of conjunctiva bounded by the lids at the medial angle of the eye (fig. 900). This lake is largely occupied by a reddish elevation, the *lacrimal caruncle* [caruncula lacrimalis] (fig. 897); it is an island of modified skin provided with minute hairs, sebaceous glands and sweat glands. Lateral to the caruncle is a vertical crescentic fold of conjunctiva named the *plica semi-*

lunaris conjunctivæ (fig. 897); this fold is a rudimentary expression of the third eyelid, or nictitating membrane, well represented in birds and many other vertebrates.

1. Structure of the conjunctiva.—Over the tarsal plates the highly vascular palpebral conjunctiva is bound down closely by a thin lamina of tunica propria, while beyond the convex attached borders of the tarsi the mucous membrane becomes loose and folded (fig. 898). In the vicinity of the fornices lymphocytes appear and these may even accumulate into small *lymph-nodules* [noduli lymphatici conjunctivales]. In this locality (especially in the upper lid), and also along the attached tarsal borders, small glands occur which have been called the *mucosal glands* (of Krause) [glandulæ mucosæ], or accessory lacrimal glands (fig. 898). Passing onto the scleral surface of the eyeball, the mucosa is smooth but still freely movable; here it is thin and transparent, the meager blood-vessels being visible in life. Near the corneal margin the conjunctiva becomes reduced to its epithelial component alone which adheres closely to the anterior corneal surface (fig. 871). The epithelium near the margins of the lids and over the cornea is of the stratified squamous type; elsewhere it is stratified columnar.

2. Vessels and nerves.—The *arterial* supply is chiefly from the two arcades of the eyelids, already described. Near the sclerocorneal junction there are anastomoses with branches derived from the anterior ciliary arteries. The *veins* follow the arterial pattern; most drain into palpebral vessels but near the corneal margin the venules pass backward along the rectus muscles. *Lymphatics* converge toward the two palpebral commissures and then follow the course described for the other vessels of the eyelids.

The *nerves* are supplied by the ophthalmic division of the trigeminus through the infratrochlear branch medially and the lacrimal branch laterally (fig. 888).

3. Clinical aspects.—The conjunctival blood-vessels become plainly visible when inflamed (*conjunctivitis*). They are then readily distinguished by their relatively large size, tortuosity, bright red color and movability. The *bulbar conjunctiva* is freely movable and may become highly edematous (*chemosis*). Hemorrhages are easily induced in this location; they spread freely and retain an arterial color, due to the ready penetration of oxygen through the thin mucosal covering. The participation of conjunctival vessels in the fermation of pannus and salmon patches has already been explained (p. 1136). The relative thickness, high vascularity and sensitivity of the *palpebral conjunctiva* have practical significance. To the vascularity is owed the hot, red, tense swelling of purulent ophthalmia. The exquisite suffering in the same disease, or the acute distress caused by a foreign body, is explained by the numerous sensory nerve-endings of this region. To the thickness and abundance of the connective tissue are due the contraction and permanent thickening which may occur in granular lids. The so-called granulations, encountered in this disease on the palpebral conjunctiva, are really enlarged nodules of lymphoid tissue surrounded by fibrous investments. The scar tissue following such a process, or after any other severe inflammation, is apt to lead to a contraction that curls the eyelid inward (*entropion*). When both the bulbar and the palpebral surface of the conjunctiva have been destroyed, as by introduced caustic substances, the lid will fuse to the eyeball to produce the condition designated *symblepharon*.

G. The Lacrimal Apparatus

The tears are secreted by the **lacrimal gland** through fine excretory ducts which empty into the conjunctival sac. Thence the fluid flows across the exposed

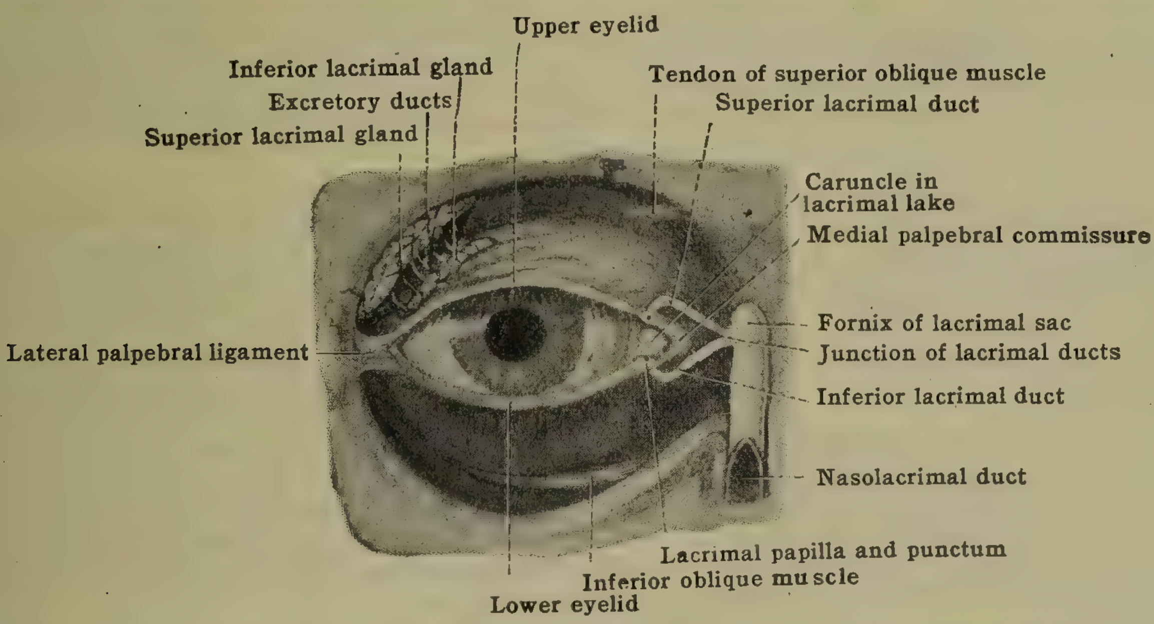


Fig. 900.—Dissection of the Right Orbit to Show the Lacrimal Apparatus in Front View. Natural Size.

eyeball to the inner angle of the eye, where it is drained off through **lacrimal ducts** into the **lacrimal sac** and finally reaches the nose by way of the **nasolacrimal duct**.

1. The lacrimal gland.—This gland consists of two unequal parts, imperfectly separated by the tendinous expansion of the levator palpebræ superioris muscle

and without a very definite capsule (figs. 899, 900, 901). The upper and larger subdivision, the **superior lacrimal gland** [glandula lacrimalis superior] (pars orbitalis NK), is situated on the roof of the orbit, laterally and near the front. It occupies a shallow depression, or *fossa of the lacrimal gland* [fossa glandulæ lacrimalis], in the orbital plate of the frontal bone and lies parallel with the orbital margin. The superior gland is a firm, almond-shaped body, about 20 mm. long and 12 mm. wide. Fibrous tissue connects its convex border to the orbital periosteum, while below it rests upon an arch of fascia between the sheaths of the superior and lateral rectus muscles.

The **inferior lacrimal gland** [glandula lacrimalis inferior] (pars palpebralis NK), one-third as large and with more loosely arranged lobules, lies below and in front of the major gland. It overlies the lateral third of the upper conjunctival fornix and, projecting into the upper eyelid, can be seen in the living subject when the eye is directed downward and the lid is drawn back. *Accessory lacrimal glands* [gl. lacrimales accessoriæ] are numerous at the conjunctival fornices and in the eyelids (p. 1163).

Structure of the lacrimal glands.—The lacrimal glands are compound and of the tubulo-alveolar type; their secretion is a clear, watery fluid, the tears [lacrimæ]. The *excretory ducts* [ductuli excretorii] are fine tubules, between 6 and 12 in number (fig. 900). Those from the superior gland pierce the inferior gland and are joined by some ducts from the latter. There are, however, independent inferior ducts, and all open finally into the conjunctival sac along a line just in front of the fornix (fig. 901).

Vessels and nerves.—The lacrimal *artery*, a branch of the ophthalmic, and the infraorbital branch of the internal maxillary artery supply blood to the gland (fig. 887). The lacrimal *vein* becomes tributary to the ophthalmic vein (fig. 887). *Lymphatics* are probably superficial and drain into the preauricular lymph glands.

The *nerve-supply* is from the lacrimal ramus of the ophthalmic division of the trigeminus, and also from the facial nerve and sympathetic system (fig. 888).

Clinical aspects.—The lacrimal gland rarely inflames but sometimes becomes the seat of a mixed tumor. In either event the enlargement may displace the eyeball downward and forward. An abscessed gland most commonly ruptures through the upper lid. Obstruction of the excretory ducts can lead to the formation of cysts. Any irritation of the ophthalmic nerve induces lacrimation.

2. The lacrimal ducts.—Winking movements of the eyelids distribute the tear secretion over the surface of the eye and tend to collect it in the lacrimal lake. The lacrimal passages commence at the *puncta lacrimalia*, upper and lower, each situated at the top of its respective *papilla* [papilla lacrimalis] on the margin of the upper or lower eyelid, as already mentioned (p. 1159; fig. 897). The tips of both papillæ point into the conjunctival sac, so that the puncta are well situated for receiving fluid accumulating there. The *lacrimal ducts* [ductus lacrimales] (ductuli lacr. NK) themselves continue as small tubes about 10 mm. long from the puncta medially within the margins of the eyelids, thus paralleling the borders of the lacrimal lake (figs. 890, 900). At the medial angle of the eye the two ducts open close together into the lacrimal sac; sometimes they unite into a short, common stem before joining the sac.

The inferior lacrimal duct is slightly longer than its fellow, since the larger, inferior papilla is located farther laterally; similarly, the lower punctum is larger, whereas both are oval apertures with lips somewhat compressed anteroposteriorly. From its point of origin each duct first runs vertically upward or downward for a short distance and then bends sharply nasalward, converging slightly toward its mate to reach the lacrimal sac (fig. 900). The lumen measures 0.2 mm. at the punctum, expands into an *ampulla* [ampulla ductus lacrimalis] of 1 mm. diameter at the bend, and continues at a nearly uniform calibre of 0.5 mm. throughout the horizontal portion (fig. 901).

Structure of the lacrimal ducts.—The wall of each duct consists of elastic and white fibrous tissue, lined internally with stratified squamous epithelium and covered externally by striated muscle fibers from the orbicularis oculi. The muscle fibers lie parallel with the duct in the horizontal part of its course but they encircle the vertical segment as a sort of sphincter. Just before terminating, the ducts pierce the periosteal thickening that constitutes the posterior limb of the medial palpebral ligament.

3. The lacrimal sac.—This portion of the lacrimal passages receives the lacrimal ducts laterally above its middle and merges below into the nasolacrimal duct, of which it is really the upper, slightly dilated extremity (figs. 890, 900). The *lacrimal sac* [saccus lacrimalis] is a short tube, sometimes constricting perceptibly at the lower end. Since it lies in a vertical depression on the anterior medial wall of the orbit, known as the *fossa of the lacrimal sac* [fossa sacci lacrimalis], the shape of the sac is adjusted to this shallow groove. Accordingly, the lateral wall

slopes upward toward the medial wall; this progressive compression gives a tapered, bluntly triangular contour in front view, the sac ending in a blind *fundus* [fornix sacci lacrimalis] (fig. 890).

Structure of the lacrimal sac.—The lacrimal sac measures about 12 mm. in length and 6 mm. by 3 mm. in diameter. Just medial to its fossa are the anterior ethmoidal air cells. The orbital periosteum lines the fossa while a fascial continuation covers completely the lateral surface of the sac (fig. 884). However, there is loose connective tissue and a venous plexus between this fascial investment and the true wall of the sac. The upper anterior half of the lacrimal sac is covered completely by the medial palpebral ligament; posteriorly there is the thin reflected limb of the same ligament and then the pars lacrimalis of the orbicularis muscle. The wall of the lacrimal sac consists of fibro-elastic tissue, infiltrated with lymphoid tissue and lined with pseudostratified (but incompletely ciliated) epithelium.

4. The nasolacrimal duct.—A terminal duct completes the lacrimal passages by extending from the lower end of the lacrimal sac to the nose where it opens under cover of the inferior concha (fig. 890). The *nasolacrimal duct* [ductus nasolacrimalis] lies within the bony *nasolacrimal canal* [canalis nasolacrimalis] whose main direction, traced from above, is downward, but also with a slight inclination backward and laterally; just lateral to the canal is the maxillary sinus (fig. 890). The duct does not usually open directly into the nasal

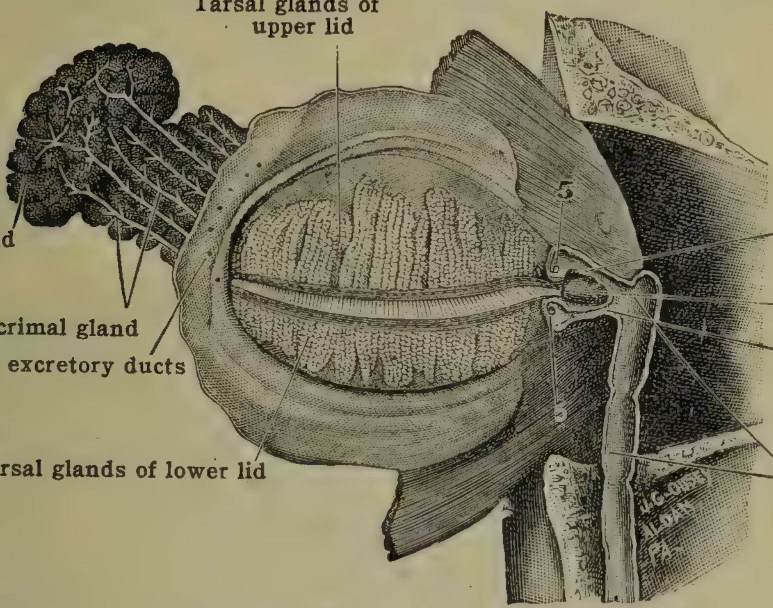


Fig. 901.—Dissection of the Left Eyelids and Lacrimal Apparatus, Viewed from Behind. Natural Size. (After Fox.)

cavity at the lower end of the bony canal, but extends for a short distance beneath the nasal mucosa, piercing the latter very obliquely; as a result of this mode of entrance a flap of mucous membrane, the *plica lacrimalis* (of Hasner), often guards the slit-like opening (fig. 890).

The nasolacrimal duct varies in length according to the position of the lower opening but averages about 17 mm. Its shape is that of a cylinder, whose diameter is 4 mm., and there is merely a slight constriction at its junction with the lacrimal sac. The opening of the nasolacrimal duct into the inferior meatus of the nose is located about 35 mm. from the posterior margin of the nostril, or one-fourth the way back in the meatus (fig. 1043). The mucosa of the duct is thrown into folds in certain locations; although inconstant, some of these have been interpreted as valves. The structure of the duct and its relation to the bony canal are similar to those of the lacrimal sac already described.

Vessels and nerves of the lacrimal passages.—The *arteries* are branches of the ophthalmic and the external and internal maxillary arteries. The *veins* are tributaries of the facial and internal maxillary vessels. *Lymphatics* mostly reach the submaxillary lymph glands but some from the lower part of the duct find the retropharyngeal and deep cervical glands.

The *nerves* come from the ophthalmic division of the trigeminus; in addition, the lower duct receives a twig from the maxillary division of the same nerve.

Clinical aspects.—Overflow of tears (*epiphora*) is produced mainly either by an obstruction somewhere in the lacrimal passages (commonest at the narrowed junction of the lacrimal sac and nasolacrimal duct) or by the removal of the lower punctum from contact with the eyeball for any cause (*e.g.*, inturned, out-turned or swollen lid; facial paralysis). Inflammation ascends readily from the nose to the lacrimal sac, and collecting pus usually locates there. An abscessed sac, when ready to discharge, always points below the medial palpebral ligament where the wall is weakest; at this level the draining incision is made. When blockage of the nasolacrimal duct is suspected, a probe can easily be passed downward from the sac, even though the lumen be normally closed and though there be several folds that can arrest the progress of the probe. The course of the duct is followed when the probe is directed toward the

site of the first molar tooth. The nasolacrimal duct frequently is congenitally obstructed, but the stenosed region is usually membranous and can be perforated by a probe.

DEVELOPMENT OF THE EYE

The eye differentiates partly from ectoderm and partly from mesoderm. The retina and optic nerve develop from an evaginated portion of the ectodermal wall of the forebrain on each side, while the lens comes from the superficial ectoderm of the head. On the other hand, the sclera, cornea (except epithelium) and vascular coat are all secondary acquisitions from the nearby mesoderm. The main steps of development may be followed in the stages shown in fig. 902.

In embryos of 3 mm., during the fifth week of development, a swollen outgrowth bulges from the ventrolateral wall of the forebrain on each side. Each takes the shape of a hollow sacculation and accordingly is named the *primary optic vesicle* (fig. 902A). The main portion of the vesicle continues to expand, while its connection with the brain, the *optic stalk*, remains slender (B) and is finally converted into the optic nerve (D, E). The optic vesicle presently

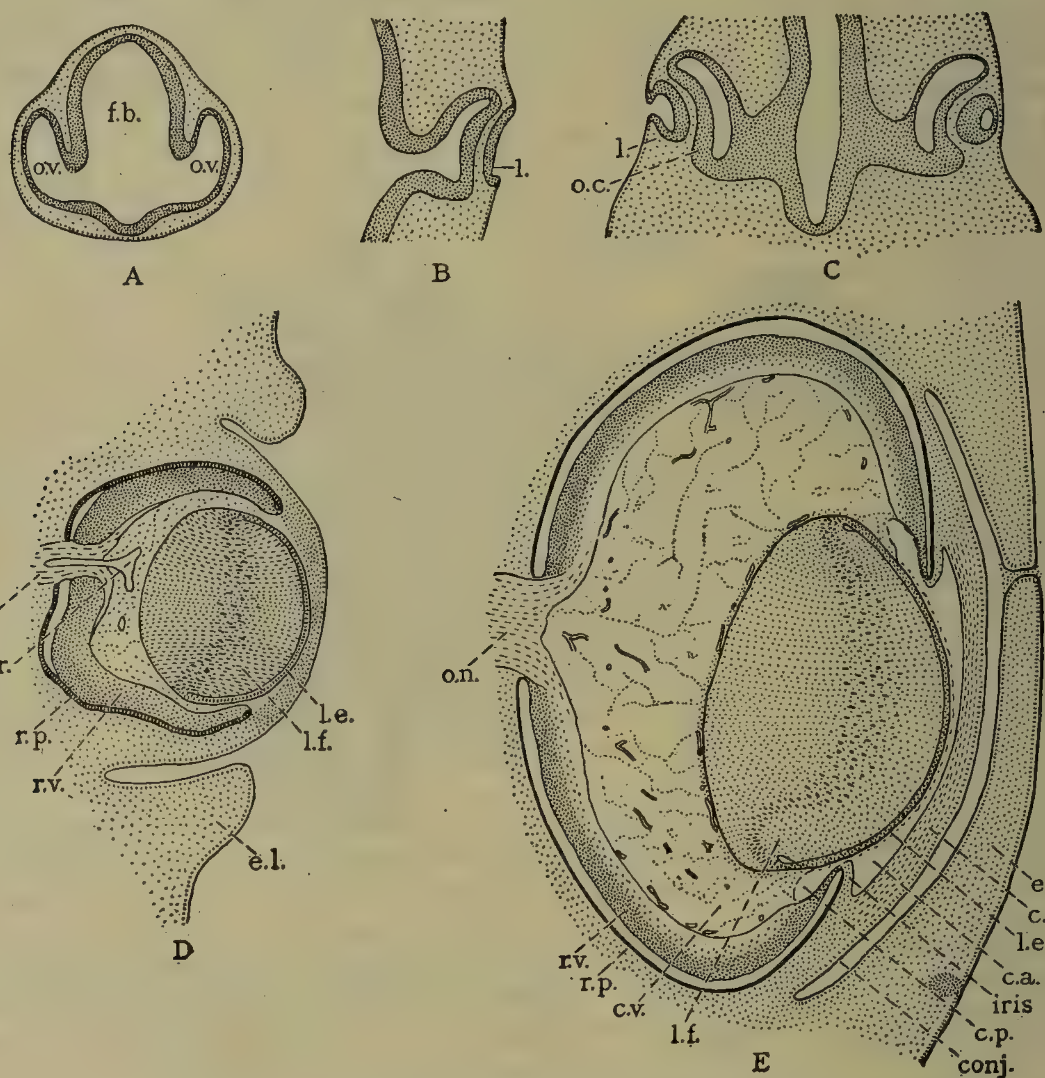


Fig. 902.—Sections Showing the Development of the Eye in Rabbit Embryos. (Lewis.) A, at 3 mm.; B, at 5.4 mm.; C, at 5 mm.; D, at 12 mm.; E, at 29 mm.

a.c.r., Central artery of retina; *c.*, cornea; *c.a.*, anterior chamber; *conj.*, conjunctiva; *c.p.*, posterior chamber; *c.v.*, corpus vitreum; *e.l.*, eyelid; *f.b.*, forebrain; *l*, lens; *l.e.*, lens epithelium; *l.f.*, lens fibers; *o.c.*, optic cup; *o.n.*, optic nerve; *o.v.*, optic vesicle; *r.p.*, pigment layer of retina; *r.v.*, nervous layer of retina.

invaginates on its superficial, unattached surface to form a double-walled structure, the secondary optic vesicle or *optic cup* (B, C). From it differentiates the whole of the nervous, or *retinal tunic*. This tunic is necessarily composed of two layers, with a narrow slit-like interval between them, but the layers are continuous with each other at the margin of the cup (D, E). In the fully developed eye this margin is found at the pupillary border of the iris. The outer wall of the optic cup becomes the permanent *pigment layer*, while the inner, infolded wall gives rise to the *nervous layer* of the eye—both the pars optica over the bottom of the cup, and its insensitive extension as the pars ciliaris in the ciliary region and the pars iridica near the pupillary margin of the original cup (E). The nervous layer rapidly thickens and differentiates into the neuroepithelial sensory cells and the nerve cells proper. From the innermost ganglion cells, *optic nerve fibers* grow back through the optic stalk to the brain.

A temporary *chorioid fissure* is present almost from the first stages as a groove on the ventral aspect of both the optic cup and stalk; it is formed by a longitudinal infolding of the wall. In this cleft is found vascular mesoderm passing to the hollow of the optic cup. The margins of the fissure soon meet and fuse, at the same time enclosing the vessels to the interior of the eye; in this manner the central artery of the retina comes to lie within the optic nerve and the hyaloid artery courses through the interior of the vitreous body to the lens (D).

The *lens* is originally a simple thickening of the surface ectoderm, opposite the hollow of the optic cup (B). By invagination a purse-shaped sac is formed whose margins meet and fuse to enclose a cavity (C). This lens vesicle, sinking in more deeply, then loses its connection with the surface, and a layer of mesoderm grows in between. The outer layer of the vesicle remains as the *lens epithelium*, but the inner layer thickens greatly and its cells transform into *lens fibers* (D, E). Although the lens and the primitive retina are for a short time in contact with each other they gradually draw apart, and the intervening space is filled by the *vitreous body* (E). The origin of the vitreous is disputed, but it appears to be developed primarily from the adjacent ectoderm of the optic cup even though the surrounding mesoderm contributes as well.

The optic cup and the lens are from the first surrounded by mesoderm, and from it come the vascular and fibrous tunics. The *tunica vasculosa* includes the *chorioid, ciliary body* and *iris*. The *tunica fibrosa* becomes the *sclera* and *cornea* (except the corneal epithelium).

The *anterior* and *posterior chambers* arise through cleavage of the mesoderm subjacent to the cornea, simple spaces first appearing which then fill with aqueous fluid (E). The early mesoderm also organizes into a vascular covering about the lens, termed the *vascular tunic of the lens;* the portion in front of the lens (*i.e.*, the pupillary membrane) persists longest but even this disappears from the surface of the lens in the later fetal months.

The *eyelids* and *conjunctiva* are specializations of the integumentary covering of the eye. The former are folds of the skin which meet and fuse with one another, only to separate again late in fetal life (D, E). The *lacrimal gland* is developed from a series of outgrowths from the conjunctival sac.

The lacrimal passages result from the hollowing of an ectodermal band which sinks into the mesoderm along the nasolacrimal groove; the latter extends along the line of union of the lateral nasal and maxillary processes. This cord (the *lacrimal sac* and *nasolacrimal duct*) loses its primitive connection with the groove and is reunited to the lid margins by secondary epithelial buds (the *lacrimal ducts*) which grow into the margins of the lids. Similarly, a secondary connection is later made with the nasal cavity at the lower end of the duct.

THE EAR

The organ known as the **ear** [organon auditus] (organon status et auditus NK) is really a compound organ which not only is sensitive to sound waves but also

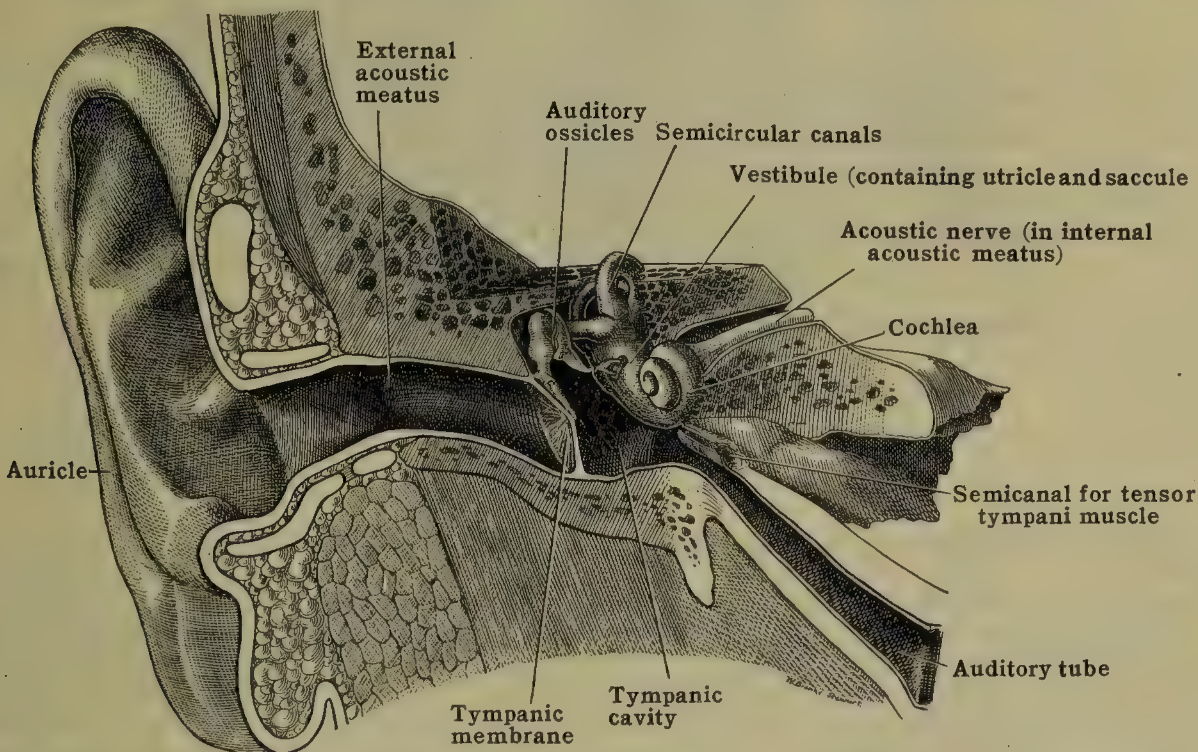


Fig. 903.—Dissection of the Right Ear, Anterior Half Removed. Natural Size.

enables the effects of gravity and the movements of the head or body to be appreciated. The auditory organ consists of three main parts, each possessing distinct structural and functional characters (fig. 903).

1. The first portion, often known as the **external ear**, is subdivided into: (*a*) a sound-collecting organ placed upon the surface of the head, the *auricle* (or pinna); and (*b*) a short conducting tube, the *external acoustic meatus*, which leads toward the interior and is closed at its deep end by the tympanic membrane.

2. The second component is the **middle ear.** It is represented chiefly by the *tympanic cavity*, which is a small, air-containing chamber in the petrous portion of the temporal bone, connected with the nasal part of the pharynx by a canal known as the *auditory* (or Eustachian) *tube.* From the tympanic chamber a recess passes posteriorly and leads to a cavity in the mastoid portion of the temporal bone, the *tympanic* (or mastoid) *antrum.* A chain of three small *ear*

bones transmits across the middle ear the vibrational effects produced by sound waves on the tympanic membrane.

3. The third part, or **internal ear** [auris interna], contains the essential sensory apparatus and is extremely irregular in shape. It consists of membranous sacs and ducts, the *membranous labyrinth,* which lie within those intricate cavities in the interior of the petrous temporal bone designated as the *osseous labyrinth.* The internal ear includes: (*a*) the *utricle* and *saccule,* two small vesicular structures contained within the bony *vestibule;* (*b*) the membranous *semicircular ducts,* surrounded by corresponding bony *semicircular canals;* and (*c*) the membranous *cochlear duct,* similar in general shape to the snail-like bony *cochlea* encasing it. Of these several parts, the semicircular ducts, utricle and saccule are concerned with the static or equilibratory sense while the cochlea is specialized for hearing.

I. THE EXTERNAL EAR

The external ear consists of the **auricle,** attached to the side of the head, and the **external acoustic meatus** leading from it to the middle ear (fig. 906).

A. The Auricle

The **auricle** [auricula], or pinna, is an oval, plate-like structure which lies upon the side of the head. It presents a lateral and a medial surface. The lateral

Fig. 904.—Lateral Surface of the Left Auricle. Natural Size.

surface is irregularly concave and the medial surface correspondingly convex (figs. 904, 905). The deepest part of its concavity, situated near the center, is termed the *concha auriculæ;* this is partially divided by a prominent oblique ridge (the crus of the helix) into a superior part, the *cymba conchæ,* and a large inferior part, the *cavum conchæ.* The latter cavity leads into the external acoustic meatus.

The cavum conchæ is bounded anteriorly by a prominent process, the *tragus,* which projects posteriorly over the entrance to the meatus. The tragus is separated from the crus of the helix by a well-marked depression, the *anterior incisure* [incisura anterior], and sometimes bears a small *supertragic tubercle* [tuberculum supertragicum] superiorly. Bounding the cavum conchæ posteriorly and inferiorly is a projection, the *antitragus,* lying opposite but inferior to the tragus, and between the two is a deep notch, the *intertragic incisure* [incisura intertragica]. A prominent semicircular ridge, the *anthelix,* bounds the concha posteriorly and superiorly. Inferiorly it is separated from the antitragus by a slight depression, the *posterior auricular sulcus* [sulcus auriculæ posterior]. Superiorly the anthelix divides into two ridges, the *crura of the anthelix* [crura anthelicis], and between these is a shallow depression, the *triangular fossa* [fossa triangularis]. The superior and posterior margin of the auricle is inverted and forms a prominent rim, the *helix,* which is continued anteriorly into the *crus of the helix* [crus helicis] and inferiorly into the *lobule* [lobulus auriculæ]. An elongate depression, partly overlapped by the helix and termed the *scapha,* separates the helix from the anthelix. Superiorly and posteriorly the free margin of the helix frequently presents a slight projection, the *auricular tubercle* (of Darwin) [tuberculum auriculæ], which is thought to correspond to the apex of the ear in lower mammals.

Upon the medial surface of the auricle the depressions of the lateral surface are represented by complementary elevations, namely (figs. 905 B, 907): the *eminence of the concha* [eminentia conchæ], the *eminence of the scapha* [eminentia scaphæ], and the *eminence of the triangular fossa* [eminentia fossæ triangularis]. Similarly, the lateral elevations become depressed areas on the medial surface, namely: the *fossa of the anthelix* [fossa anthelicis], the *transverse sulcus of the anthelix* [sulcus anthelicis transversus], and the *sulcus of the crus of the helix* [sulcus cruris helicis]. The attachment of approximately one-third of the medial surface to the head covers and hides the two latter depressions. The *cephaloauricular angle*, between the posterior free part of the auricle and the side of the head, averages about 25 degrees.

1. Structure of the auricle.—The features of the auricle just described are mainly produced by an internal plate of yellow elastic cartilage, the *auricular cartilage* [cartilago auriculæ]. Besides the elevations and depressions already noted, it presents the following additional parts (fig. 905). Projecting anteriorly from the helix, near the crus, is a small tubercle, the *spine of the helix* [spina helicis]. At the other end the posterior margin of the helix terminates in a pointed, tail-like process, the *cauda helicis*, which is separated inferiorly from the antitragus by the deep *antitragohelicine fissure* [fissura antitragohelicina]. Another deep notch, the *terminal incisure* [incisura terminalis auris], separates the cartilage of the auricle from that of the meatus, leaving only a narrow strip, the *isthmus* [isthmus cartilaginis auris], connecting the two. The cartilage of the tragus, the *lamina tragi*, is separated from that of the auricle proper and is attached to the lateral margin of the cartilage of the meatus.

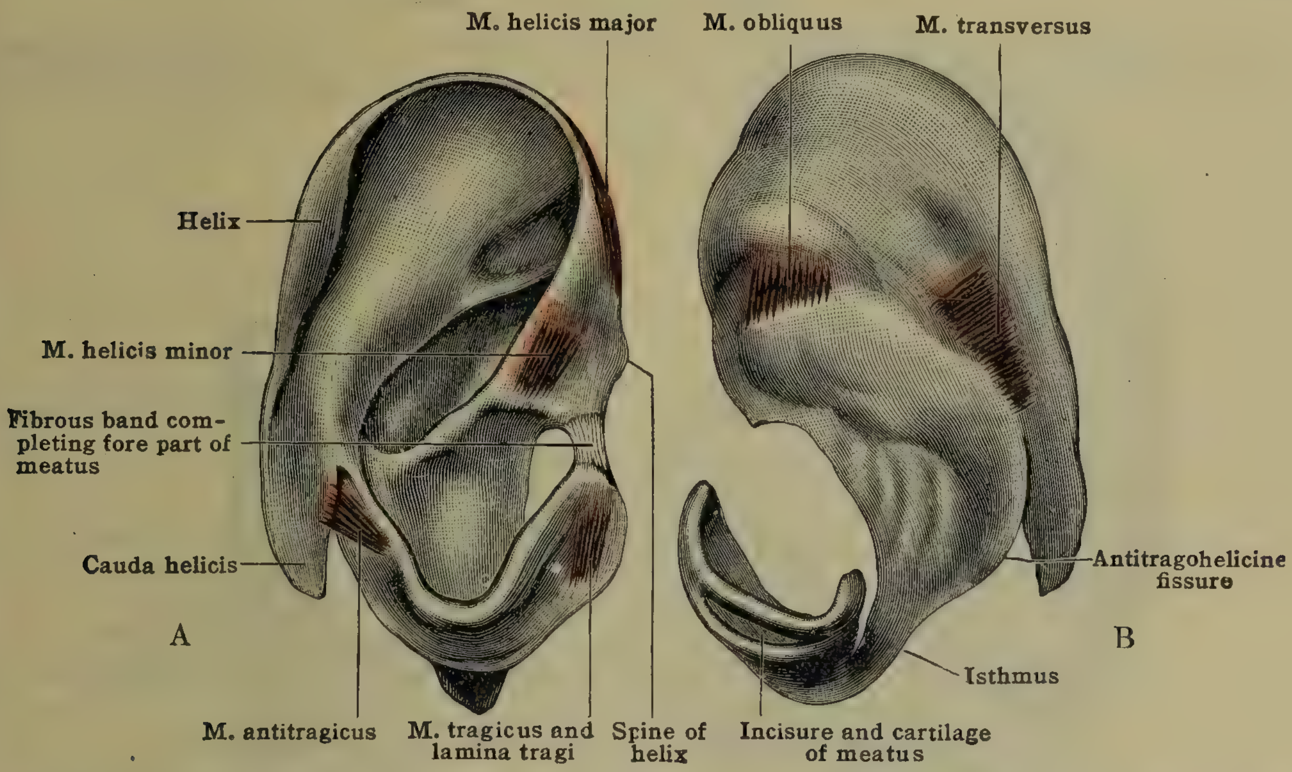


Fig. 905.—The Cartilage and Intrinsic Muscles of the Right Auricle. Natural Size. A. Lateral surface; B. medial surface.

The auricle is covered on both its medial and lateral aspects by skin which closely follows the irregularities of the cartilage. Thus it is tightly bound to the perichondrium of the lateral surface by subcutaneous areolar tissue, but is much more loosely attached to the medial surface. In the subcutaneous tissue there is little fat, except in the lobule which is made up almost entirely of fat and tough fibrous tissue. *Hairs* are abundant but rudimentary, except in the region of the tragus and antitragus; here they may be large and long, particularly in males and in the aged. *Sebaceous glands* are found on both surfaces, and are especially well developed in the concha and triangular fossa, but *sudoriferous glands* are few and scattered.

2. Ligaments and muscles.—The auricle is attached to the side of the head by the skin, by the continuity of its cartilage with that of the acoustic meatus, and by certain extrinsic ligaments and muscles. Three extrinsic ligaments may be identified in the connective tissue: (*a*) the *anterior ligament* [lig. auriculare anterius], stretching from the zygoma to the helix and tragus; (*b*) the *superior ligament* [lig. auriculare superius], from the superior margin of the bony external acoustic meatus to the spine of the helix; and (*c*) the *posterior ligament* [lig. auriculare posterius], from the mastoid process to the eminence of the concha. There are also three extrinsic muscles—the *anterior, superior*, and *posterior auricular* (fig. 403). Six intrinsic muscles are distinguished, but these are poorly represented in man and vary much in degree of development. Upon the lateral surface (fig. 905 A) the *musculus helicis major* stretches from the spine of the helix to the anterosuperior margin of the helix; the *m. helicis minor* overlies the crus of the helix; the *m. tragicus* runs vertically upon the tragus; and the *m. antitragicus* stretches from antitragus to cauda helicis. Upon the medial surface (fig. 905 B) the *m. transversus auriculæ* stretches between the eminences of the concha and scapha, and the *m. obliquus auriculæ* between the eminences of the concha and triangular fossa. Two additional small muscles occasionally present are the *m. pyramidalis auriculæ* (of Jung) and the *m. incisuræ helicis* (of Santorini).

3. Vessels and nerves.—The *arteries* are branches of the posterior auricular (fig. 524) and superficial temporal vessels (fig. 537)—both subdivisions of the external carotid artery. The

veins are the anterior auricular tributaries of the temporal vein and the auricular branches of the posterior auricular vein (fig. 588). The latter vessels sometimes join the transverse sinus through the mastoid emissary vein. The *lymphatics* empty into the neighboring anterior, posterior and inferior auricular lymph glands (figs. 631, 635).

The sensory *nerves* of the auricle are branches of the great auricular and small occipital nerves from the cervical plexus (fig. 823), the auriculotemporal branch of the mandibular nerve (fig. 809), and the auricular branch of the vagus (fig. 813). The muscles are supplied by the temporal and posterior auricular branches of the facial nerve (fig. 809).

4. Variations.—There are many variations in the size, shape and configuration of the auricle and in the cephaloauricular angle. These are associated not only with differences in sex, age and race but also are found in individuals of the same family.

5. Clinical aspects.—Faulty development of the tubercles which normally combine into the auricle occasionally results in supernumerary, tag-like growths just in front of the ear. Imperfect union of these tubercles leaves gaps in the auricle, while a rare congenital fistula that communicates with the pharynx follows defective closure of the first branchial cleft. The thin and closely adherent skin of the auricle is underlaid by meager subcutaneous tissue and fat. This is the reason why frost-bite, which may lead to gangrene, is common in spite of the rich supply of superficially located blood-vessels. Bloody tumors (*hematomata*), caused by extravasations between the perichondrium and cartilage, frequently disfigure the ears of boxers and wrestlers. Recurrence produces the common 'cauliflower ear.'

B. The External Acoustic Meatus

The **external acoustic meatus** [meatus acusticus externus] is the auditory canal which extends from the concha to the tympanic membrane (fig. 906).

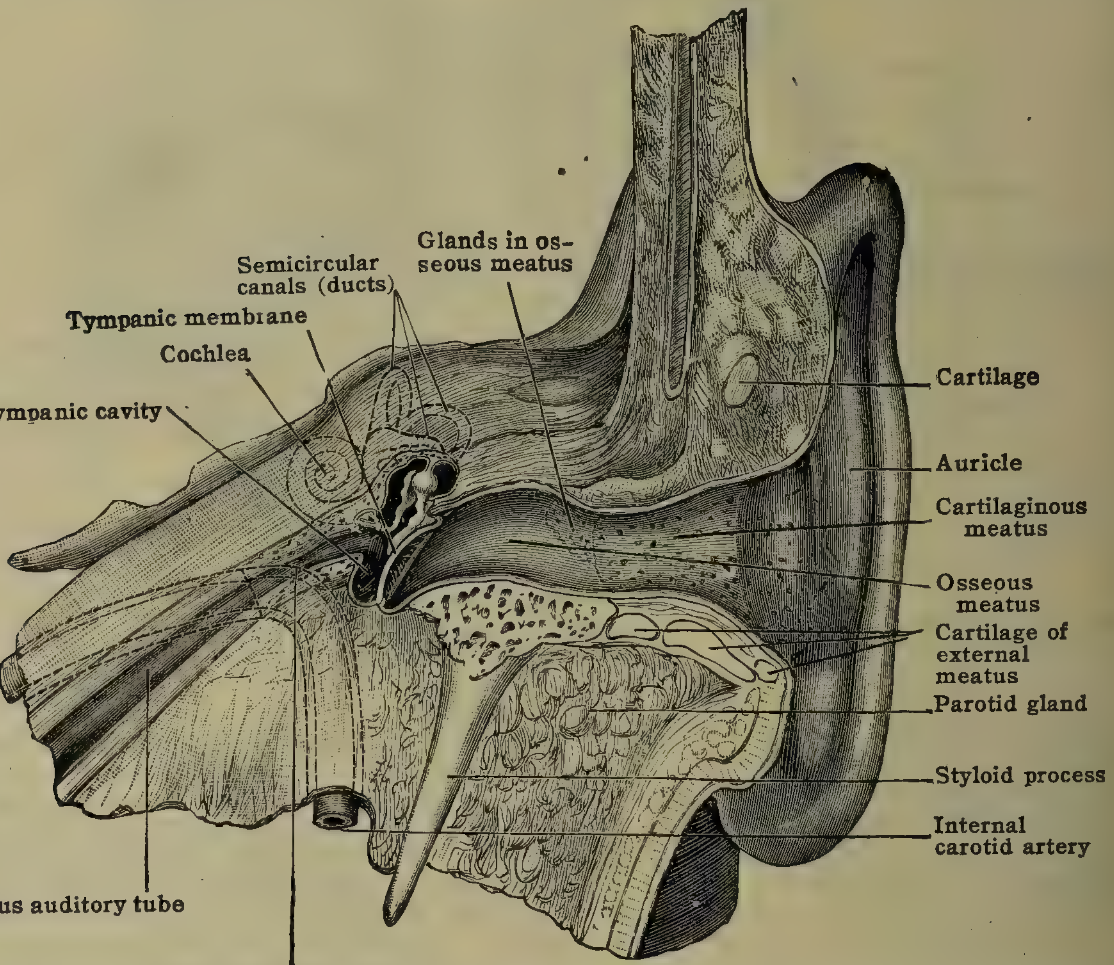


Fig. 906.—Frontal Section through the Left External and Middle Ear, Anterior Half Removed. Slightly Enlarged.

It is about 25 mm. long on the superoposterior wall, whereas, owing to the obliquity of the tympanic membrane, its anteroinferior wall is 6 mm. longer. The canal consists of an outer *cartilaginous meatus* [meatus acusticus externus cartilagineus] and an inner *osseous meatus* [meatus acusticus externus osseus] (figs. 906, 909). The acoustic meatus courses medially in a general anteroinferior direction, and in doing this is slightly tortuous, S-fashion, but not confined to a single plane (fig. 907). Near the auricular end it is convex anteriorly, while at the tympanic end the curve is reversed and is concave in the same direction. The lumen is irregularly elliptical in outline, the longer axis being vertical at the auricular end but nearly horizontal at its tympanic extremity. The meatus is constricted about midway and also near the ear drum.

1. Relations.—The *anterior wall* of the meatus is in relation with the condyle of the mandible medially and with the parotid gland laterally (fig. 909). The *inferior wall* is closely bound to the parotid gland (fig. 908). The *posterior wall* of the bony part is partitioned from the mastoid cells by thin bone only (fig. 909). The *superior wall* is separated at its medial end by a thin plate of bone from the epitympanic recess, while laterally thicker bone intervenes between meatus and cranial cavity (fig. 908).

2. Structure of the meatus.—The walls of the meatus are formed laterally of fibrocartilage and medially of bone, while both parts are lined by skin reflected inward. The *cartilage of the acoustic meatus* [cartilago meatus acustici] takes the shape of a trough open superiorly and posteriorly (fig. 905 B), but the edges are united by dense fibrous tissue so that a tubular canal results. Medially the cartilage constitutes about one-third of the circumference; laterally, two-thirds. Two fissures, the *incisures of the cartilaginous meatus* (of Santorini) [incisuræ cartilaginis meatus] (foramina c.m. NK), usually occur in the anterior wall (fig. 905 B). Laterally the cartilage is directly continuous with the cartilage of the auricle and medially it is connected firmly with the lateral lip of the bony meatus. The osseous portion of the meatus, which comprises slightly more than half the canal, is a tunnel through the temporal bone. The anterior wall, floor, and lower part of the posterior wall are formed by the tympanic component of the temporal bone; the remainder of the posterior wall and the roof are supplied by the squama (fig. 162).

The *skin* of the meatus furnishes a continuous lining for the canal and an external covering for the tympanic membrane. It is relatively thick in the cartilaginous part of the meatus,

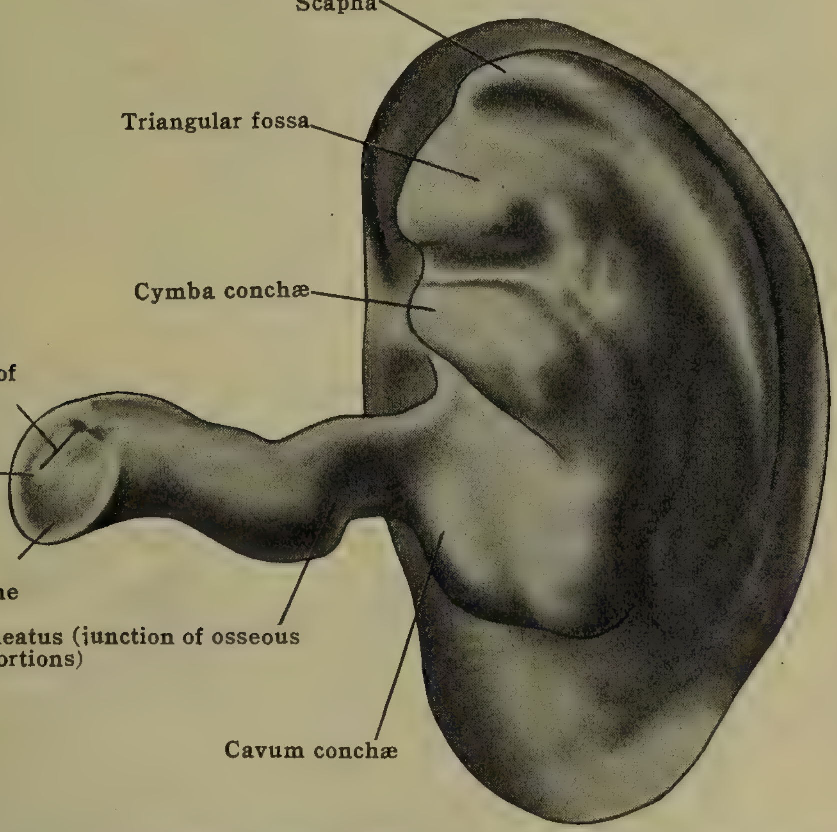


FIG. 907.—CAST OF THE CAVITY OF THE RIGHT AURICLE AND EXTERNAL ACOUSTIC MEATUS, VIEWED FROM ABOVE AND BEHIND. × 1.5.

but very thin in the bony portion, especially near the tympanic end where it is tightly bound to the periosteum (fig. 906). In the cartilaginous meatus the skin contains numerous fine hairs and sebaceous glands, whereas neither is found in the bony meatus. Tubular *ceruminous glands*, which resemble modified sweat glands and secrete the *cerumen* (or ear wax), form a nearly continuous layer throughout the cartilaginous meatus, but occur on only a small part of the posterior and superior walls of the bony canal. The openings of their ducts appear as dark points to the naked eye (fig. 906).

3. Vessels and nerves.—The *arteries* are derived from the external carotid through branches from the posterior auricular, superficial temporal (fig. 533), and deep auricular arteries (fig. 531). The *veins* (fig. 588) and *lymphatics* (figs. 632, 635) connect with those of the auricle and empty similarly. The *nerves* are sensory branches from the auriculotemporal ramus of the mandibular nerve (fig. 809) and from the auricular ramus of the vagus (fig. 813).

Clinical aspects.—It is useful to remember that the external acoustic meatus, promontory, cochlea and internal acoustic meatus are situated nearly in line. In examinations of the ear the natural bend of the external meatus is straightened by drawing the auricle upward and a little outward and backward. The firm union of the skin to the cartilage or bone of the auricle and meatus allows septic inflammation to give rise to severe pain with but little swelling. The inner cartilaginous segment of the external meatus may have painfully abscessed sebaceous glands, while its ceruminous glands sometimes plug the ear with wax. The fissures in the cartilaginous support of the meatal floor permit an abscess to break through from the nearby parotid gland. The extraction of foreign bodies occasionally offers great difficulty, especially if they locate beyond the constricted middle of the meatus; this is chiefly because the sloping tympanic membrane forms a recess with the floor of the external meatus in which small objects tend to lodge. The auricular branch of the vagus nerve supplies the posterior wall of the external ear and has relations centrally with the vagal nuclei; this explains why foreign bodies or

even the introduction of instruments can induce such responses as coughing or vomiting. Similarly, the presence of the auriculotemporal branch of the trigeminus explains why earache may accompany a diseased condition of the tongue or lower teeth.

II. THE MIDDLE EAR

Under the term **middle ear** there are included the **tympanic cavity,** the **tympanic antrum** and the **auditory** (Eustachian) **tube** (figs. 903, 914). These constitute a continuous irregular passage, filled with air and located for the most part within the temporal bone. The middle ear cavity is shut off from the external ear by the **tympanic membrane,** and from the chamber which forms the internal ear by the structures which occupy the cochlear and vestibular windows. It communicates with the pharynx by the auditory tube and leads backward through the antrum to the mastoid cells (fig. 914). The structures of the middle ear are

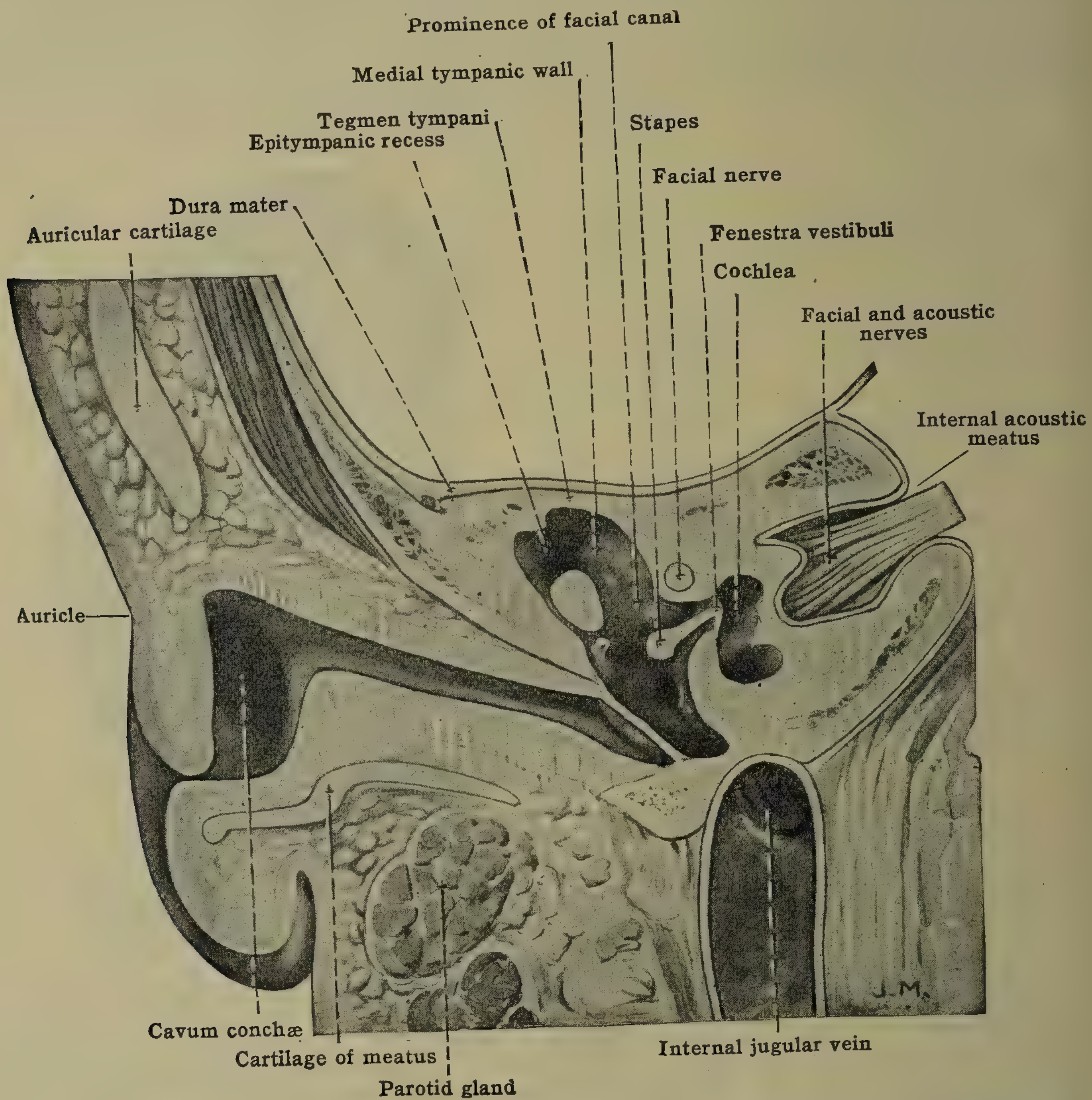


FIG. 908.—FRONTAL SECTION THROUGH THE RIGHT EAR, ANTERIOR HALF REMOVED. × ABOUT 2.

of importance, but their study is somewhat difficult on account of their small size, the depth at which they lie, and the hard character of the surrounding bone.

The parts to be considered in order are the tympanic membrane, the tympanic cavity and its contents, the tympanic antrum, and the auditory tube.

A. THE TYMPANIC MEMBRANE

The **tympanic membrane** [membrana tympani], or ear drum, serves as a common membranous partition between the external acoustic meatus and the tympanic cavity; thus it furnishes a medial wall for the one and a lateral wall for the other (figs. 903, 910, 913). The membrane is a thin, semitransparent disk, elliptical in shape. Its long axis is nearly vertical, measuring 9 to 10 mm.; the least diameter is 8 to 9 mm. Set obliquely, the membrane slopes medially from the posterosuperior to the anteroinferior wall of the auditory meatus (figs.

908, 909). The angle formed with the superior wall is usually 140 degrees, but the membrane varies greatly in form, size and obliquity. It is slightly concave on its external aspect; this is through traction from the manubrium of the malleus (the outermost of the three small ear bones) which is firmly attached to the inner, or medial surface (fig. 906).

FIG. 909.—HORIZONTAL SECTION THROUGH THE RIGHT EAR, LOWER HALF REMOVED. × 1.5.

The most depressed point, the *umbo membranæ tympani*, is slightly inferior and posterior to the center of the membrane and corresponds to the tip of the manubrium (figs. 907, 910, 911). From here a whitish streak, the *malleolar stria* [stria malleolaris], caused by the manubrium shining through, is seen in an external view passing toward the superior margin. At the superior end of the stria is a slight projection, the *malleolar prominence* [prominentia malleolaris], formed by the lateral process of the malleus (fig. 910). From it the *anterior* and the *posterior*

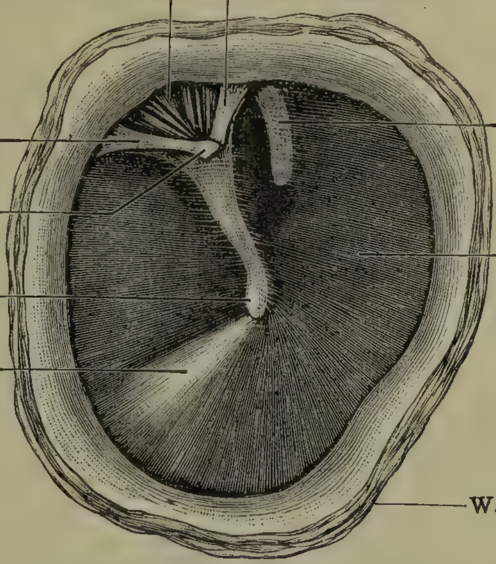


FIG. 910.—LATERAL SURFACE OF THE LEFT TYMPANIC MEMBRANE. × 4.

malleolar fold [plica malleolaris anterior et posterior] (plica chordæ tympani NK) stretch to the respective extremities of the tympanic sulcus of the temporal bone. The small, triangular area of the membrane bounded by the plicæ is termed the *flaccid portion* [pars flaccida], or Shrapnell's membrane. It is thin and lax, and is attached directly to the petrous bone at the *tympanic notch* (of Rivinus) [incisura tympanica]. The larger part of the tympanic membrane, the *tense portion* [pars tensa], is inferior to the plicæ and is tightly stretched. Its thickened *border* [limbus membranæ tympani] is attached by a *fibrocartilaginous ring* [annulus fibrocartilagineus] to the

tympanic sulcus of the temporal bone (fig. 911), while at the terminal spines of the sulcus-bearing tympanic ring the limbus is continuous with the plicæ.

1. **Structure of the tympanic membrane.**—The tympanic membrane is about 0.1 mm. thick and consists of four sheet-like lamellæ: (*a*) The lateral surface is covered by a *cutaneous layer* [stratum cutaneum], which is merely a thin continuation of the skin lining the external auditory meatus. (*b*) Next deeper is a *radiate fibrous layer* [stratum radiatum], composed of connective tissue; its fibers are attached to the manubrium of the malleus and radiate outward, finally passing directly into the peripheral fibrocartilaginous ring. (*c*) Still deeper is the *circular fibrous layer* [stratum circulare], which has its fibers arranged concentrically and is best developed near the circumference. These two closely united fibrous layers are not represented in the pars flaccida. (*d*) The *mucous layer* [stratum mucosum], which is a portion of the mucosa of the middle ear cavity, covers the medial surface of the tympanic membrane smoothly except where the embedded manubrium of the malleus causes an elevation.

2. **Vessels and nerves.**—The *arteries* occur in two sets, one on each surface of the tympanic membrane, and the two connect through anastomoses. The cutaneous vessels originate from the deep auricular branch of the internal maxillary artery; the supply to the mucous surface is from the anterior tympanic branch of the internal maxillary and from the stylomastoid branch of the posterior auricular. The *veins* communicate with those of the external meatus and tympanic cavity. *Lymphatics*, like the blood-vessels, are arranged in two communicating sets; they probably drain into lymph-glands in the region of the mastoid process, tragus and auditory tube.

The *nerves* accompany the vessels; they are derived chiefly from the auriculotemporal branch of the mandibular nerve, but these are supplemented by twigs from the auricular branch of the vagus and the tympanic branch of the glossopharyngeus.

3. **Clinical aspects.**—The tympanic membrane can be ruptured by explosive concussions and blows on the ear. The weakest part of the membrane is the pars flaccida which lacks the supporting fibrous layer present elsewhere. Hence the retained products of inflammation which frequently press the tympanic membrane outward sometimes perforate the pars flaccida and escape from the middle ear through the tympanic notch without rupturing the drum proper. It is here also that violent concussions transmitted by the air may cause the tympanic membrane to loosen its attachment. The membrane is poorly elastic and gapes but slightly after injury, so that surgical perforations heal rapidly. The region below the umbo is less vascular and sensitive and does not lie close to important structures, such as the auditory ossicles and chorda tympani nerve located at a higher level. Advantage is taken of this in puncturing the drum (*paracentesis*) to tap the tympanic cavity; the posteroinferior segment is the usual site chosen since this location also provides good drainage. Nevertheless, injury to the stapes, opposite, must be avoided in this procedure.

B. The Tympanic Cavity

The **tympanic cavity** [cavum tympani], or tympanum, is an irregular space within the temporal bone, situated between the external and internal ear. It is lined with mucous membrane and not only contains air, entering from the auditory tube, but also is traversed by a chain of small bones which transmits vibrations from the tympanic membrane across to the labyrinth (fig. 906). The cavity is a flattened cleft which extends in an oblique anteroposterior plane. The longer vertical and anteroposterior diameters measure about 15 mm. each, whereas the transverse dimension varies between 2 mm. at the narrowest region midway to 6 mm. superiorly and 4 mm. inferiorly (fig. 911). Since the bony walls have already been described under the temporal bone (pp. 155–157), the account which follows will apply especially to the appearance in the fresh, unmacerated condition.

It is apparent in fig. 908 that the floor of the tympanic cavity is at the same horizontal plane as the floor of the external meatus and the lower margin of the tympanic membrane. The roof, on the other hand, lies at a much higher level than the upper margin of that membrane. Hence the cavity has been divided into two regions (figs. 911, 913): (1) a lower part, corresponding in vertical extent to the tympanic membrane, constitutes the **tympanic cavity proper**; (2) the upper region, extending above the upper border of the membrane, is known as the **epitympanic recess** [recessus epitympanicus]. It is on the posterior part of this latter chamber that a communication into the *tympanic antrum* [antrum tympanicum] (a. mastoideum NK) is found (fig. 914).

The tympanic cavity proper has the shape of a very short cylinder with concave ends, the outer end being formed by the tympanic membrane and the inner end by the lateral wall of the labyrinth (fig. 911). The epitympanic recess is a definite chamber whose height is about one-third that of the entire tympanic cavity; it overlies somewhat the external acoustic meatus (fig. 908) and contains the head of the malleus and the body and short limb of the incus (figs. 911, 913).

1. **Walls of the tympanic cavity.**—Considered as a whole, the tympanic cavity may be said to be bounded by six not too clearly demarcated walls, facing one another in pairs (figs. 911, 914, 915). These are: (*a*) a roof, or *tegmental wall;*

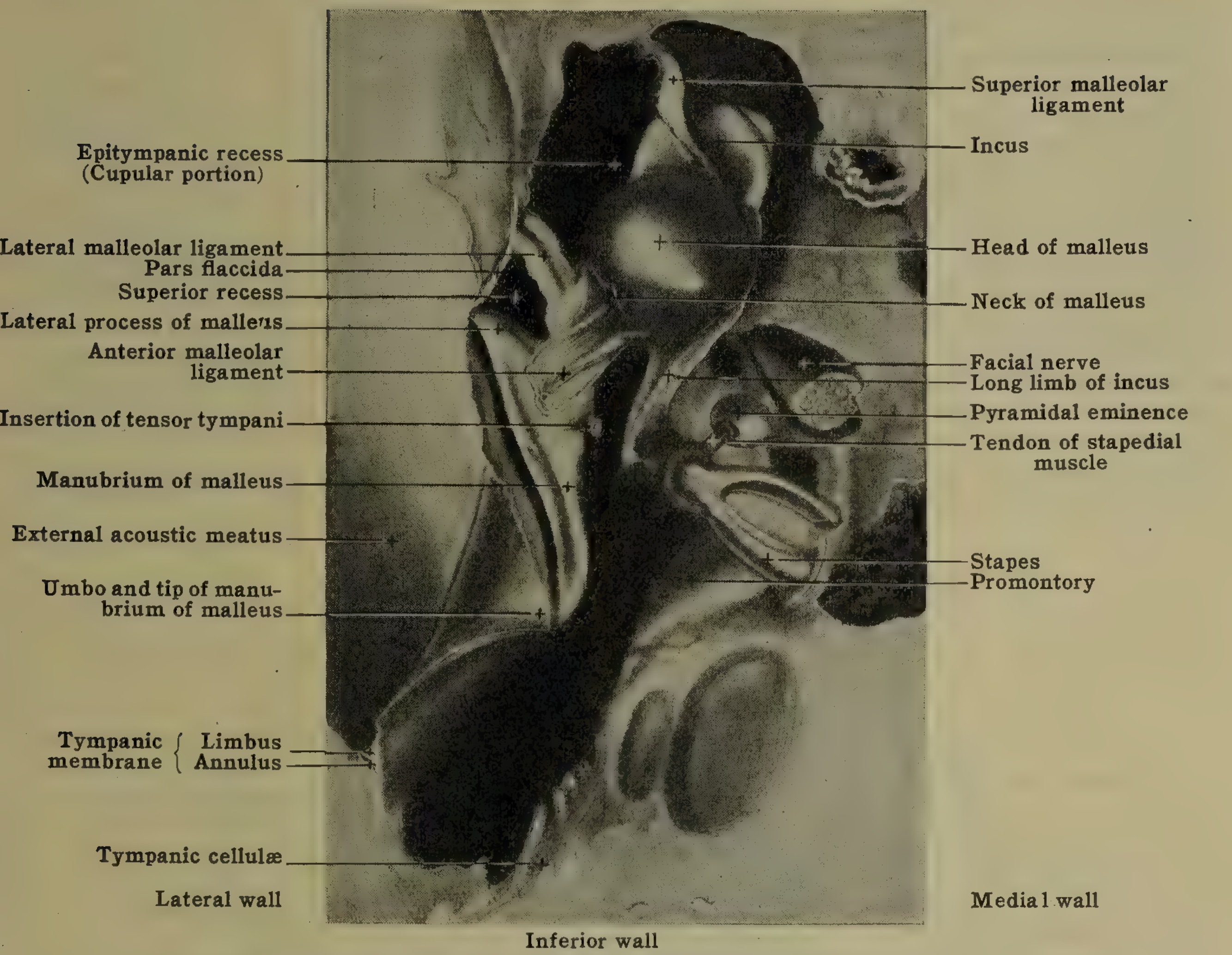


FIG. 911.—FRONTAL SECTION THROUGH THE RIGHT TYMPANIC CAVITY, ANTERIOR WALL REMOVED. × 6.

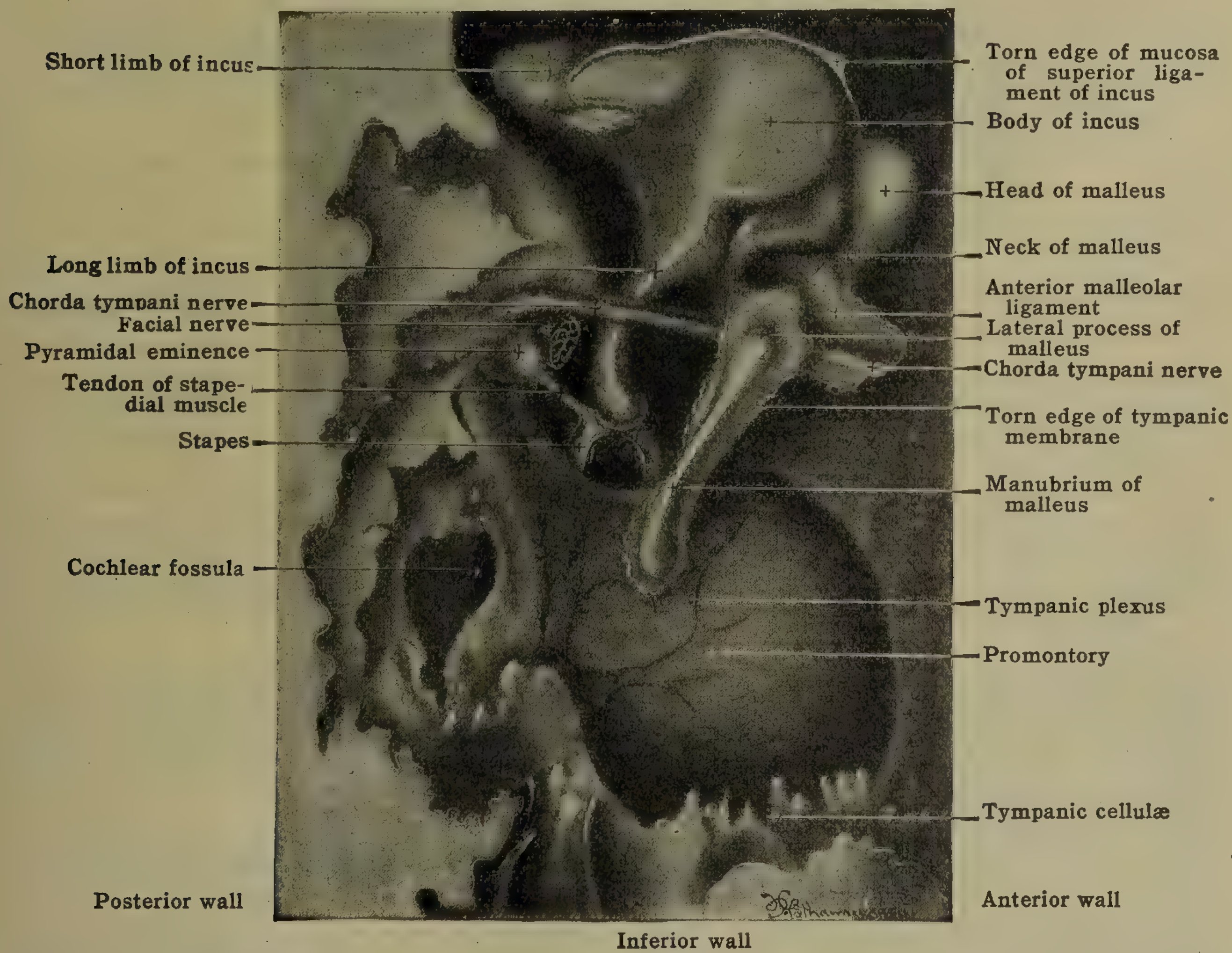


FIG. 912.—THE MEDIAL WALL OF THE RIGHT TYMPANIC CAVITY, WITH THE AUDITORY OSSICLES IN POSITION. × 6.

(*b*) a floor, or *jugular wall;* (*c*) a posterior, or *mastoid wall;* (*d*) an anterior, or *carotid wall;* (*e*) a lateral, or *membranous wall;* (*f*) a median, or *labyrinthine wall.*

a. The roof, or **tegmental wall** [paries tegmentalis], is furnished by a portion of the tegmen tympani, a thin plate of bone which is both continued backward to form the roof of the tympanic antrum and prolonged forward as the roof of the canal for the tensor tympani muscle (figs. 914, 915). This plate is a part of the petrous temporal bone, and at its lateral margin occurs the petrosquamous suture where a slight deficiency in the roof may occur.

b. The floor, or **jugular wall** [paries jugularis], is very narrow transversely and is in intimate relation with the internal jugular vein (fig. 908). As shown in figs. 911, 912, 915, the surface is frequently very irregular from stalagmite-like projections between which are the *tympanic cells* [cellulæ tympanicæ], or air-cells, while near the back there is occasionally a marked *styloid prominence* [prominentia styloidea] corresponding to the root of the styloid process.

c. The posterior, or **mastoid wall** [paries mastoideus] is wider above than at its lower part where there are many additional tympanic air-cells (fig. 912). Higher than these occurs an elevation, the *pyramidal eminence* [eminentia pyramidalis], on whose apex is an aperture transmitting the tendon of the stapedius muscle (figs. 912, 915). The fleshy belly of that muscle is contained in a cavity within the interior of the pyramid itself. Lateral to this is a foramen, the *apertura canaliculæ chordæ,* through which the chorda tympani nerve enters the tympanic cavity, covered by a reflection of the mucous membrane (fig. 912). Between this opening and the pyramidal eminence is a slight elevation, and above it is a fossa, termed the

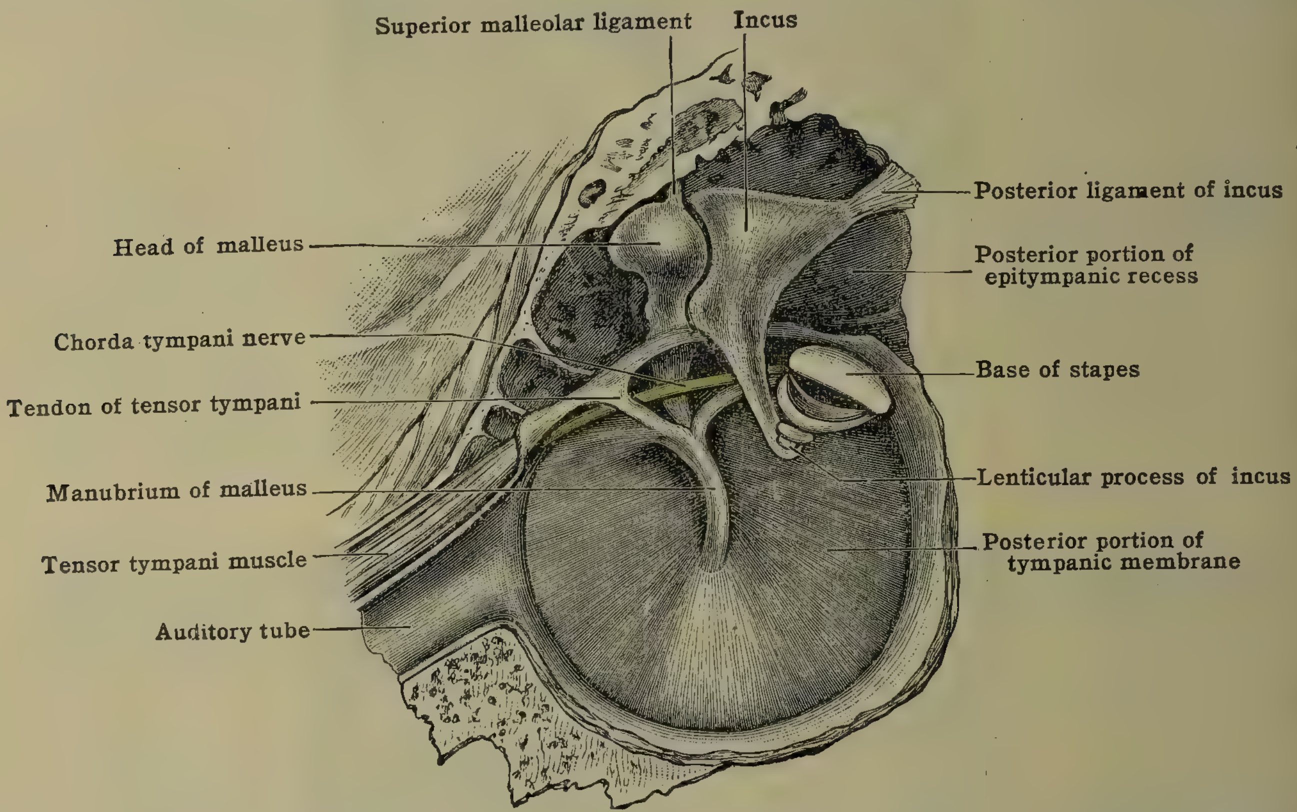


Fig. 913.—The Lateral Wall of the Right Tympanic Cavity, with the Auditory Ossicles in Position. × 4.

posterior sinus [sinus posterior]. Above this again is a recess where the posterior ligament of the incus is attached, known as the *fossa of the incus* [fossa incudis]. The epitympanic recess invades the upper part of the posterior wall, while off from the recess opens the tympanic antrum (figs. 914, 915).

d. The anterior, or **carotid wall** [paries caroticus] also is wider above than below. It presents superiorly the *tensor tympani muscle* in its semicanal, and at a lower level the tympanic orifice of the *auditory tube* by means of which a direct communication is established into the nasopharynx (figs. 913, 914, 915). Inferiorly a thin, bony wall, covered with tympanic air-cells and pierced by the caroticotympanic nerves, separates the tympanic cavity from the carotid canal (figs. 906, 914, 915).

e. The lateral, or **membranous wall** [paries membranaceus] is formed mainly by the tympanic membrane, already considered (p. 1172), together with the small rim of temporal bone to which it is attached (figs. 913, 914). This osseus *tympanic ring* [annulus tympanicus], deficient superiorly at the *tympanic notch* (of Rivinus) (cf. fig. 163), bears the *tympanic groove* [sulcus tympanicus] where the tympanic membrane is attached (fig. 911). Superiorly the lateral wall of the epitympanic recess is represented by the *scutum,* a plate of bone belonging to the squama (figs. 913, 914).

f. The medial, or **labyrinthine wall** [paries labyrinthicus] presents various features, most of which can be identified in fig. 915. Inferiorly there is the *promontory* [promontorium], produced by the bulging first turn of the cochlea, with the nervous *tympanic plexus* (of Jacobson) [plexus tympanicus] lodged in grooves upon its surface. Inferior and posterior to the promontory is a depression (the *fossula fenestræ cochleæ*), at the bottom of which is the *cochlear window* [fenestra cochleæ], or round window of older usage; its orifice is closed by the fibrous, mucosal-covered *secondary tympanic membrane* [membrana tympani secundaria]. Posterior to the promontory is a smooth projection, the *support of the promontory* [subiculum promontorii],

which forms the inferior border of a rather deep depression known as the *tympanic sinus* [sinus tympani]. Superiorly and posteriorly are three landmarks: (*a*) a depression (the *fossula fenestræ vestibuli*) leading to the *vestibular window* [fenestra vestibuli], formerly called the oval window, which is closed by the base of the stapes; (*b*) the *prominence of the facial canal* (of Fallopius) [prominentia canalis facialis] that indicates the position of the canal containing the facial nerve; it crosses the medial wall and turns downward along the mastoid wall; and (*c*) the broadly bulging *prominence of the lateral semicircular canal* [prominentia canalis semicircularis lateralis]. Anteriorly and superiorly is the curved end of the bony semicanal in which the tensor tympani muscle runs; this terminal portion is the *cochleariform process* [processus cochleariformis].

g. With the foregoing descriptions of middle-ear landmarks in mind the walls of that subdivision of the tympanic cavity called the *epitympanic recess* can now be stated. Superiorly it is bounded by the tegmen tympani, medially by the prominence of the lateral semicircular canal and the prominence of the facial nerve, laterally by the scutum, and inferiorly by the fossa incudis and the irregular bony surface just behind it. The boundary line between the tympanic cavity proper and the epitympanic recess is marked by the prominence of the facial canal medially and the fossa incudis inferiorly.

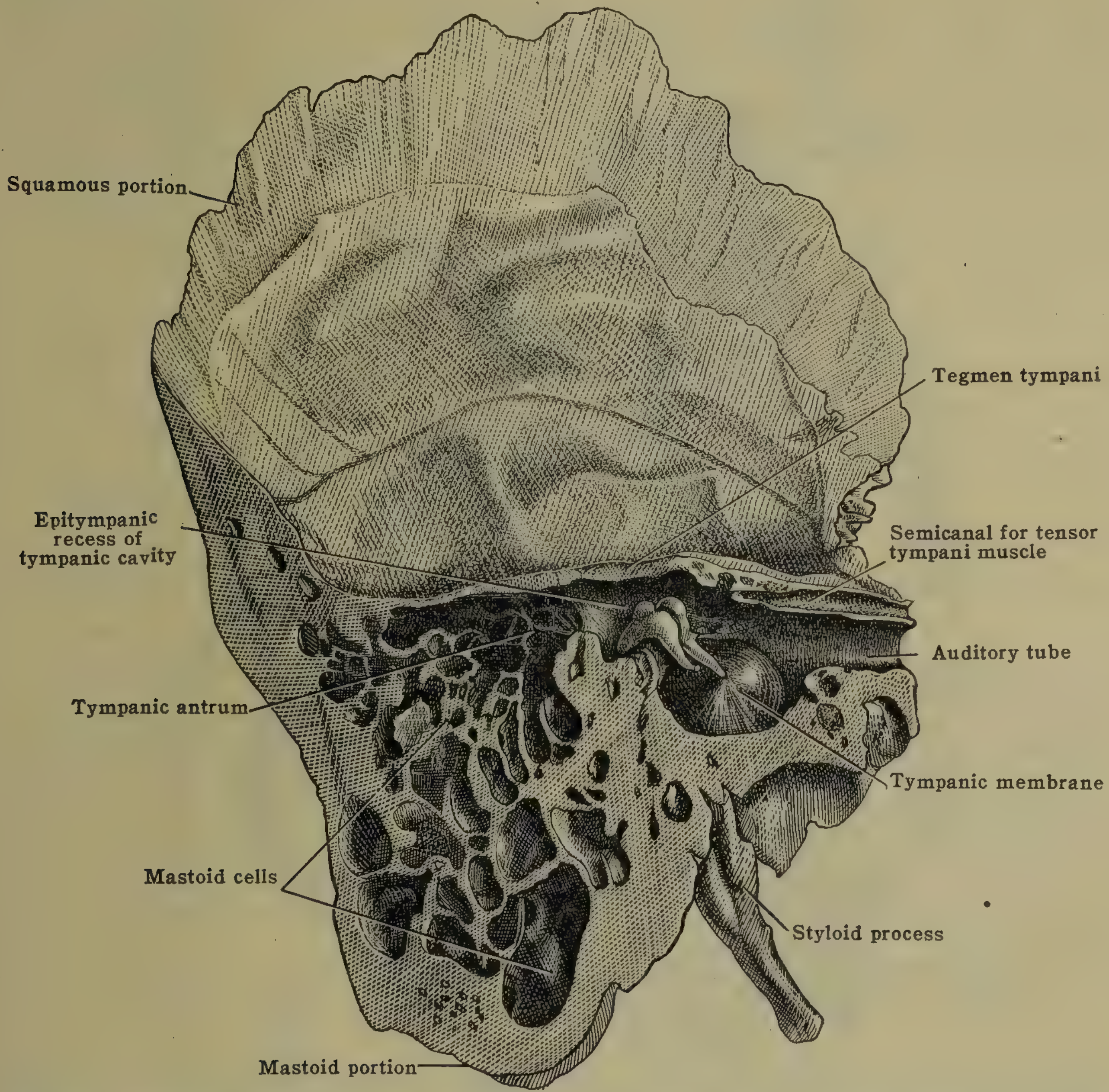


FIG. 914.—SECTION THROUGH THE LEFT TEMPORAL BONE, SHOWING THE LATERAL WALL OF THE MIDDLE EAR. × 1.5.

2. The tympanic mucous membrane.—The tympanic cavity is lined with a folded mucosal tunic [tunica mucosa tympanica] which furnishes a complete covering for both its walls and its contents. It is continuous anteriorly with the mucosa of the auditory (Eustachian) tube and posteriorly with that of the tympanic antrum and mastoid cells. Structurally it is a thin, transparent, vascular membrane intimately united to the periosteum; the epithelium is simple and mostly of the low, nonciliated type. Passing from the walls to the contents of the tympanic cavity, the mucosa not only invests the ligaments of the malleus and the incus and the tendons of the tensor tympani and stapedius muscles but also forms a number of special folds and pouches. Portions of the mucosal reflections over the auditory ossicles themselves are shown as torn edges in fig. 912.

The *anterior malleolar fold* [plica malleolaris anterior] is reflected from the tympanic membrane over the anterior process and ligament of the malleus and over the adjacent part of the chorda tympani nerve. The *posterior malleolar fold* [plica malleolaris posterior], stretching between the manubrium of the malleus and the posterior tympanic wall, surrounds the lateral ligament of the malleus and the posterior part of the chorda tympani. Each of these folds presents inferiorly a concave free border, and between them and the tympanic membrane are two blind pouches, the *anterior* and the *posterior recess of the tympanic membrane* [recessus membranæ tympani anterior et posterior] (r.m.t. oralis et aboralis NK), or pouches of Tröltsch. Connected with the posterior recess is a third cul-de-sac, the *superior recess of the tympanic membrane* [recessus membranæ tympani superior] (r.m.t. tegmentalis NK), or Prussak's space, situated between the pars flaccida of the tympanic membrane and the neck of the malleus

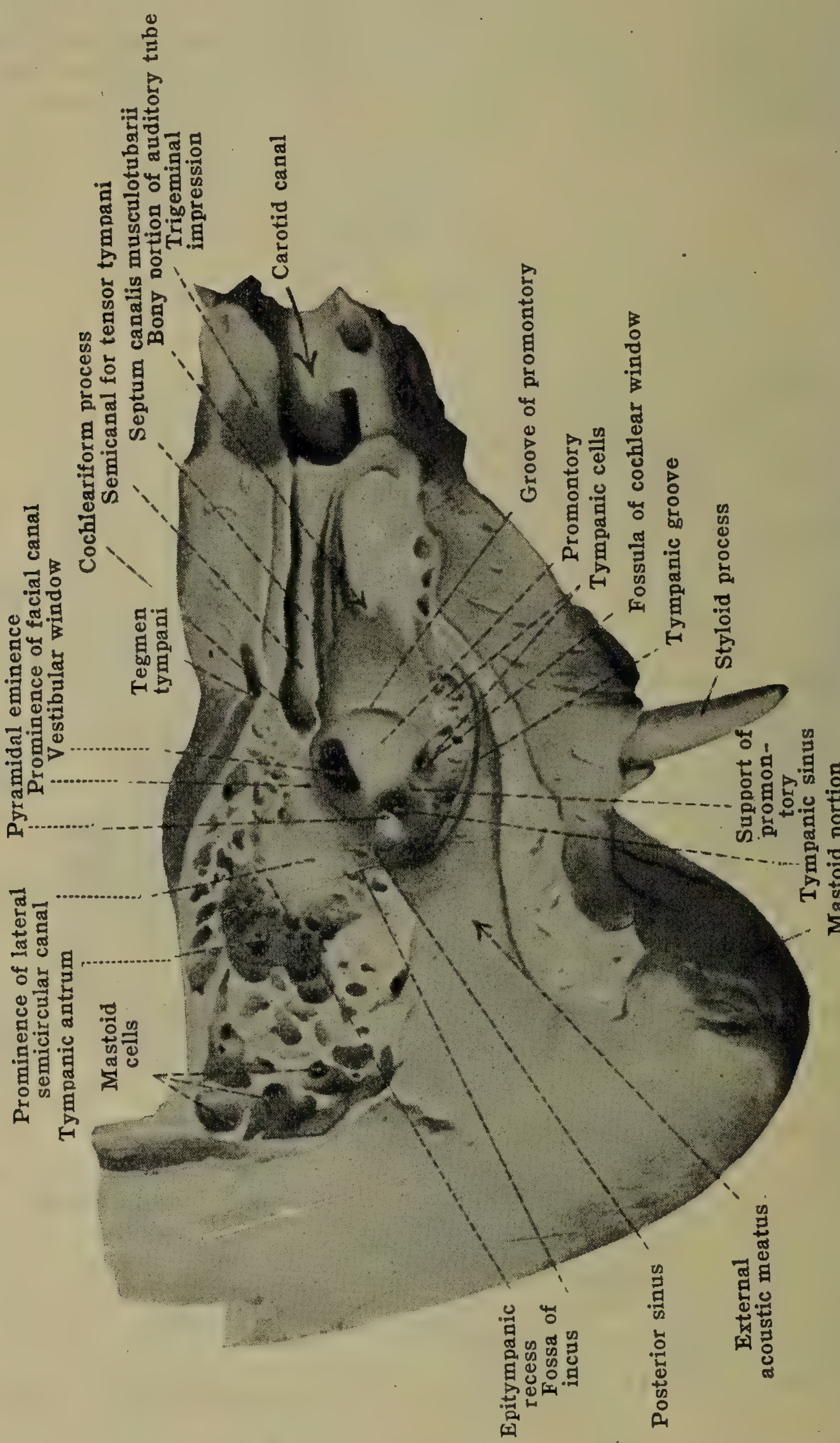


FIG. 915.—THE RIGHT TEMPORAL BONE, OPENED TO DISPLAY THE MEDIAL WALL OF THE MIDDLE EAR. × 1.7. (Sobotta.)

(fig. 911). The floor of this recess, formed by the lateral process of the malleus, is lower than its outlet; therefore, it may serve as a pocket in which pus or other fluid accumulates. A somewhat variable fold of mucosa, the *incudal fold* [plica incudis], passes from the roof of the tympanic cavity to the body and short limb of the incus. The body and short limb of the incus, the head of the malleus, and this fold incompletely separate off a lateral *cupular portion* [pars cupularis] of the epitympanic recess (fig. 911). A *stapedial fold* [plica stapedis] stretches from the posterior wall of the tympanic cavity and surrounds the stapes, including the obturator membrane which stretches between its two limbs. Other inconstant folds have been described.

3. The auditory ossicles.—The tympanic cavity contains three small, movable bones, the *malleus, incus* and *stapes* (fig. 916). Their osteological details are described on p. 157. These auditory ossicles extend like a chain across the tympanic cavity, the better to connect functionally the tympanic membrane

with the vestibular (oval) window (fig. 903). The outermost ossicle is the malleus, firmly attached to the tympanic membrane; the innermost, the stapes, is fixed into the vestibular window and is in direct contact with the fluid perilymph of the internal ear; intermediate between the other two lies the incus. The three bones are bound together by articulations and also effect ligamentous connections with the walls of the containing cavity. This compound osseus system acts like a bent lever to convert the vibrations of the tympanic membrane into intensified thrusts of the stapes against the perilymph.

4. Articulations of the ossicles.—The manubrium and lateral process of the malleus are embedded in the tympanic membrane (figs. 911, 912). The head of the malleus bears an elliptical articular surface on its posterior side; the margin of this is bound to the body of the incus by a thin capsular ligament, forming a diarthrodial joint known as the *incudomalleolar articulation* [articulatio incudomalleolaris] (fig. 913). From the inner surface of the capsular ligament a wedge-shaped circular rim projects into the joint cavity and incompletely divides it. The long limb of the incus lies parallel to the superior and medial aspect of the manubrium of the malleus and ends in the lenticular process (figs. 912, 913). The convex extremity of this process fits into the concavity on the head of the stapes, thereby creating a diarthrodial joint, the *incudostapedial articulation* [articulatio incudostapedia]. From this connection with the incus the stapes passes almost horizontally across the tympanic cavity to its junction with the wall of the labyrinth (fig. 911). The cartilage-covered edge of the stapedial base is bound to the cartilage-covered rim of the vestibular window by the annular ligament of the base of the stapes, thus constituting the *tympanostapedial syndesmosis* [syndesmosis tympanostapedia].

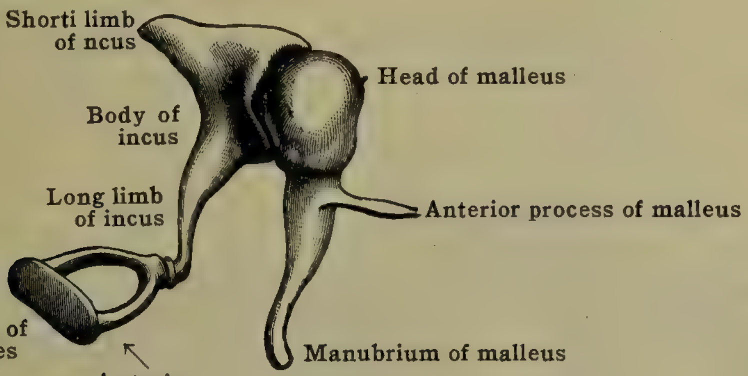


FIG. 916.—THE AUDITORY OSSICLES OF THE LEFT MIDDLE EAR, VIEWED FROM THE ANTEROMEDIAL ASPECT. × 4. (Modified after Henle.)

5. Ligaments of the ossicles.—In addition to the attachment of the manubrium of the malleus and the base of the stapes to the walls of the tympanic cavity, the bones have additional ligamentous attachments, most of which are illustrated in figs. 911 to 913. The *superior malleolar ligament* [lig. mallei superius] descends almost vertically from the roof of the epitympanic recess to the head of the malleus. The *anterior malleolar ligament* [lig. mallei anterius] extends from the angular spine of the sphenoid bone through the petrotympanic (Glaserian) fissure to the anterior, or long process of the malleus, which it surrounds; the actual insertion is into the neck of the malleus. The *lateral malleolar ligament* [lig. mallei laterale] is short and thick, connecting the margins of the tympanic notch (of Rivinus) with the neck of the malleus. The *posterior incudal ligament* [lig. incudis posterius] passes from the fossa incudis on the posterior tympanic wall to the short limb of the incus. The *superior incudal ligament* [lig. incudis superius] is little more than a fold of mucous membrane which descends from the tympanic roof to the body of the incus. The *annular ligament of the stapedial base* [lig. annulare baseos stapedis] is a ring of elastic fibers encircling the base of the stapes and uniting it to the rim of the vestibular window.

6. Muscles of the ossicles.—Each of the two muscles of the ossicles is contained within a bony canal. The *m. tensor tympani* is a pinniform muscle about 2 cm. long. It arises from the cartilaginous part of the auditory tube, from the adjacent part of the great wing of the sphenoid bone, and from the bony walls of the *semicanal* [semicanalis m. tensoris tympani] which encloses it (figs. 909, 915, 919). It ends in a round tendon which turns almost at right angles over the cochleariform process and passes laterally across the tympanic cavity to be attached to the manubrium of the malleus near the neck (fig. 913). This muscle serves to draw the manubrium medially and thus tighten the tympanic membrane; it is supplied by the trigeminal nerve through the tensor tympani branch from the otic ganglion. The *m. stapedius*, smallest of all skeletal muscles, arises in the interior of the hollow pyramidal eminence (fig. 915). Its tendon escapes through the opening at the apex and then turns inferiorly to insert on the posterior surface of the neck of the stapes (figs. 911, 912). The muscle draws laterally the anterior border of the base of the stapes; it is innervated by the stapedial branch of the facial nerve.

7. Vessels and nerves.—The *arteries* of the tympanic cavity are mostly derivatives of the external carotid. They are: (*a*) the anterior tympanic, derived from the internal maxillary artery and distributed to the anterior part of the cavity, including the tympanic membrane (fig. 531); (*b*) the stylomastoid, from the posterior auricular artery, to the posterior tympanic cavity and mastoid cells (fig. 534); (*c*) the superficial petrosal, from the middle meningeal artery (fig. 532); (*d*) the inferior tympanic, from the ascending pharyngeal (fig. 526). In

addition, the caroticotympanic branch, from the internal carotid, supplies the anterior wall (fig. 534). The *veins* roughly parallel the arteries and empty into the superior petrosal sinus and the pterygoid plexus (fig. 599). The *lymphatics* begin as a network in the mucous membrane and end chiefly in the retropharyngeal and parotid lymph glands.

The *nerves* of the mucosa are represented by the tympanic plexus (fig. 808), formed by the tympanic branch of the glossopharyngeus; besides this there are additions from the inferior and superior caroticotympanic nerves which come from the internal carotid plexus of the sympathetic, and other contributions from the small superficial petrosal nerve. The chorda tympani merely crosses through the tympanic cavity from the posterior to the anterior wall (figs. 807, 912).

8. **Clinical aspects.**—Infections reach the tympanic cavity from the auditory tube anteriorly and from the tympanic antrum posteriorly. Rather poor natural drainage is afforded by the auditory tube, and escape of pus by rupture of the ear drum is common. Infection spreads from the tympanic cavity by several routes: (a) The tympanic cavity has a thin, easily perforable roof which in infants also contains the unossified suture between the squamous and petrous portions of the temporal bone. By these paths the meninges and superior petrosal sinus become involved. (b) The lowest part of the narrow floor is below the level of both auditory tube and tympanic cavity; this allows pus to collect there and infection may extend by small veins to the internal jugular vein and thence to the transverse sinus. (c) On the medial wall the facial canal is covered by such thin bone, especially in infants, that inflammatory disturbances of the middle ear can affect the enclosed nerve. A direct route inward is through the cancellous bone of the medial wall itself. Rarely the internal ear is reached through the fenestræ ovale and cochlearis. (d) Posteriorly there is ready access to the antrum and mastoid cells.

C. The Tympanic Antrum and Mastoid Cells

An aperture in the upper part of the posterior wall of the epitympanic recess leads into the chamber known as the **tympanic antrum** [antrum tympanicum]

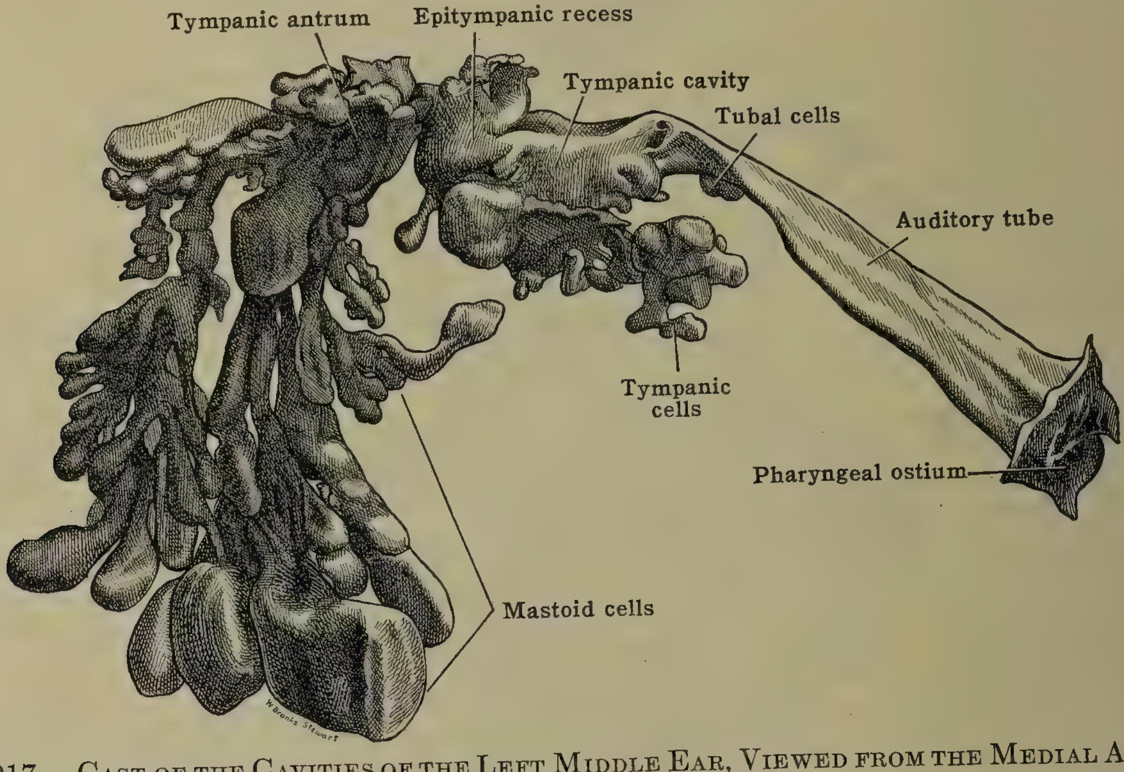


Fig. 917.—Cast of the Cavities of the Left Middle Ear, Viewed from the Medial Aspect. × 1.5. (After a model by Siebenmann.)

(antrum mastoideum NK). This is a comparatively large cavity, about the size of a small bean and of irregular form, lying mainly behind but also somewhat above and lateral to the tympanic cavity (figs. 914, 915, 917). It is lined by thin mucous membrane, continuous with that of the tympanic cavity, and into it open the abundant **mastoid cells** [cellulæ mastoideæ]. These cells are small, irregular cavities mostly located behind and below the antrum within the substance of the mastoid process of the temporal bone (figs. 909, 914). They communicate with one another freely, vary exceedingly in size and arrangement, and are not present at birth. Fig. 917 represents a cast of the cavities of the entire middle ear system; the relations of the mastoid cells to the antrum and of the antrum to the epitympanic recess and tympanic cavity are plainly shown. Some further details concerning the antrum and mastoid region are given on pp. 155, 156.

Clinical aspects.—The antrum is present at birth but the formation of mastoid cells accompanies the growth of the mastoid process which becomes definitely marked at the second year. There are wide variations in the degree to which the mastoid process becomes pneumatic.

Since the floor of the antrum is below the level of the passage communicating with the epitympanic recess, pus in the antrum tends to collect in the mastoid cells. The spread of septic infection from the mastoid region is by several routes: (1) *upward*, through the thin roof to involve the meninges or through the petrosquamous suture to the superior petrosal sinus; (2) *downward*, to reach the internal jugular vein or the digastric fossa; (3) *forward*, to produce a subperiosteal abscess just behind the auricle or to perforate and discharge into the external acoustic meatus; (4) *backward*, to involve the transverse sinus; (5) *outward*, especially in children, through the thin bone or the unclosed squamosomastoid suture; (6) *inward*, to the transverse sinus.

The transverse sinus, facial nerve, semicircular canals and middle cranial fossa are all in danger during operations upon the tympanic antrum and mastoid cells. Since the position of the antrum is the key to all operative procedure its exact location becomes of prime importance. The antrum lies beneath a shallow 'suprameatal triangle' found superficially on the temporal bone a little above and behind the external acoustic meatus; its boundaries are the posterior root of the zygoma above, the superoposterior segment of the bony external meatus below,

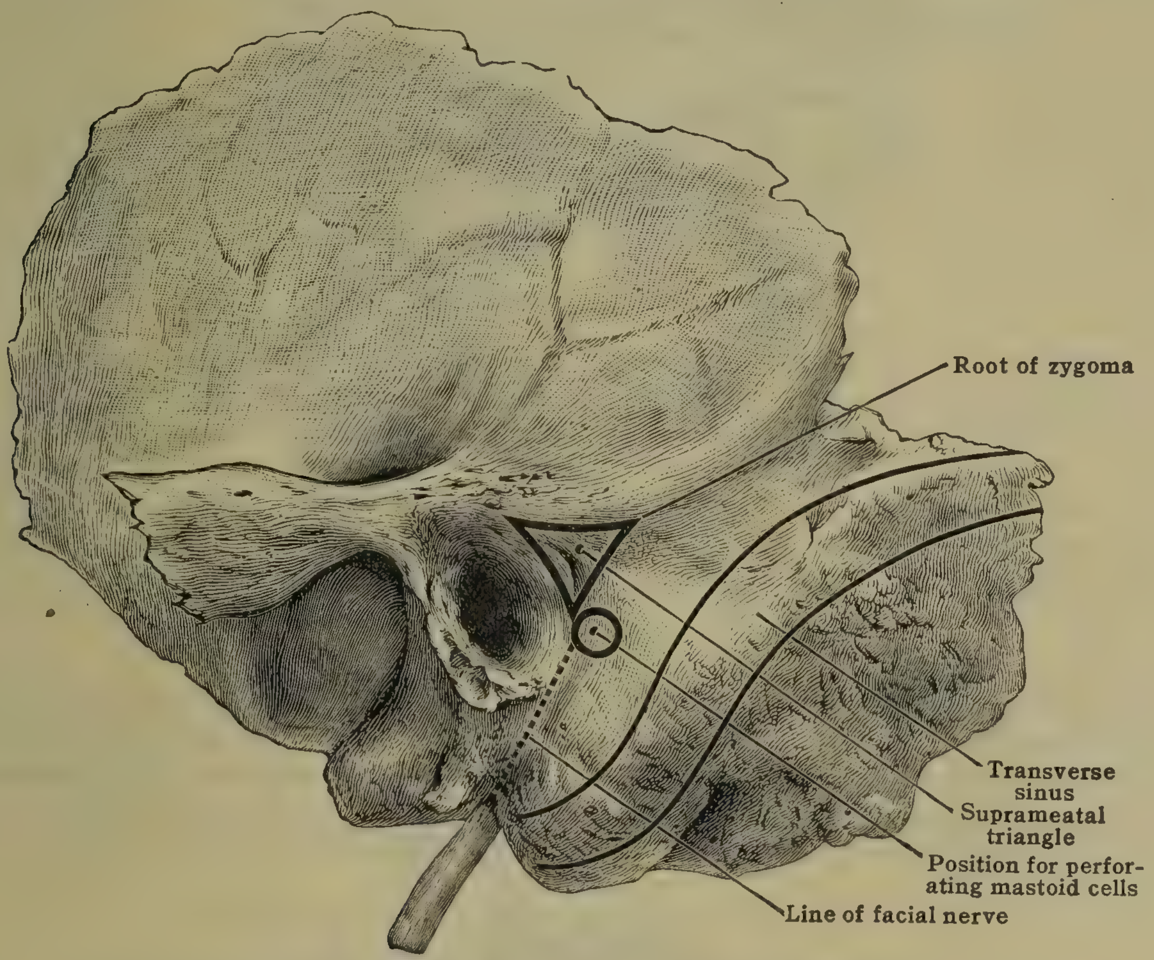


FIG. 918.—THE LEFT TEMPORAL BONE IN LATERAL VIEW, SHOWING THE POSITIONS OF THE SUPRAMEATAL TRIANGLE AND TRANSVERSE SINUS. × 1.3. (Barr.)

and an imaginary line joining these two landmarks (fig. 918). In the child these bony prominences are not developed and the bone just behind the superoposterior quadrant of the external auditory meatus is the best guide. When opening the antrum through the suprameatal triangle the chisel is directed forward and medially so as to avoid the transverse sinus; at the same time the facial nerve is protected by hugging the root of the zygoma and the upper part of the bony meatus as closely as possible. The posterior wall of the meatus is paralleled, and the more oblique is the meatus, the more anterior is the antrum situated.

D. THE AUDITORY TUBE

The **auditory tube** [tuba auditiva], or Eustachian tube, extends from the *tympanic orifice* [ostium tympanicum tubæ auditivæ] on the carotid (anterior) wall of the tympanic cavity inferiorly to reach the pharynx (fig. 903). During this descent it also inclines medially and anteriorly. The entire tube is about 37 mm. long. In the lateral (or tympanic) one-third of its length it has a bony wall which constitutes a *semicanal* [semicanalis tubæ auditivæ], while in the medial (or pharyngeal) two-thirds the wall is cartilaginous (fig. 919). The *osseous portion* [pars ossea tubæ auditivæ] (see p. 153) begins at the tympanic ostium on the anterior wall of the tympanic cavity (figs. 914, 915). Superiorly a thin *septum* [septum canalis musculotubarii] alone separates the lumen from the tensor tympani muscle, while the medial wall is in relation with the carotid canal (figs. 909, 919). The irregularly triangular lumen gradually contracts toward the

jagged anteromedial extremity of the bony tube; this is the narrowest point in the entire auditory tube and is named the *isthmus* [isthmus tubæ auditivæ] (fig. 917). The *cartilaginous portion* [pars cartilaginea tubæ auditivæ] is firmly attached to the osseous segment and lies in a sulcus at the base of the angular

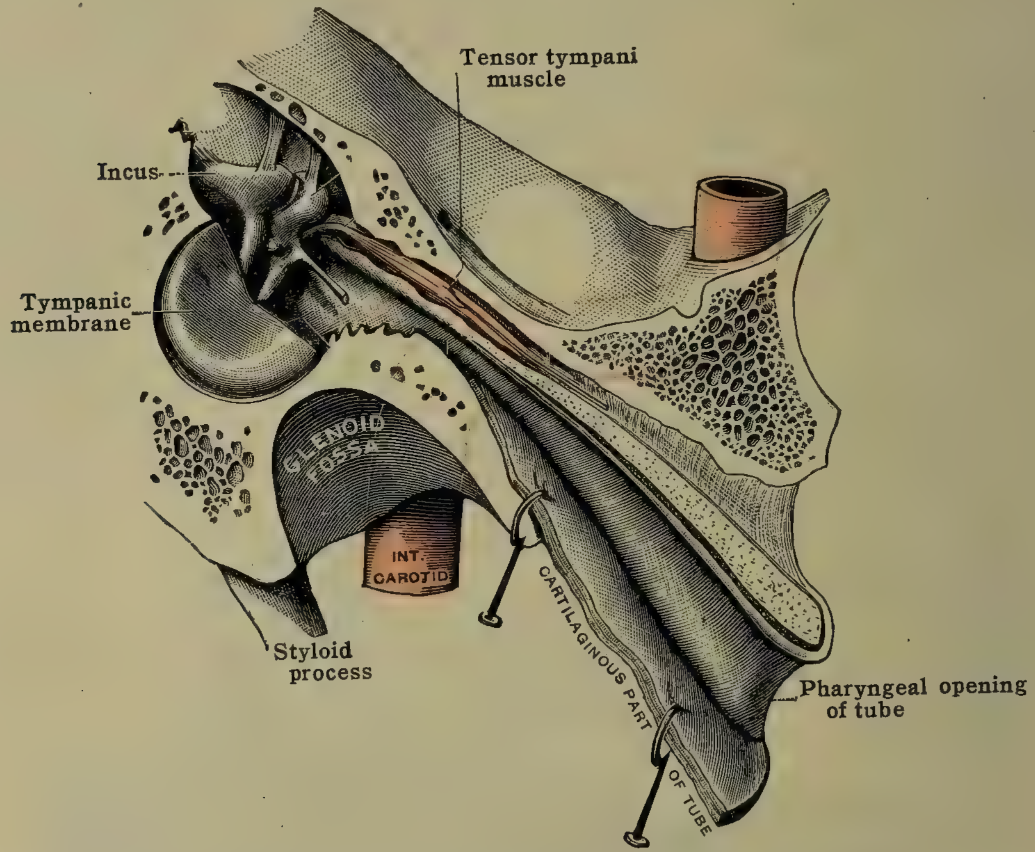


Fig. 919.—The Right Auditory Tube, Opened Lengthwise. Natural Size. (From Testut in Gerrish's 'Anatomy,' Lea & Febiger.)

spine of the sphenoid bone. It dilates gradually in its passage toward the lateral wall of the pharynx, where its opening, the *pharyngeal orifice* [ostium pharyngeum tubæ auditivæ], is just posterior to the inferior nasal concha and in front of the lateral pharyngeal recess (of Rosenmüller) (fig. 1041). The walls of the cartilaginous portion are chiefly supported by the *tubal cartilage* [cartilago tubæ auditivæ]

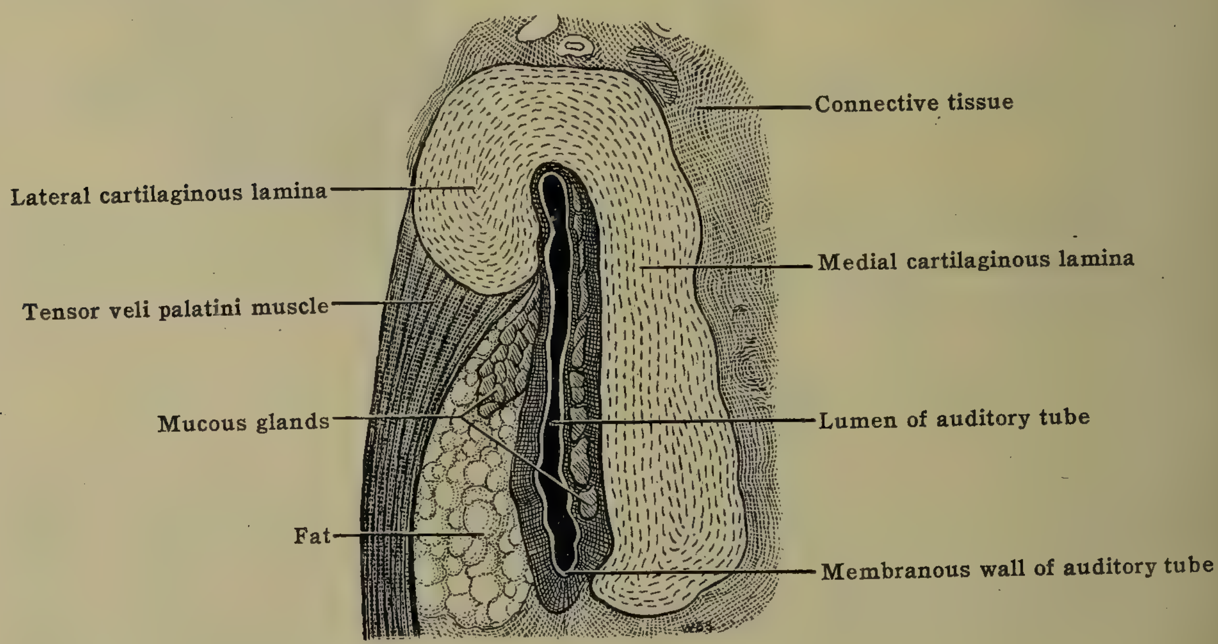


Fig. 920.—Transverse Section through the Middle of the Cartilaginous Portion of the Auditory Tube. × 7.

in the form of a plate which is folded so as to make a trough-like structure; this consists of a broad *medial lamina* [lamina medialis] and a narrower *lateral lamina* [lamina lateralis], completed laterally and inferiorly by a *membranous lamina* [lamina membranacea] of connective tissue (fig. 920). The lining of the auditory

tube is a *mucous membrane* [tunica mucosa] continuous with that of the tympanic cavity, on the one hand, and pharynx, on the other.

A small stretch of the lumen in the superior part of the cartilaginous tube remains permanently open; elsewhere the walls are in contact, except during swallowing when they are said to be opened chiefly by the tensor veli palatini muscle. The mucous membrane lining of the osseous portion is thin and firmly attached to the bony supporting wall. In the cartilaginous portion the mucosa becomes thicker, looser and folded; here it contains *mucous glands* [glandulæ mucosæ], especially near the pharynx where there is also some adenoid tissue aggregated into *lymph nodules* [noduli lymphatici tubarii] (fig. 920). The ciliated epithelium varies from simple columnar at the tympanic end to the pseudostratified type nearer the pharynx.

1. Vessels and nerves.—The *arteries* are from the external carotid through the ascending pharyngeal (fig. 526), the middle meningeal, and the artery of the pterygoid canal (fig. 532). The *veins* drain into the pterygoid venous plexus (fig. 589) and so reach the internal jugular. The *nerves* are derived both from the tympanic plexus and from the pharyngeal branches of the sphenopalatine ganglion (figs. 801, 808).

2. Clinical aspects.—The opening of the auditory tube on the anterior wall is too high to drain the tympanic cavity efficiently. In children the tube is shorter, broader and more horizontal than in adults, so that ascending infections by way of the tube are easier; yet at the same time drainage from the tympanic cavity is better. The tube is usually closed, but opens in swallowing or yawning; advantage is taken of this by airplane passengers to equalize the pressure on both sides of the drum during rapid changes of altitude. Temporarily swollen or closed tubes commonly need opening which is accomplished by some method of inflation. Permanent occlusion of the auditory tube by adenoids, operative scarring or ulceration leads to pressure inequalities, ringing of the ear and defective hearing.

III. THE INTERNAL EAR

The **internal ear,** located within the petrous temporal bone, receives the terminations of the acoustic nerve and is the essential part of the organ of hearing (fig. 903). Its irregular and complex shape has led to the name *labyrinth* which also designates it. There are two component parts to the internal ear: (1) the **osseous labyrinth** [labyrinthus osseus], a series of continuous cavities within the bony matrix; (2) the **membranous labyrinth** [labyrinthus membranaceus], a system of communicating epithelial sacs and ducts contained within the bony passages just mentioned.

A. The Osseous Labyrinth

The bony labyrinth (capsula ossei labyrinthi NK) is about 2 cm. long. The osseous matrix bordering the cavities is harder than the rest of the petrous

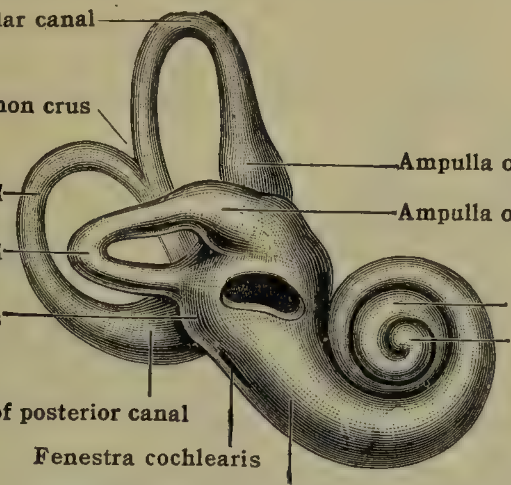


Fig. 921—The Right Osseus Labyrinth, in Lateral View. × 3. (Modified after Soemmering.)

bone, and because of this difference in texture it is possible, especially in infants, to separate away this most internal part of the labyrinth as a bony shell (fig. 921). There are three incompletely divided component regions: (1) the **vestibule;** (2) the **semicircular canals;** and (3) the **cochlea.** The entire bony labyrinth is lined with thin periosteum, which in turn is surfaced internally with a delicate epithelioid layer; it contains a fluid perilymph which surrounds the smaller sized membranous labyrinth.

1. The vestibule.—The bony *vestibule* [vestibulum] is an ovoid, central chamber about 4 mm. in diameter (fig. 921). Anterosuperiorly the vestibule leads into the cochlea, while posteroinferiorly it receives the ends of the semicircular canals (fig. 922). The interior of the vestibular wall shows depressions

and ridges which correspond to definite parts of the contained membranous labyrinth.

Superiorly and posteriorly on the medial wall is the *elliptical recess* [recessus ellipticus] (r. pro utriculo NK) for the utricle, while inferiorly and anteriorly occurs the *spherical recess* [recessus sphericus] (r. pro sacculo NK) which accommodates the saccule (fig. 922). Between these two hollows is an oblique ridge, the *vestibular crest* [crista vestibuli], which divides posteriorly into two limbs bounding a small depression; this concavity is the *cochlear recess* [recessus cochlearis] which lodges the beginning of the cochlear duct (fig. 923). There are also definite openings in the bony wall. Tiny grouped foramina, the *maculæ cribrosæ* (areæ cribriformes NK) (*i.e.*, sieve areas), accommodate the nerves entering to supply the several sensory fields of this central labyrinthine region (fig. 923). Larger apertures serve for the transmission of the endolymphatic duct, for the openings of the semicircular canals, and for a communication with the cochlea (fig. 922). On the lateral wall, next the tympanic cavity, occurs the *fenestra vestibuli*, or oval window, which is closed by the base of the stapes; below it is the *fenestra cochleæ*, or round window (fig. 921).

2. The semicircular canals.—There are three *osseus semicircular canals* [canales semicirculares ossei] situated superoposteriorly to the vestibule (fig. 921). Each describes about two-thirds of a circle and lies in a plane located at right angles to the other two; this makes the relation of their planes like the three adjoining sides about the corner of a cube. The bony canals measure about 1

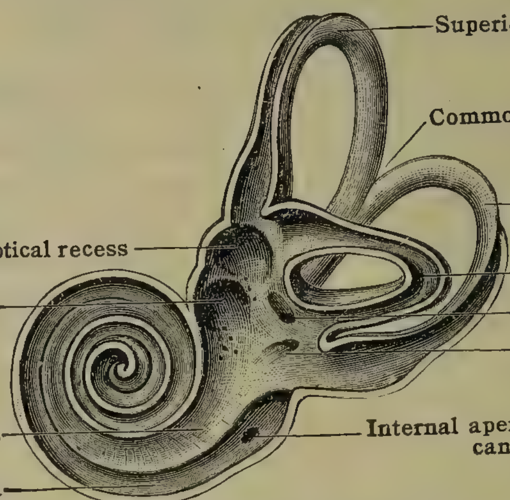


FIG. 922.—THE INTERIOR OF THE LEFT OSSEUS LABYRINTH. × 3. (Modified after Soemmering.)

mm. in diameter, but at one end each becomes dilated into an *osseous ampulla* [ampullæ osseæ], twice as large. The canals open into the vestibule by five (instead of six) apertures, since in one instance a single orifice serves for two fused canals (fig. 922).

The *superior* and *posterior semicircular canals* [canalis semicircularis superior et posterior] (c.s. parietalis et occipitalis NK) lie in nearly vertical planes, the right angle included between them opening laterally (fig. 169). The anterolateral end of the superior canal and the inferior end of the posterior canal are ampullated (fig. 921). The other extremities of these two canals join to form the *common limb* [crus commune] which opens into the vestibule by a single orifice (fig. 922). The *lateral semicircular canal* [canalis semicircularis lateralis] bows in the horizontal plane and is the shortest of the three; its ampulla lies close to that of the superior canal. The lateral canal occupies the same plane as its mate of the other ear, while the superior canal of one ear is parallel to the posterior canal of the other.

3. The cochlea.—The bony *cochlea* resembles a snail shell, from which the name is taken. In form the cochlea is conical, its *base* [basis cochleæ] lying upon the internal acoustic meatus and its apex, or *cupola*, directed anteriorly and laterally (fig. 923). The base measures 9 mm. while the axial height is 5 mm. Most of the cochlea consists of the *spiral cochlear canal* [canalis spiralis cochleæ]. This is a spiral tube over 30 mm. long, coursing through nearly two and three-quarters turns about a central bony axis, or *modiolus* (fig. 927). Projecting outward from the modiolus is a thin bony plate, the *osseus spiral lamina* [lamina spiralis ossea]; it winds about the modiolus like the flanged thread of a screw and ends apically in the hook-like *hamulus* (fig. 923). In this manner the cochlear canal is partially subdivided into an upper passage, the *scala vestibuli*, and a lower passage, the *scala tympani*. Nevertheless, the two scalae join apically at the *helicotrema* where the partitioning spiral lamina ends freely (fig. 927).

The base of the cochlea corresponds to the *cochlear area* [area cochleæ] at the bottom of the internal acoustic meatus. This area lies on the medial wall of the vestibule and contains the

spiral tract of foramina [tractus spiralis foraminosus] for the passage of nerves to the cochlea (fig. 166). Nearby are other cribriform areas transmitting nerves to the rest of the membranous labyrinth. The modiolus is a short, tapering column which is tunnelled by *longitudinal modiolar canals* [canalis longitudinalis modioli] and a *spiral modiolar canal* [canalis spiralis modioli], serving both for the conduction of blood vessels and nerves. The beginning of the bony cochlear canal presents three openings. One effects a connection with the vestibule (fig. 923); another, the *fenestræ cochleæ*, leads to the tympanic cavity (fig. 921); the third is the orifice of the

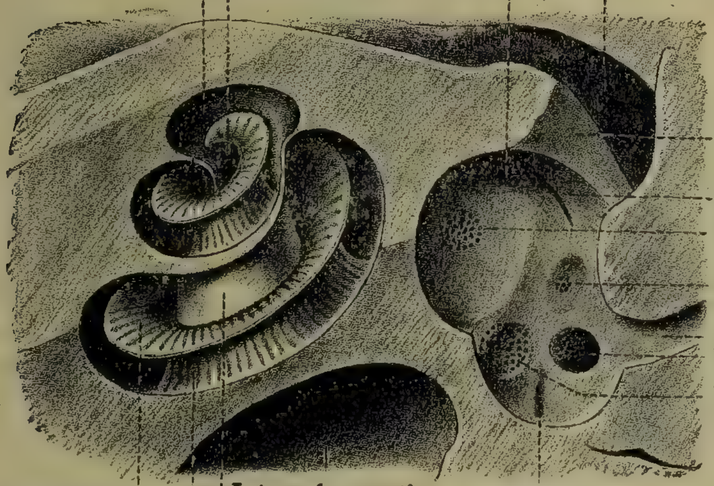


FIG. 923.—THE RIGHT COCHLEA AND VESTIBULE, VIEWED FROM ABOVE AFTER REMOVING THE ROOF OF THE BONY LABYRINTH. × 5. (Testut.)

cochlear caniliculus [canaliculus cochleæ] which establishes a communication between the scala tympani and the subarachnoid cavity (fig. 922).

B. THE MEMBRANOUS LABYRINTH

The **membranous labyrinth** [labyrinthus membranaceus] lies within the bony labyrinth and, though much smaller, resembles it more or less in form (fig. 924). The two labyrinths are separated by a *perilymphatic space* [spatium perilym-

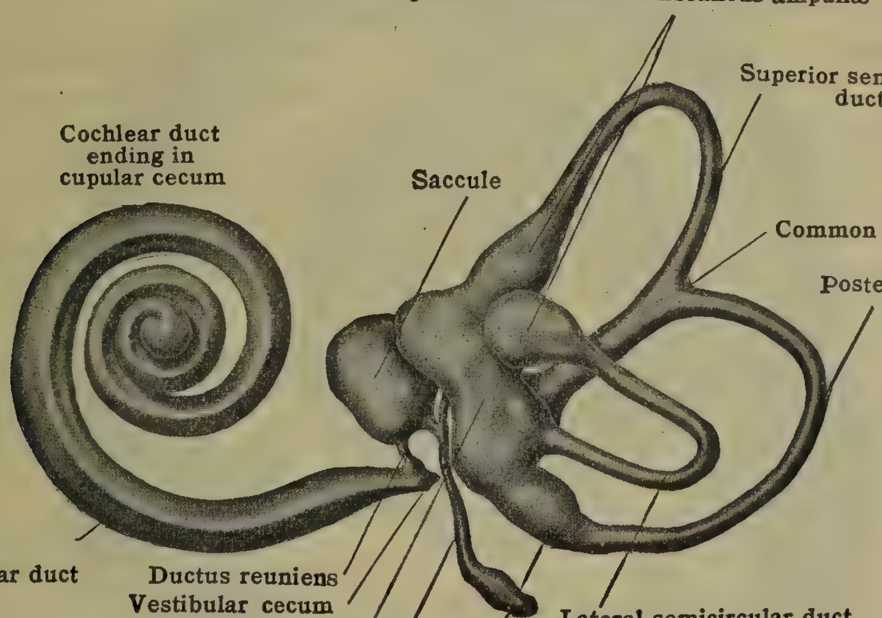


FIG. 924.—DIAGRAM OF THE LEFT MEMBRANOUS LABYRINTH, IN LATERAL VIEW. × 4. (After Deaver.)

phaticum] containing *perilymph* [perilympha], except where the two are united intimately by fibrous tissue. However, fibrous trabecular strands pass inward from the periosteum to the wall of the membranous labyrinth, and the irregular spaces so produced are comparable to the subarachnoid cavity about the brain and spinal cord. The membranous labyrinth is filled with a separate fluid, the *endolymph* [endolympha], and in its internal epithelial wall terminate the arboriza-

tions of the acoustic nerve. The *cochlear duct* [ductus cochlearis] and the *semicircular ducts* [ductus semicirculares] follow quite closely the configuration of the similarly named bony canals. On the other hand, the membranous components of the vestibule do not preserve so faithfully the form of the containing cavity; instead, they are fashioned into two sacs, the *utricle* [utriculus] and *saccule*

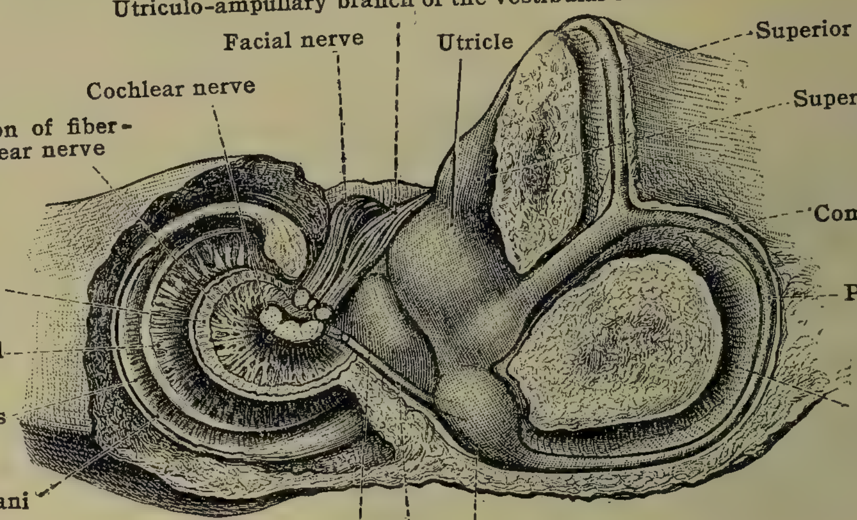


Fig. 925.—The Right Membranous Labyrinth of a Newborn, Exposed by Partial Removal of the Bony Labyrinth and Viewed from Behind. × 4. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

[sacculus], which, nevertheless, connect indirectly with each other and also with the cochlear and semicircular ducts.

1. The utricle.—The *utriculus* is an ovoid, slightly flattened sac whose rounded end occupies the elliptic recess in the superoposterior region of the vestibule (figs. 924, 925). Here it is attached firmly by connective tissue and by entering filaments from the utricular branch of the vestibular division of the

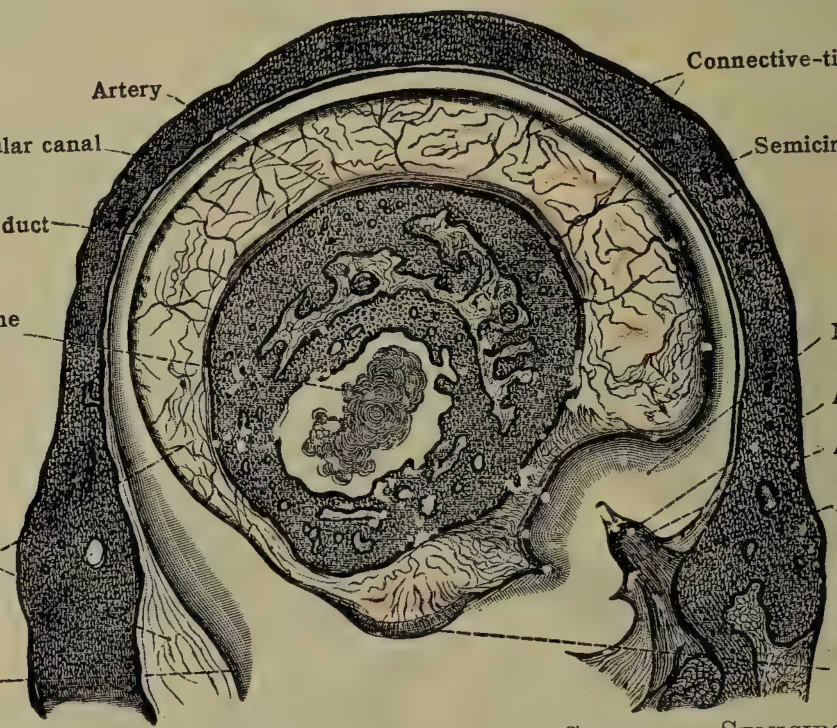


Fig. 926.—Longitudinal Section through the Superior Semicircular Duct and the Utricle. × 6. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

acoustic nerve. Anteriorly and laterally an oval, thickened area, the *macula acustica utriculi* (*i.e.*, the utricular acoustic spot), marks the region of ultimate utricular nerve distribution (figs. 926, 930). On the posterior wall are the openings of the semicircular ducts and on the anterior wall a slender tube that communicates with the saccule (fig. 924).

2. The saccule.—The *sacculus* is also ovoid but smaller than the utricle (fig. 924). It lies in the anterior and inferior part of the vestibule and is bound

to the spherical recess by fibrous tissue and by the saccular branch of the vestibular division of the acoustic nerve. An oval thickening occurs anteriorly where the saccular nerve filaments end in the *macula acustica sacculi* (figs. 927, 930 A). The connections of the saccule with the cochlear duct and utricle can be seen in fig. 924.

At the anterior end of its inferior surface the saccule gradually passes into a short, narrowing canal, the *ductus reuniens*, which connects with the cochlear duct. Posteriorly the very slender *endolymphatic duct* [ductus endolymphaticus] arises to extend through the vestibular aqueduct and reach the posterior surface of the petrous temporal bone; here it ends in a dilated, blind pouch, the *endolymphatic sac* [saccus endolymphaticus], situated just outside the dura mater. Close to the saccule, the endolymphatic duct is joined at an acute angle by a short canal of minute caliber; this *utriculosaccular duct* [ductus utriculosaccularis] opens into the anterior wall of the utricle and, together with the endolymphatic duct, connects it with the saccule.

3. The semicircular ducts.—Three membranous tubes run within the bony semicircular canals and resemble them in name, number, shape and position

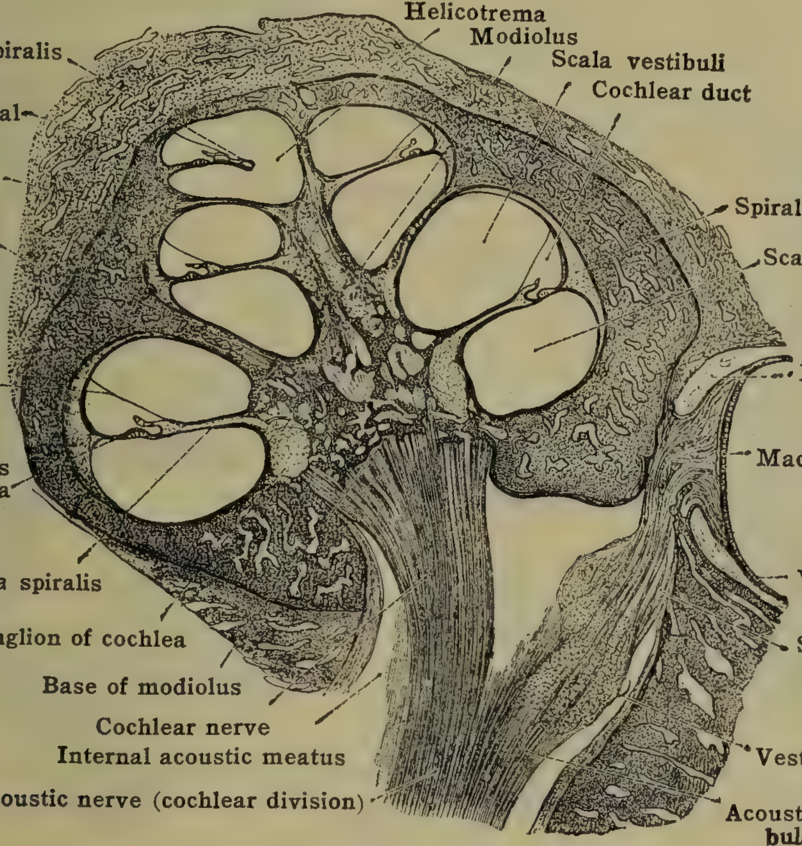


FIG. 927.—AXIAL SECTION THROUGH THE DECALCIFIED COCHLEA OF A NEWBORN. × 6. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

(figs. 924, 925). Each *semicircular duct*, however, is less than one-third the diameter of the containing bony canal, from which it is separated by a large perilymphatic space except at a line of attachment along the greater curvature (fig. 926). Each *membranous ampulla* [ampulla membranacea] bears on its attached surface an external transverse groove, the *ampullary sulcus* [sulcus ampullaris], for the entrance of the ampullary branch of the vestibular division of the acoustic nerve; corresponding to the sulcus internally there is a ridge, the *ampullary crest* [crista ampullaris], which projects into the lumen and receives the nerve endings (fig. 926).

Structure of the utriculus, sacculus and semicircular ducts.—The walls of the utricle, saccule and semicircular ducts consist of three layers. Externally there is loose connective tissue, containing blood-vessels and pigment cells and bordering upon the trabeculate perilymphatic spaces already described. The intermediate layer is an ordinary basement membrane, while the internal lining is mostly a simple, low epithelium. At the maculæ and cristæ all three layers are thickened to produce the elevations characteristic of these regions (figs. 926, 930A). Here the epithelium elongates to the columnar type in which slender *supporting cells* and flask-shaped, sensory *hair cells* intermingle. Between and upon the projecting hairs is a gelatinous membrane, which in the utricle and saccule contains superficially a mass of minute calcareous granules, the *otoconia* (statoconia NK). Naked axis cylinders of the vestibular division of the acoustic nerve branch and form basket-like terminations about the hair cells.

4. The cochlear duct.—The term scala media was formerly applied to this spiral tube lying within the bony cochlea and attached to its outer wall. The

cochlear duct begins as a blind pouch, the *vestibular cecum* [cæcum vestibulare], which occupies the cochlear recess of the vestibule; following the spiral canal of the bony cochlea it makes a basal, middle, and incomplete apical turn, and then ends blindly just beyond the hamulus of the spiral lamina in a second blind pouch named the *cupular cecum* [cæcum cupulare] (fig. 924). Close to the vestibular cecum the cochlear duct is joined to the saccule by the *ductus reuniens.*

The cochlear duct is an epithelial-lined tube, somewhat triangular in transverse section, whose general relations are illustrated in figs. 927, 928. Its floor is formed chiefly by thickened periosteum, overlying the peripheral part of the bony lamina spiralis, and by a fibrous *basilar membrane* [lamina basilaris] which stretches from the free border of the spiral lamina to the periosteum lining the peripheral wall of the osseous cochlear canal. The epithelium of this cochlear floor is greatly elevated and specialized, constituting the complicated *spiral organ* (of Corti) [organon spirale] (organon terminale auditus NK) in which the fibers of the cochlear nerve terminate and in which the sense of hearing resides.

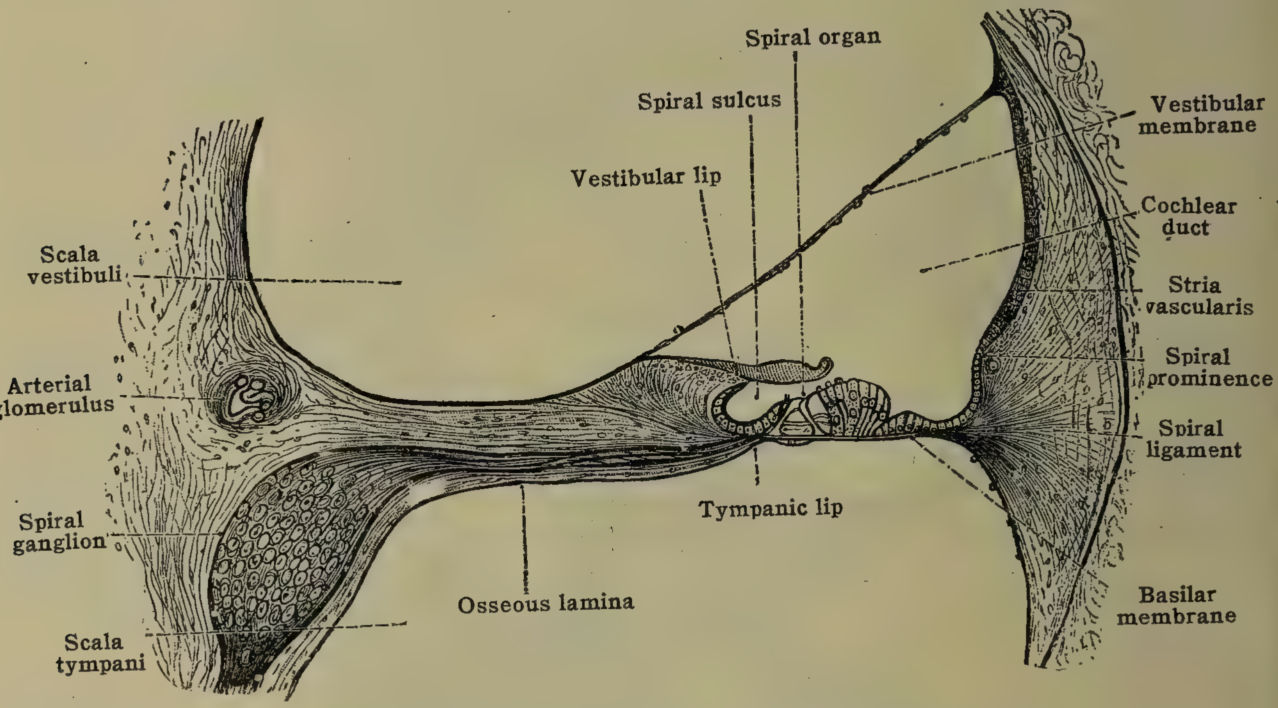


FIG. 928.—RADIAL SECTION THROUGH ONE OF THE COILS OF THE COCHLEA. × 50. (From Toldt's 'Atlas of Human Anatomy,' The Macmillan Co.)

The peripheral supporting wall of the cochlear duct is supplied by the thickened periosteum of the outer wall of the bony cochlear canal; this is designated as the *spiral ligament of the cochlea* [lig. spirale cochleæ]. The third wall, or roof, is a thin *vestibular membrane* (of Reissner) [membrana vestibularis] which passes unsupported from the spiral ligament to the osseous lamina spiralis near its free margin, forming with the latter an angle of 45 degrees.

The cochlear duct and the bony spiral lamina divide the entire cochlear canal into an upper perilymphatic passage, the *scala vestibuli,* and a lower passage, the *scala tympani* (figs. 927, 928). The two scalæ unit apically at the *helicotrema* where the cochlear duct comes to an end (figs. 923, 927).

The scala vestibuli communicates through a slit-like fissure with the perilymph space of the vestibule (fig. 923), and this in turn is separated from the tympanic cavity by the base of the stapes with is inserted into the vestibular fenestra. Near its beginning the scala tympani gives off a minute canal, the *perilymphatic duct* [ductus perilymphatici], which occupies the cochlear canaliculus and connects with the subarachnoid cavity (fig. 922). The scala tympani is separated from the tympanic cavity by the *secondary tympanic membrane* [membrana tympani secundaria] which closes the cochlear fenestra (fig. 921).

Structure of the cochlear duct.—The *vestibular membrane* is only 0.003 mm. thick. It consists of a middle layer of connective tissue, bordered on each free surface by thin epithelium (fig. 928). The lateral wall of the cochlear duct is supported by thickened and altered periosteum. This so-called *spiral ligament* contains many blood-vessels in its upper portion (*i.e.,* nearer the junction with the vestibular membrane), and these extend even into the irregular pseudostratified epithelium which clothes it. Accordingly, this especially vascular region is designated the *stria vascularis* (fig. 928).

The floor of the cochlear duct is most highly specialized of all (figs. 928, 929). On the side of the scala tympani the periosteum of the osseus lamina spiralis is continued past the lamina

itself and, as the fibrous *lamina basilaris* (or basilar membrane), stretches to the spiral ligament of the lateral wall. On the side next the duct lumen the periosteum is thicker, forming the *limbus laminæ spiralis* which serves for the attachment of the *tectorial membrane.* The latter is a delicate, flexible, gelatinous membrane overlying the rest of the sensory receptive mechanism; it is an epithelial derivative, cuticular in nature. The *spiral organ* (of Corti) is the special epithelial apparatus which is affected by sound. It is an elevated epithelial band, placed upon the basilar membrane and extending the full length of the cochlear duct. The organization of

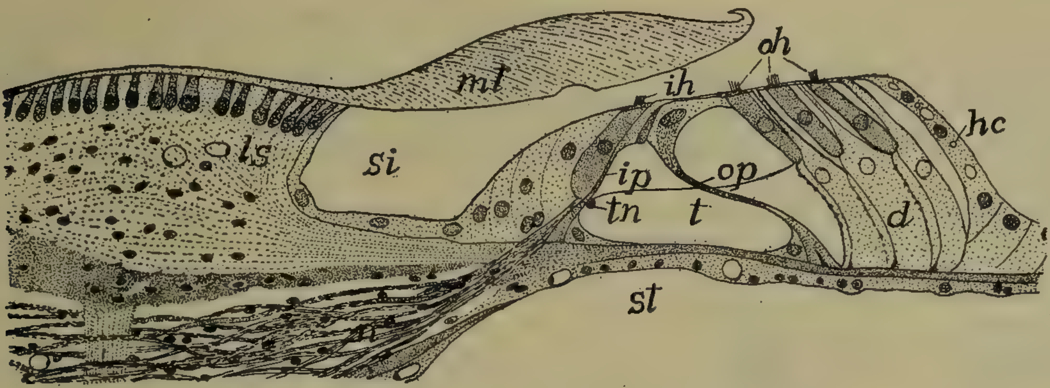


FIG. 929.—RADIAL SECTION THROUGH THE SPIRAL ORGAN OF THE GUINEA PIG. × ABOUT 250. (Kingsley, after Schneider.)

d, Deiter's cells; *hc*, Hensen's cells; *ih*, inner hair cells; *ip*, inner pillar cells; *ls*, limbus spiralis; *mt*, tectorial membrane; *n*, nerve fibers; *oh*, outer hair cells; *op*, outer pillar cells; *si*, inner sulcus; *st*, scala tympani; *t*, tunnel; *tn*, tunnel nerve.

the spiral organ is somewhat complex, but in general it consists of inert *supporting cells* and shorter *hair cells.* The supporting cells are all tall, slender elements, extending from the basilar membrane to the free surface. Conspicuous types are the pillar cells which bound the central *tunnel,* an axial canal throughout the whole length of the organ. The two groups of hair cells, inner and outer according to their relation to the tunnel, are short cylinders with rounded bases which reach scarcely half way to the basilar membrane; their free ends bear numerous stiff cilia. Nerve fibers from the cochlear division of the acoustic nerve take a complex course but their terminal branches finally embrace the bodies of hair cells.

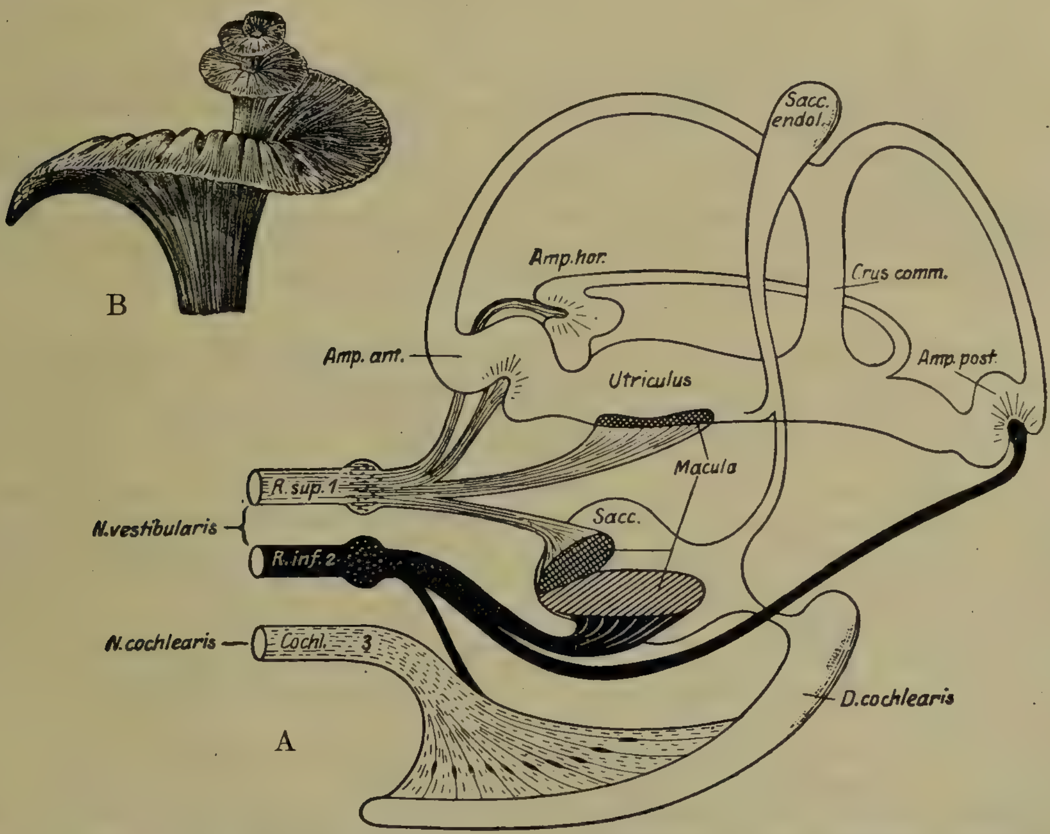


FIG. 930.—A. DIAGRAM OF THE DISTRIBUTION OF NERVES TO THE MEMBRANOUS LABYRINTH. (Kolmer, after de Burlet.)

B. THE COCHLEAR NERVE, REMOVED FROM THE BONY COCHLEA. × 4. (After Arnold.)

5. Vessels and nerves.—The chief *artery* of the labyrinth is the internal auditory, a branch of the basilar artery (fig. 592). It divides into vestibular and cochlear divisions and accompanies the similar divisions of the acoustic nerve. The stylomastoid artery also supplies some minute twigs to the cochlea. The *veins* accompany the arteries and unite into the internal auditory vein which drains either into the transverse or the inferior petrosal sinus. Both the aquæductus vestibuli and canaliculus cochleæ transmit small veins. True *lymphatics* are absent.

The *nerve* of the membranous labyrinth is the acoustic which divides into two divisions (pp. 1023, 1024). The vestibular nerve arises from cells of the vestibular ganglion, situated at the bottom of the internal acoustic meatus (fig. 927); its fibers are distributed in two rami to the maculæ of the utricle and saccule and to the ampullæ of the semicircular ducts (fig. 930 A). Contained in the spiral canal of the modiolus is the spiral ganglion of the cochlear nerve (figs. 927, 928); its peripheral fibers pass from the modiolus through the spiral lamina to reach the hair cells in the organ of Corti, about which the fibers arborize (figs. 925, 928, 929, 930 B).

DEVELOPMENT OF THE EAR

The sensory epithelium lining the internal ear is derived from the surface epithelium of the embryonic head. On the other hand, the external and the middle ear are portions of the primitive branchial apparatus secondarily adapted to auditory purposes.

The ear of the child still differs structurally from that of the adult in several important respects, as explained on p. 41.

The internal ear.—A thickened *auditory placode* of ectoderm, adjacent to the hindbrain, appears during the fifth week of development and invaginates first into a dimpled pit (fig.

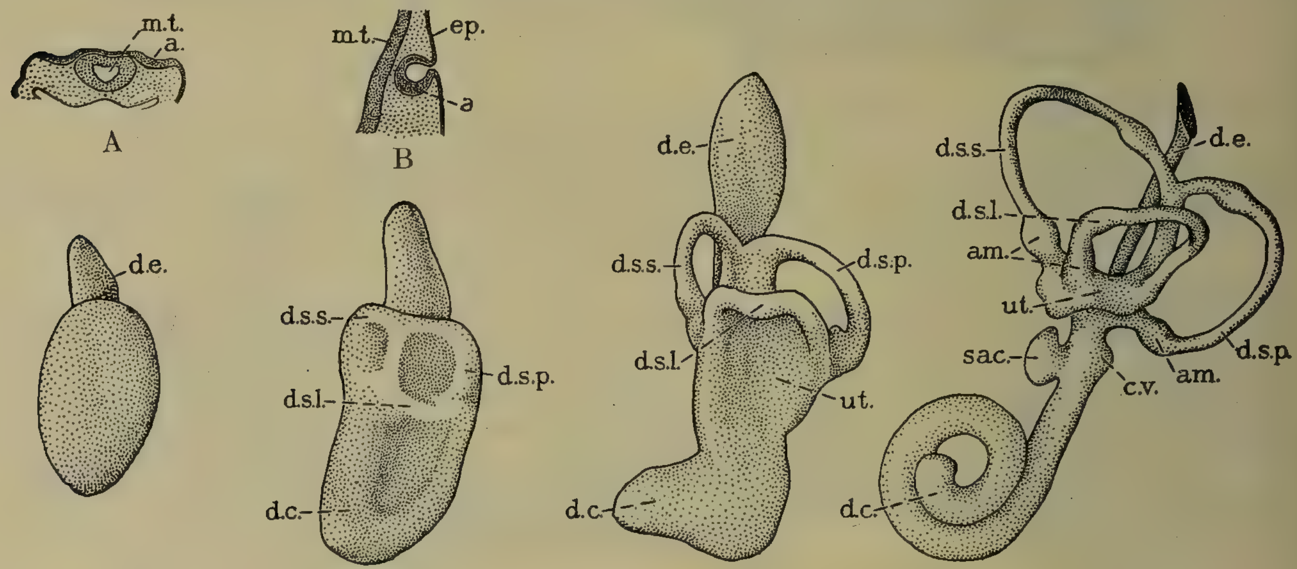


FIG. 931.—THE DEVELOPMENT OF THE MEMBRANOUS LABYRINTH.

A, B, Sections through the auditory placode and otocyst from rabbit embryos of about 4 mm. × 9. (Lewis.)

C–F. Models of the left membranous labyrinth, in lateral view, from human embryos of 7 to 22 mm. (After His.)

a., Auditory placode and otocyst; *am.*, ampulla; *c.v.*, vestibular cecum; *d.c.*, cochlear duct; *d.e.*, endolymphatic duct; *ep.*, epidermis; *d.s.l.*, *d.s.p.*, *d.s.s.*, lateral, posterior and superior semicircular ducts; *m.t.*, neural tube; *sac.*, sacculus; *ut.*, utriculus.

931 A). This soon forms a complete pouch, loses its connection with the surface, and sinks toward the interior (B). This stage is named the *otocyst*, or *otic vesicle.* It is at first ovoid in shape, but near the upper end there is a small, hollow stalk destined to become the *endolymphatic duct* of the adult (C). The otocyst itself then elongates and undergoes marked alterations in shape and form.

From the wider, dorsal portion of the otocyst two flattened, pouch-like projections arise, one placed vertically, the other horizontally. Along the free margins of the pouches are differentiated the *semicircular ducts*, the superior and posterior from the vertical pouch and the lateral duct from the horizontal one (D). The walls of the central part of each pouch become adherent, and the fused, plate-like areas are then absorbed; with this change the peripheral rim of each plate assumes the characteristic looped appearance of the final duct (E, F).

In the meanwhile, the opposite, ventral end of the otocyst elongates and coils into the *cochlear duct* (D-F). The epithelium of part of the floor thickens and differentiates into the sensory *spiral organ.*

The portion of the otocyst lying between the semicircular and cochlear ducts is the primitive vestibule (E). It becomes subdivided into two chambers (F). The more dorsal sac connects with the semicircular ducts and constitutes the *utricle.* A more ventral region is the *saccule,* which remains in communication both with the utricle and with the cochlear duct. The endolymphatic duct retains its connection with the internal ear through the narrow, branched stalk connecting utricle and saccule.

Clefts in the mesenchyme about the epithelial internal ear produce the two perilymph spaces, the *scala vestibuli* and *scala tympani,* while from the condensed mesenchyme itself differentiates the bony *cochlea.*

The middle ear.—The *auditory tube* and *tympanic cavity* result from the perpetuation and enlargement of the first pharyngeal pouch (fig. 61, V.P.[1]). The tympanic cavity is at first quite small but later increases greatly at the expense of the loose areolar tissue which surrounds the auditory ossicles. There is also an additional absorption of the neighboring bone and a simultaneous advance of the tympanic epithelium to line the new cavities thus excavated. In this manner the *tympanic antrum* and the *air cells* come into existence.

The *auditory ossicles* and their muscles are derived from the neighboring branchial arches. The malleus and incus, together with the tensor tympani muscle, differentiate from the mesenchyme of the first arch, while the stapes and stapedius muscle come from the second arch (fig. 30). Although the tympanic epithelium wraps about the ossicles, they always remain outside the tympanic cavity in the true sense of the word.

The external ear.—The *external acoustic meatus* is a direct derivative of the first branchial groove and is accordingly lined with ectoderm. The *tympanic membrane* represents the common plate which separates the floor of the auditory meatus (first branchial groove) from the tympanic cavity (first pharyngeal pouch).

The *auricle* is formed from nodular thickenings of the tissue bounding the outer end of the first branchial groove. Three nodules appear on the first (mandibular) arch and three on the second (hyoid) arch (fig. 13). Behind the latter, the free margin of the auricle (the *helix*) arises through a folding off of the integument. From the mandibular nodules are differentiated mainly the *crus of the helix* and the *tragus;* from the hyoid tubercles, the *crus of the anthelix*, the *antitragus*, and the *lobule* (fig. 15).

References for special sense organs.—*Development:* Keibel, Human Embryology (Keibel and Mall), vol. 2. *Comprehensive bibliographies:* Smell and taste, Kallius, Handbuch d. Anatomie des Menschen (Bardeleben), Bd. 5, Abt. 1, Teil 1; Kolmer, Handbuch d. mikr. Anatomie (Möllendorff), Bd. 3, Teil 1. Eyeball and orbit (gross), Whitnall, The Anatomy of the Human Orbit etc. Eyeball (structure), Salzmann, The Anatomy and Histology of the Human Eyeball etc. Retina, chorioid and sclera (cytology); Arey, Special Cytology (Cowdry), 2nd ed., vol. 2. Ear, Kolmer, *op. cit.;* Shambaugh, Special Cytology (Cowdry), vol. 2. *General anatomy:* Schäfer and Symington, Elements of Anatomy (Quain), 11th ed., vol. 3, pt. 2. Poirer-Charpy, Traité d'anatomie humaine. *Olfactory organ:* Schaeffer, The Nose and Olfactory Organ; Kolmer, *op. cit.;* Kallius, *op. cit.* *Gustatory organ:* v. Ebner, Handbuch d. Gewebelehre (Koelliker), 6th ed., Bd. 3; Kallius, *op. cit.;* Kolmer, *op. cit.* *Eye:* Graefe-Saemisch, Handbuch d. ges. Augenheilkunde; Salzmann, *op. cit.;* Whitnall, *op. cit.;* Arey, *op. cit.;* *Ear:* Kolmer, *op. cit.;* Shambaugh, *op. cit.*

SECTION X

DIGESTIVE SYSTEM

By C. M. Jackson, M.S., M.D., LL.D.

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF MINNESOTA

In order to furnish the living protoplasm with the materials necessary for energy, growth and repair, a constant supply of food must be provided. Most foods must be rendered soluble, and must undergo certain preliminary chemical changes, in order to make them suitable for absorption and assimilation. For this preparation of the food-supply, the *digestive system* [apparatus digestorius] (systema digestorium NK) is provided, which includes the alimentary canal and certain accessory glands (salivary glands, liver and pancreas). The alimentary canal is divided into a number of successive segments varying in size and

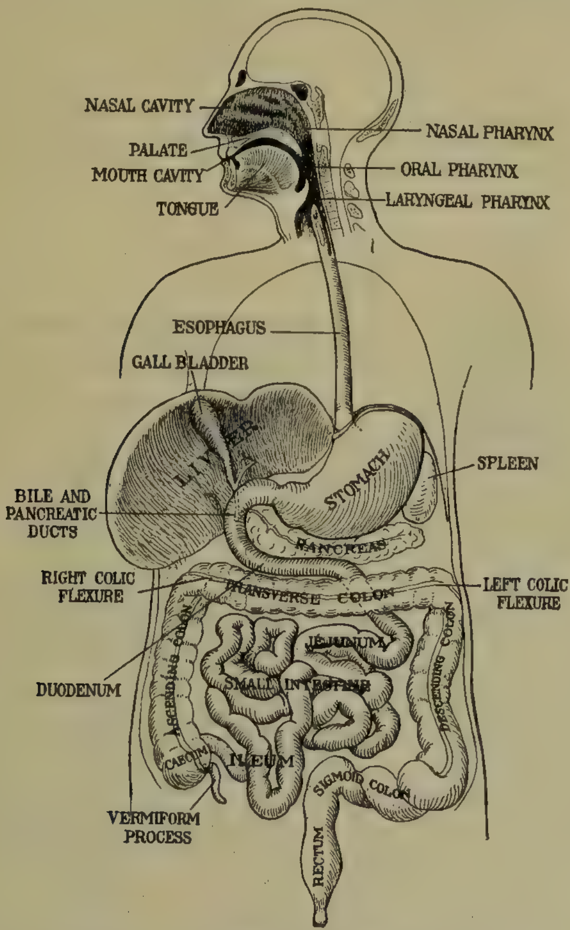


Fig. 932.—Diagram of the Alimentary Canal.

structure according to their function. These segments (fig. 932) include the mouth, pharynx, esophagus, stomach, small and large intestines.

Typical structure.—The most important layer of the tubular alimentary canal is the inner *mucous membrane* [tunica mucosa]. From its epithelial lining, the various digestive glands are derived, and through it the process of absorption takes place. The epithelium is supported by a fibrous tunic [lamina propria mucosæ] beneath which is a thin layer of smooth muscle [lamina muscularis mucosæ]. The layer next in importance is the *muscular* coat [tunica muscularis] which propels the contents along the canal. It is typically composed of two layers of smooth (involuntary) muscle, the inner circular and the outer longitudinal in arrangement. Between the mucosa and the muscularis is a loose, fibrous *submucous* layer [tela submucosa], which allows the folds in the mucosa to spread out when the canal is distended. Finally, there is an outer *fibrous* coat [tunica fibrosa], which in the abdominal cavity becomes the smooth *serous* coat [tunica serosa], or visceral layer of the peritoneum, that eliminates friction during

movements. The variations in the structure of the alimentary canal in different regions are due chiefly to differences in the mucosa.

Glands.—Since the glands form an important part of the digestive system, the classification of glands in general will be discussed briefly. A gland may be somewhat loosely defined as an organ that elaborates a definite substance which is either a waste product to be eliminated (excreted), or a secretion to be further utilized by the organism. Glands may be divided into (a) *ductless* or *endocrine glands* (e. g., spleen, thyroid gland), which pour their secretions directly into the blood or lymph; and (b) *glands with ducts*, which open upon an epithelial surface. Some organs, however, belong in *both* classes (e. g., liver, pancreas).

The glands with ducts (the so-called 'true' glands) are derived from an epithelial surface and may be further subdivided upon the basis of either (1) form or (2) cell-structure of the terminal secretory portions. According to form, glands are classified as either *tubular* or *saccular* (alveolar, acinous). Each of these may be either *simple* or *compound* (branched). The compound saccular form is often called *racemose*. Moreover, intermediate forms (tubulo-racemose) occur.

According to **cell-structure** and character of secretion, glands are divided into mucous, serous and other types. In the *mucous* type, the cells appear larger and lighter when swollen with mucus which is secreted for purposes of lubrication. The goblet-cells of the intestine represent unicellular glands of this type. In the *serous* (or albuminous) type of glands, the cells usually appear somewhat smaller and more deeply stained, with numerous zymogen granules. The secretion is a watery, albuminous fluid, which contains the digestive enzymes. There occurs also a *mixed* type, with separate mucous and serous saccules, or both types of cells may occur in the same saccule (the serous cells as 'demilunes' or 'crescents'). The term *cytogenic* glands is applied to those which produce cells (e.g., gonads and lymphoid organs). In all cases, the epithelial gland cells are supported by a fibrous connective-tissue stroma, which provides a rich vascular and nerve-supply, and forms also an external fibrous sheath or capsule surrounding the entire gland.

Morphology.—The alimentary canal in comparative anatomy is divided into the *headgut* (mouth and pharynx), *foregut* (esophagus and stomach), *midgut* (small intestine), and *hindgut* (large intestine). Embryologically, the midgut corresponds roughly to the portion of the archenteron attached to the yolk-sac, the portions of the archenteron anterior and posterior to the yolk-sac being designated as foregut and hindgut respectively. (See Section I, p. 41.) The lining epithelium of the alimentary tract is endodermal, excepting the anal canal and the mouth cavity, which are lined by invaginations of the ectoderm.

In the region of the mouth and pharynx, the digestive and respiratory systems are closely related in position, structure, function and origin. Morphologically, the headgut represents a primitive alimentary-respiratory apparatus.

THE MOUTH

The **oral cavity** [cavum oris] represents the first segment of the alimentary canal. Its walls are exceedingly specialized in structure, corresponding to its manifold functions (mastication, insalivation, taste, speech, etc.).

Boundaries.—The oral cavity communicates anteriorly with the exterior through the transverse *oral fissure* [rima oris], and posteriorly with the pharynx through the *isthmus of the fauces* [isthmus faucium]. The *anterolateral walls* are formed by the flexible lips and cheeks. The *roof* is chiefly immovable and is formed by the upper jaw with the hard and soft palate. The movable *floor* is formed by the lower jaw, the tongue and the sublingual region.

Subdivisions.—The oral cavity is subdivided by the alveolar and dental arches into an inner cavity, the *oral cavity proper* [cavum oris propium], and an outer *vestibule* [vestibulum oris] adjacent to the lips and cheeks (fig. 933). When the upper and the lower teeth are in apposition, the vestibule communicates with the oral cavity proper (aside from the small interdental spaces) only through a space behind the last molar teeth on each side. Opening into the oral cavity are certain accessory glands, the salivary glands.

When the teeth are clenched (as in tetany), there is still a space behind the molar teeth, through which a medium-sized catheter may be passed from the oral vestibule into the mouth cavity proper and the pharynx.

Structure.—Of the typical layers of the alimentary canal, only the mucous membrane can be recognized as a continuous layer in the mouth cavity. Even this is greatly modified and its structure somewhat resembles the skin, from which it is derived and with which it is continuous at the rima oris. The submucosa is a strong fibrous layer connecting the mucosa with adjacent structures, and lodging numerous racemose mucous glands. The muscles in the walls of the mouth cavity are not homologous with the typical muscularis of the alimentary canal. The outer fibrous tunic is also wanting.

The development of the oral cavity.—For a description of the invagination of the surface ectoderm to form the lining of the *oral sinus* (primitive oral cavity), see p. 18.

Variations.—The mouth is rarely absent, due to failure of the ectodermal invagination, or imperforate, due to atresia of the buccopharyngeal membrane. Other variations will be mentioned in connection with various mouth-organs.

Comparative.—The phylogenetic origin of the oral mucosa from the integument is indicated not only by the ectodermal origin of its lining epithelium, but by its general structure

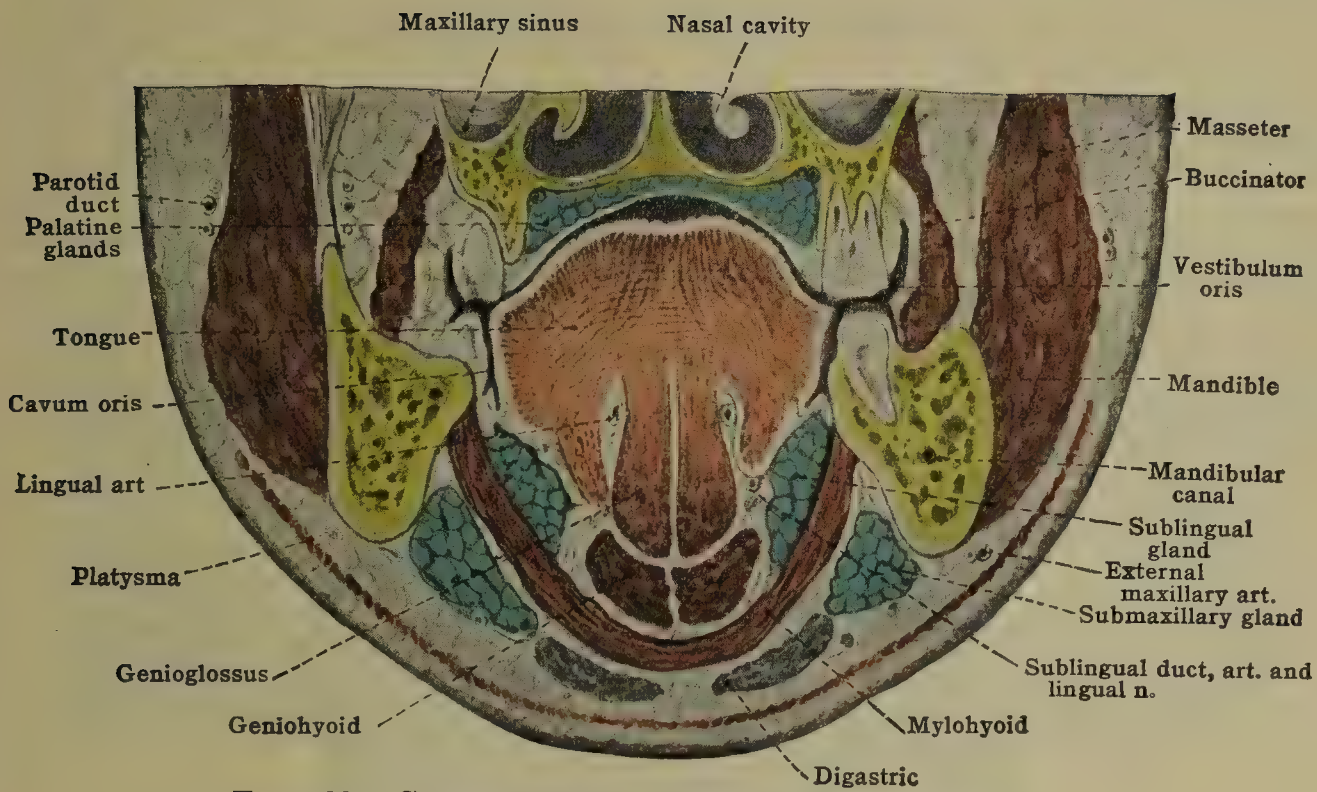


Fig. 933.—Coronal Section through Oral Region.

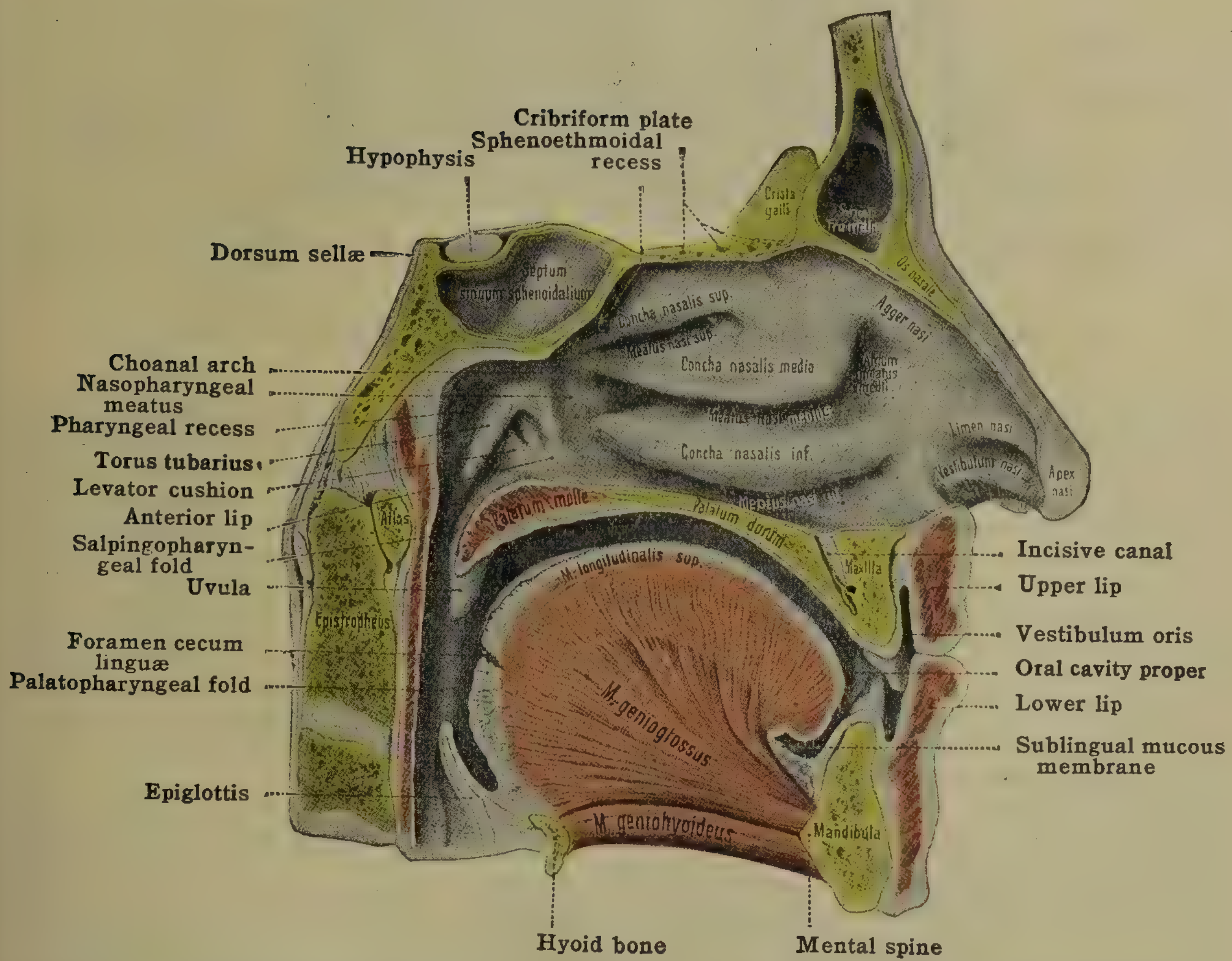


Fig. 934.—Midsagittal Section of the Head, through Oral and Nasal Regions. (Rauber-Kopsch.)

and its appendages. Among the latter may be noted the teeth (representing modified dermal papillæ), sebaceous glands, and (in some rodents) even hairs in the mucosa lining pouches in the cheeks.

THE LIPS AND CHEEKS

The **lips** [labia oris] form the anterior wall of the mouth cavity. The *lower lip* [labium inferius] (labium mandibulare NK) is marked off from the chin by the sulcus mentolabialis. The *upper lip* [labium superius] (labium maxillare NK) extends upward to the nose medially and the sulcus nasolabialis laterally. The *philtrum* is a median groove on the upper lip extending from the septum of the nose above to the *labial tubercle* [tuberculum labii superioris] below, at the middle of the rima oris. On each side of the rima oris the upper and the lower lips are continuous at the angle of the mouth [angulus oris], which is usually opposite the first premolar teeth. Laterally, the lips are continuous with the *cheeks* [buccæ], which form the lateral walls of the mouth cavity.

Fig. 935.—Sagittal Section of the Lower Lip. (Lewis and Stöhr.)

In **structure**, the *lips* (fig. 935) consist essentially in a middle layer of cross-striated muscle (orbicularis oris) covered externally by skin which is continuous through the rima oris with the oral mucosa forming the inner layer of the lips. The mucosa lines the vestibulum oris and is reflected upon the gums above and below. The labial artery lies near the free margin of the lip, just under the mucosa, where its pulsation is easily felt. There is free anastomosis between the arteries of the two sides, which should be remembered in case of hemorrhage from labial cuts. In the median line above and below, there extends from the lip to the gum a small fold of the mucosa [*frenulum* labii superioris vel inferioris]. The structure of the *cheeks* (figs. 933, 947) is similar to that of the lips but somewhat more complicated. Both are highly elastic.

The muscular basis of the **cheek** is the buccinator muscle. External to this is the dense fascia buccopharyngea and a thick layer of fat [corpus adiposum buccæ] covered partly by the dermal muscles (platysma, zygomaticus, etc.) and lastly the skin. Internally the cheek is lined by the oral mucosa, continuous with that of the lips. The parotid duct opens into the vestibule opposite the second upper molar tooth.

Glands.—The *skin* of the lips and cheeks is well supplied with the usual sudoriparous and sebaceous glands. The mucosa likewise presents two kinds of glands, the sebaceous and the mixed (mucous) glands. The *sebaceous* glands are relatively few in number and variable, being present in about 30 per cent. of cases in the adult (Stieda). They are similar in structure to those of the skin (though not associated with hair-follicles), and when present are visible as small yellowish bodies in the mucosa. They occur chiefly near the free margins of the lips and along the cheek opposite the teeth.

The *mixed* (*mucous*) *glands* are much more numerous and constantly present (figs. 936, 937). They are all of the racemose type. They are variable but small in size, and closely packed together in the submucosa of the lips [glandulæ labiales], where they may easily be felt. Those of the cheeks [gl. buccales] are less numerous. A few of them, especially in the region of the molar teeth [gl. molares] (retromolares NK), are placed outside the buccinator. The ducts of the molar glands pierce this muscle near the parotid duct to open on the surface of the mucosa.

Vessels and nerves.—The mucosa of the lips and cheeks has a characteristic reddish hue, on account of the numerous blood-vessels which are visible through the thick but transparent stratified squamous epithelium (figs. 935, 937). The numerous papillæ of the lamina propria are highly vascular. The *blood-supply* of the lips and cheeks is derived chiefly from the labial (coronary) and buccal arteries. The rich *nerve-supply* (sensory) is from the infraorbital, mental and buccal branches of the trigeminus. The lips are especially sensitive near the rima oris.

Development.—During the second month in the human embryo, ledges of epithelium grow into the substance of the mandibular and the fused frontonasal and maxillary processes.

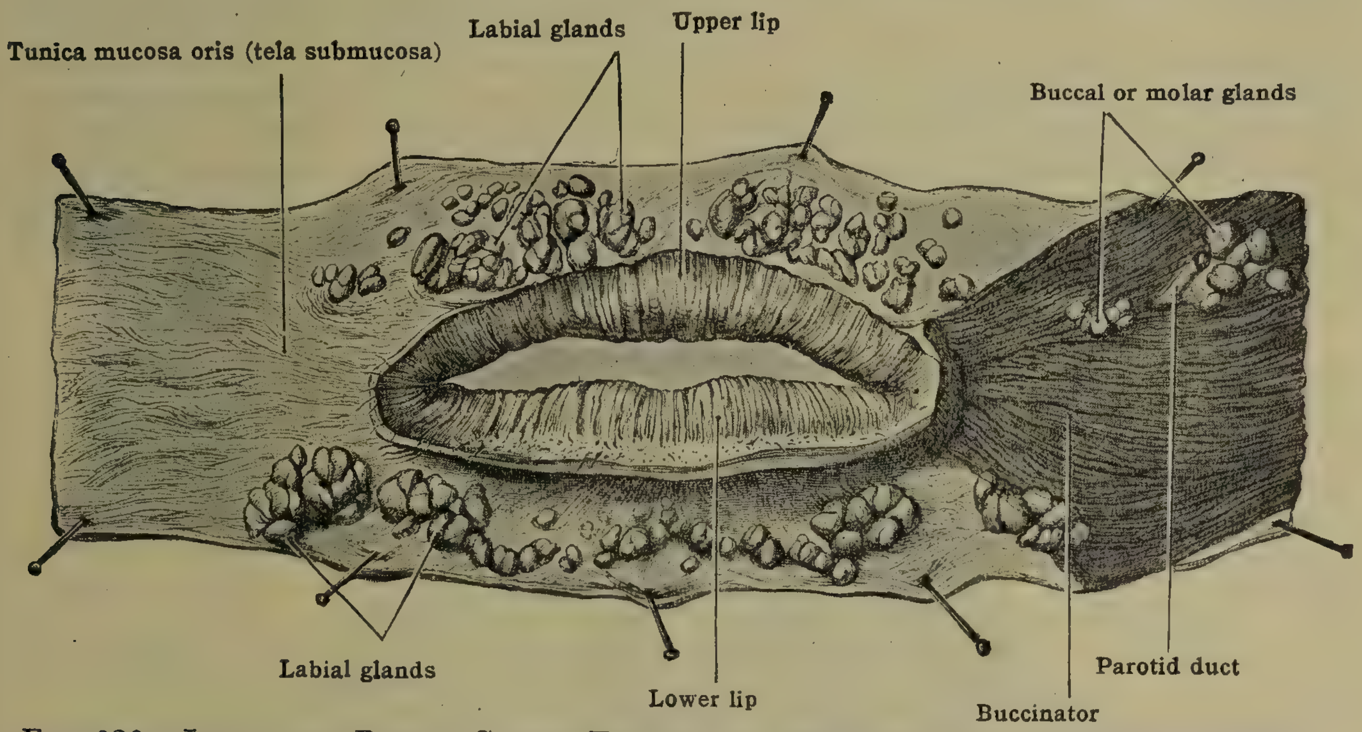


Fig. 936.—Labial and Buccal Glands Exposed by Dissection of the Skin from in Front. (From Toldt's Atlas.)

These ledges develop into grooves which separate the lower and the upper lip from the corresponding lower and upper jaws, the grooves forming the oral vestibule.

The philtrum and labial tubercle are said to correspond to the lower part of the frontonasal process. A failure of union between the medial nasal and the maxillary processes presents an arrest of development resulting in the malformation known as 'harelip.'

In the late fetus and newborn, the red portion of the lips consists of an external smooth *pars glabra,* and an inner zone, *pars villosa,* which is covered with numerous villus-like projections. The largest of these reach a length of 1 mm. They also extend backward in an irregular band along the mucosa of the cheek. They disappear during early postnatal life. In the

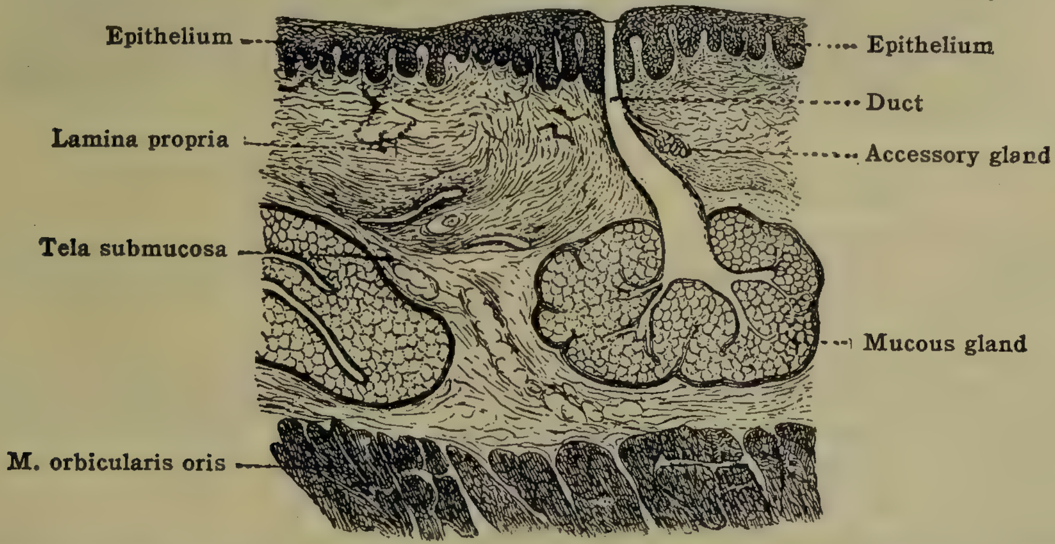


Fig. 937.—Section of Labial Mucosa, Showing Glands. × 16. (From Toldt's Atlas.)

infant, the *corpus adiposum* is especially well developed. On account of its supposed aid as a support for the buccinator in sucking, it has been called the 'sucking pad.'

The sebaceous glands of the mucosa are said not to appear until about the age of puberty.

Variations.—As is well known, the lips and cheeks are exceedingly variable in shape, size and structure in different individuals. There are also characteristic differences according to race and sex in the form and structure of the lips, rima oris, beard, etc. The 'harelip' malformation was mentioned above.

Comparative.—Typical muscular lips are found only in mammals, and are probably organs phylogenetically developed in connection with the process of suckling.

THE PALATE

The **palate** forms the roof of the mouth cavity proper, and consists of two portions, the anterior or hard palate and the posterior or soft palate.

The **hard palate** [palatum durum] (figs. 934, 938) is continuous in front and laterally with the alveolar processes of the maxilla, and gives attachment posteriorly to the soft palate. It separates the mouth from the nasal cavity. It is supported by the palatine process of the maxilla and the horizontal part of the palate bone. The *oral surface* is concave from side to side, and also from before backward. It is covered by a thick, somewhat pale mucosa, which is firmly adherent to the periosteum through the submucosa. The submucosa contains numerous mucous *glands* [gl. palatinæ] (fig. 938), similar to those of the lips.

In the median line of the hard palate is a line or ridge, the *raphe* (fig. 938) terminating anteriorly in the small *incisive papilla,* which corresponds in position to the bony incisive foramen. Anteriorly there occur four to six more or less

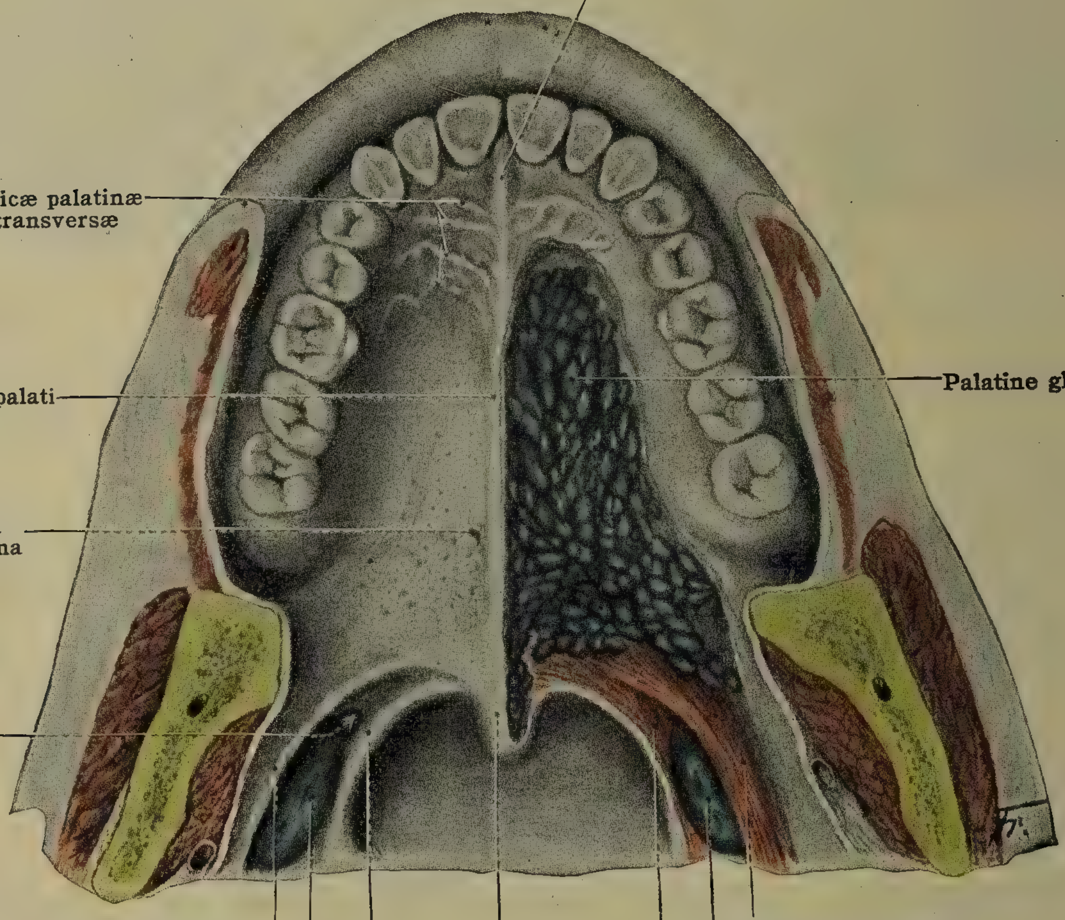


FIG. 938.—ROOF OF MOUTH, SHOWING HARD AND SOFT PALATE DISSECTED ON ONE SIDE. (Rauber-Kopsch.)

distinct *transverse ridges* [plicæ palatinæ transversæ]. Near the posterior margin of the hard palate there is on each side of the raphe a small pit (fig. 938), the *foveola palatina,* which is variable and inconstant.

The **soft palate** [palatum molle] (figs. 934, 968) separates the posterior portion of the mouth cavity from the nasal part of the pharynx. It is attached to the hard palate anteriorly and to the pharyngeal wall laterally. The posterior portion or *velum* projects backward and downward into the pharynx. Its free margin presents a median conical projection, the *uvula,* and splits laterally on each side to form two folds, the palatine arches, between which is located the palatine tonsil (fig. 938). The palatine arches and tonsil will be described later in connection with the pharynx.

Structure.—The soft palate is a fold of mucous membrane enclosing a fibrous aponeurosis, muscles, vessels, and nerves. It is marked in the middle line by a raphe indicating the line of junction of the two halves from which it was formed.

The posterior layer of the mucous fold, which is directed toward the cavity of the nasal pharynx, is continuous with the nasal mucous membrane; the anterior layer lies in the posterior

boundary of the mouth and is continuous with the mucous membrane of the hard palate. The structure of the palatal mucosa is very similar to that of the lips (fig. 935). Mucous glands are numerous in both layers, but more especially in the anterior, and make up a large portion of the mucosa and submucosa (figs. 937, 938).

The palatal aponeurosis is attached above to the posterior margin of the hard palate; laterally it is continuous with the aponeurotic layer of the pharyngeal wall; below, toward the lower margin of the velum, it gradually disappears. It gives attachment to fibers of the levator veli palatini and the pharyngopalatinus (palatopharyngeus) and to the tendon of the tensor veli palatini.

Muscles.—The muscles of the soft palate are described later (p. 1223) with those of the pharynx, with which they are closely associated.

Vessels and nerves.—The arterial supply of the *hard palate* is derived chiefly from the major palatine branches of the internal maxillary. The arteries of the *soft palate* include: (1) Ascending palatine from the external maxillary (facial); (2) pharyngeal branches of the ascending pharyngeal; (3) twigs from the descending palatine branch of the internal maxillary, which enter the smaller palatine canals, are distributed to the soft palate and tonsils, and communicate with the ascending palatine of the external maxillary (facial) artery; (4) twigs from the dorsal branch of the lingual artery. Of these arteries to the soft palate, the descending palatine is the largest.

The *sensory nerves* to the palate are derived chiefly from the trigeminus through the sphenopalatine ganglion. The hard palate is supplied by the nasopalatine and anterior palatine branches; the soft palate chiefly by the middle and posterior palatine branches. The *motor* nerves will be mentioned later in connection with the muscles.

Topography.—Behind the last molar tooth can be felt the *coronoid process of the mandible*, and higher up, the *pterygoid hamulus of the sphenoid.* The latter is a landmark to the site of the greater palatine foramen, which lies just in front of it, and which transmits the greater palatine branch of the descending palatine artery, together with the anterior palatine nerve. The vessel and nerve run forward in grooves on the lower surface of the palatine process of the maxilla, giving off anastomosing branches toward the midline, and join at the incisive foramen with the nasopalatine artery. Their position must be remembered in raising the flaps during the operation for closure of a cleft in the hard palate. To ensure the vitality of the flaps the incisions must be made lateral to the vascular arch, close to and parallel with the upper alveolus, and should not extend beyond a point opposite to and just medial to the last molar tooth, for fear of encroaching upon the posterior palatine canal.

The development of the palate.—The development of the *palatine shelves* is described on p. 42. The incisive foramen indicates the place of meeting of the medial nasal process (premaxilla) and the two lateral palate shelves, which closes the primitive communication between the oral and the nasal cavity. A lack of union of the palate shelves presents an arrest of development known as cleft palate. The *uvula* is similarly formed by the union of the posterior ends of the palatine shelves, and a failure to unite may produce a bifid uvula. Complete cleft palate may occur combined with hare-lip, and may be unilateral or bilateral. In this condition the lateral incisor tooth may be found on either the medial or the lateral side of the cleft.

In paring the edges of a cleft soft palate, the following structures would be successively cut through:—(1) Oral mucous membrane; (2) submucous tissue, with vessels, nerves, and glands; (3) glossopalatine muscle; (4) aponeurosis of tensor palati; (5) anterior fasciculus of pharyngopalatine; (6) levator palati and uvular muscles; (7) posterior fasciculus of pharyngopalatine; (8) submucous tissue, vessels, nerves, and glands; (9) posterior mucous membrane. The soft palate is thicker than it seems, the average in an adult being 6 mm. (¼ in.). The muscles widening a cleft are the tensor and levator, while the superior constrictor closes it in swallowing.

Variations.—The transverse *palatine ridges* are quite variable in number and prominence, and are better developed in the infant than in the adult. On each side of the *incisive papilla* there is often found a small pit or shallow tube, a vestige of the embryonal incisive canal (Merkel). Sometimes there is instead a single median pit, representing the lower end of the incisive (Stenson's) canal. The foveola palatina occurs in 50 per cent. of children and 70 per cent. of adults (B. Fischer).

Comparative.—The palate is absent in fishes. In amphibia, the nasal cavities open directly into the primitive mouth cavity. In some birds, the palate shelves fail to unite, leaving a normal cleft palate. The incisive (Stenson's) canal remains open permanently in some mammals (e.g., ruminants), bifurcating above and thus placing the mouth cavity in communication with the nasal cavity on each side in the vicinity of Jacobson's organ. The transverse palatine ridges are much better developed among many mammals, especially the carnivora and ungulata. The uvula in most mammals is rudimentary or absent.

THE TONGUE

The **tongue** [lingua] is a muscular organ covered with mucous membrane and located in the floor of the mouth. It is an important organ of mastication, deglutition, taste and speech. Upon its upper surface (fig. 947) is a V-shaped groove (sulcus terminalis) indicating the division of the tongue into two parts. The larger anterior part, or *body* [corpus linguæ] belongs to the floor of the mouth, while the smaller posterior part, or *root* [radix linguæ], forms the anterior wall of the oral pharynx. The *inferior* surface [facies inferior] (f. mylohyalis NK) of the tongue is chiefly attached to the muscles of the floor of the mouth, from the hyoid bone to the mandible (fig. 942). Anteriorly and laterally, however,

the inferior surface of the body is free and covered with mucosa. The superior surface of the body is called the *dorsum*. It is separated from the inferior surface by the *lateral margins*, which meet anteriorly at the *tip* [apex linguæ].

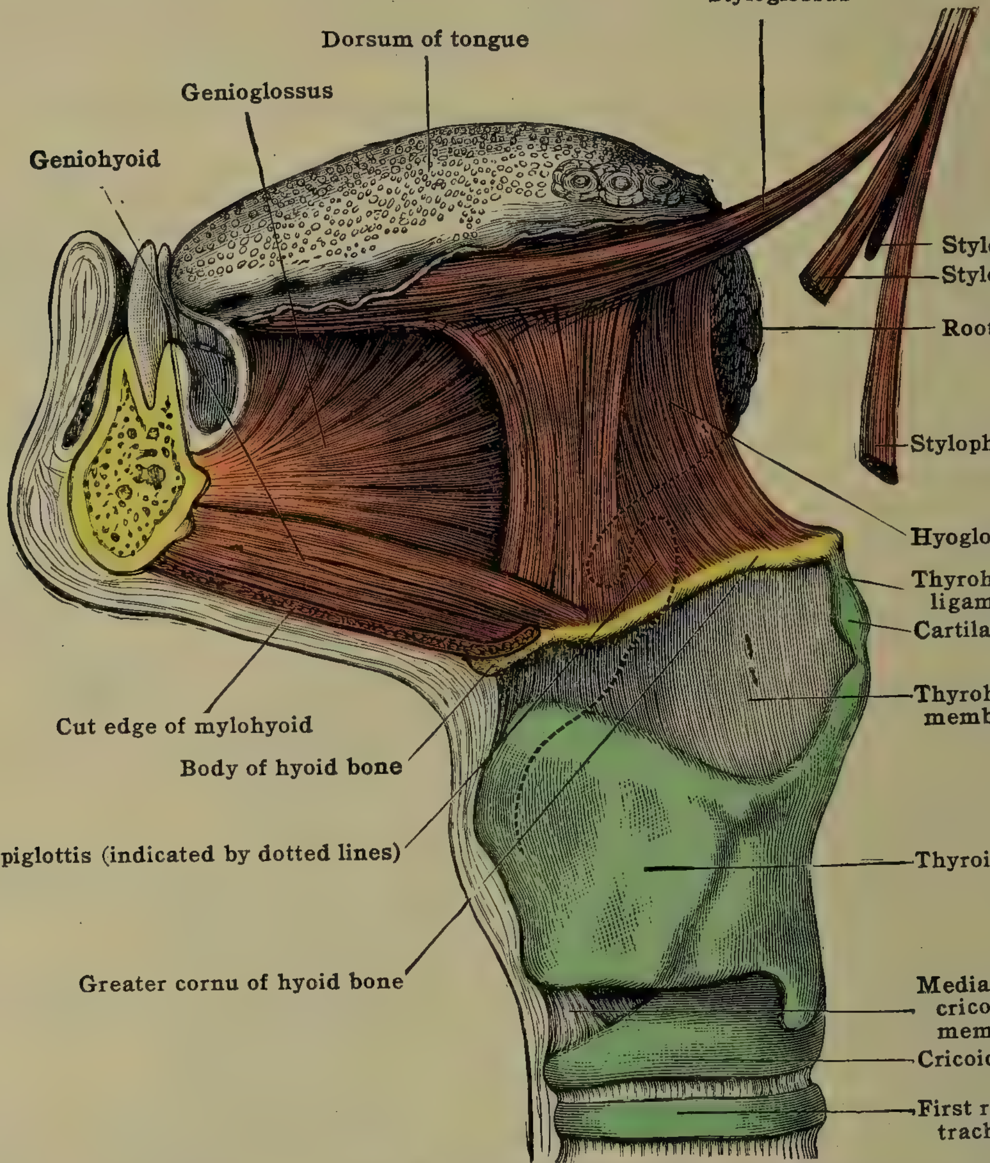


Fig. 939.—Left Side of the Tongue, with its Muscles, Etc.

The **dorsum** of the tongue usually presents a slight *median groove* [sulcus medianus linguæ]. Its posterior end corresponds to a small pit of variable depth, the *foramen cecum*, which is placed at the apex of the V-shaped *terminal sulcus*.

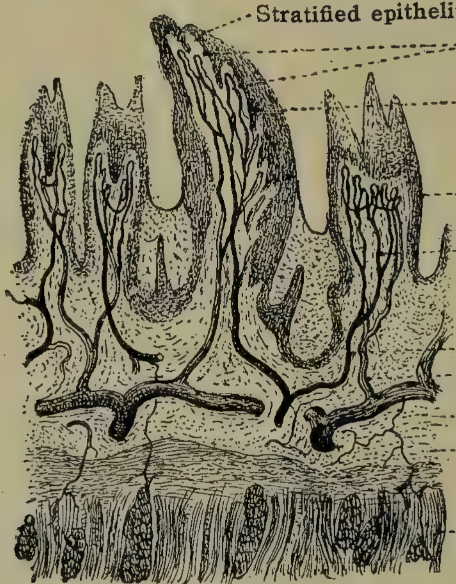


Fig. 940.—Section of Lingual Papillæ. × 20. (From Toldt's Atlas.)

The dorsum of the body has a characteristic rough appearance due to numerous small projections, the *lingual papillæ*.

Lingual papillæ.—Five or six varieties of papillæ are distinguished, between which intermediate forms occur. The *conical* [papillæ conices] and *thread-like* [papillæ filiformes] are most numerous, and are arranged more or less distinctly in rows parallel with the terminal sulcus (fig. 940). They are best developed toward the midline of the dorsum in its posterior part. As shown in vertical section (fig. 940), each papilla consists of an axial core of vascular fibrous tissue (from the lamina propria) often beset with smaller secondary papillæ. The stratified squamous epithelial covering often presents numerous thread-like prolongations from the apex of the papilla. The papillæ vary from 1 to 3 mm. in length.

The **fungiform** ('toadstool-shaped') papillæ are somewhat similar to the conical in structure, but larger and more prominent, with an expanded free portion and a slightly constricted stalk of attachment. They are relatively few in number and are scattered irregularly over the dorsum, being most numerous near the margins (fig. 938). They are easily distinguished in life by their larger size and reddish color. A smaller, flattened variety of the fungiform is sometimes called the *lenticular* ('lens-shaped') papillæ. (This term, however, is applied by Toldt to certain small rounded elevations with underlying lymphatic nodules in the mucosa of the root of the tongue.)

The **vallate** (circumvallate) papillæ [papillæ vallatæ], usually seven to eleven in number, are conspicuous and arranged in a V-shaped line parallel with and slightly anterior to the sulcus

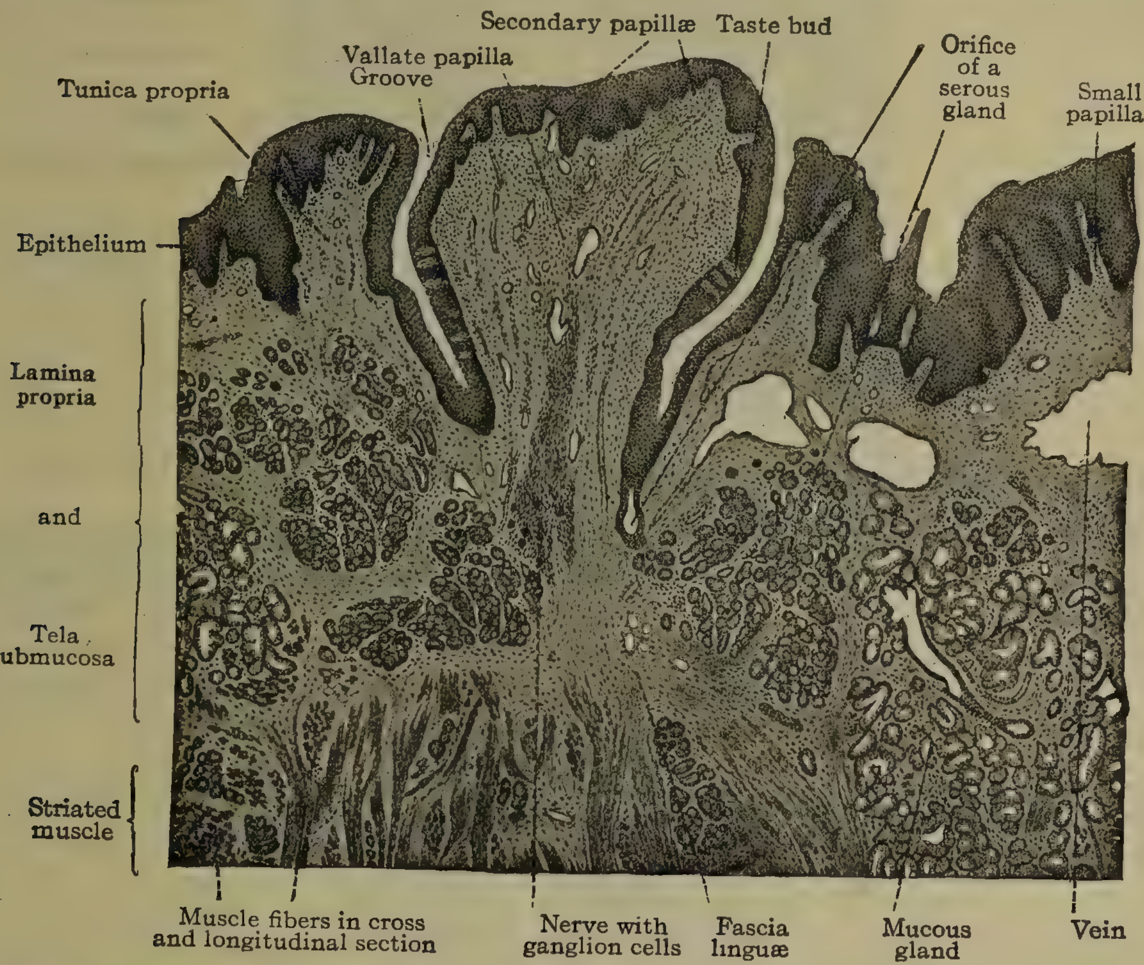


FIG. 941.—VERTICAL SECTION OF A HUMAN VALLATE PAPILLA WITH LINGUAL GLANDS. × 25. (Lewis and Stöhr.)

terminalis, (fig. 947). They are, as a rule, shaped like short cylinders, 1 to 2 mm. in width, and somewhat less in height. As is shown in section (fig. 941), each is surrounded by a trench or fossa, into the bottom of which open ducts of the serous glands of von Ebner. On the sides of the fossæ are the *taste-buds*, as described in the section on SENSE ORGANS.

The **foliate** papillæ (folia NK) are represented by a few (five to eight) parallel transverse or vertical folds of mucosa, along the margins of the tongue just anterior to the glossopalatine arch on each side (fig. 947). They are variable in size and sometimes rudimentary. In structure they somewhat resemble the vallate papillæ (though of different form), their walls being studded with taste-buds.

The free **inferior surface** of the tongue (fig. 942) is covered by a thin smooth mucosa. In the median line is a prominent fold, the *frenulum linguæ*, which connects the tongue with the mandible and the floor of the mouth. On each side of the inferior surface, an irregular, variable, fringed fold, the *plica fimbriata*, extends from near the apex backward approximately parallel with the lateral margin of the tongue (fig. 942). Between the frenulum and the plicæ fimbriatæ, the lingual (ranine) veins are visible on each side beneath the mucosa.

The **root** (or base) of the tongue [radix linguæ] belongs to the pharynx, but is here included with the mouth for convenience of description. Its free surface is directed posteriorly, and represents the continuation of the dorsum linguæ (fig.

939). Laterally it is continuous with the region of the palatine tonsils. Inferiorly it extends to the epiglottis, with which it is connected by a median and two lateral folds, between which are the depressions known as the *valleculæ.*

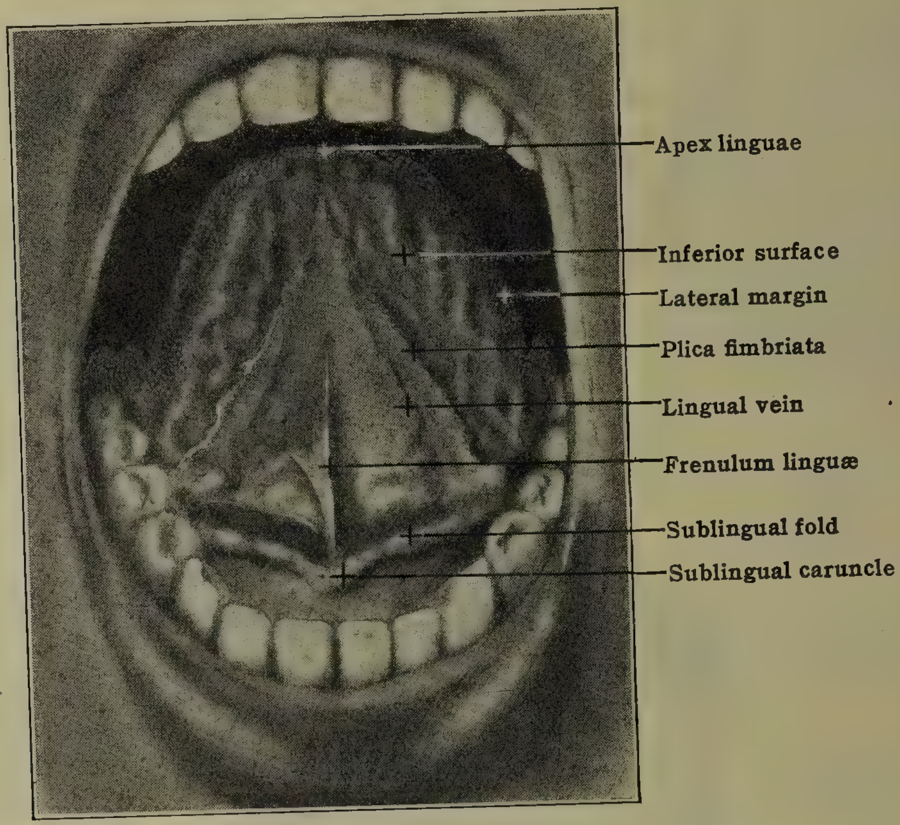


Fig. 942.—Inferior Surface of the Tongue. (Modified from Spalteholz.)

The mucosa over the root of the tongue is irregular and warty in appearance, due to the projections of the underlying nodular masses of lymphoid tissue, the *lingual follicles.* A *crypt* or tubular pocket of surface epithelium usually dips down into each of these follicles, as seen in surface view, and shown in section

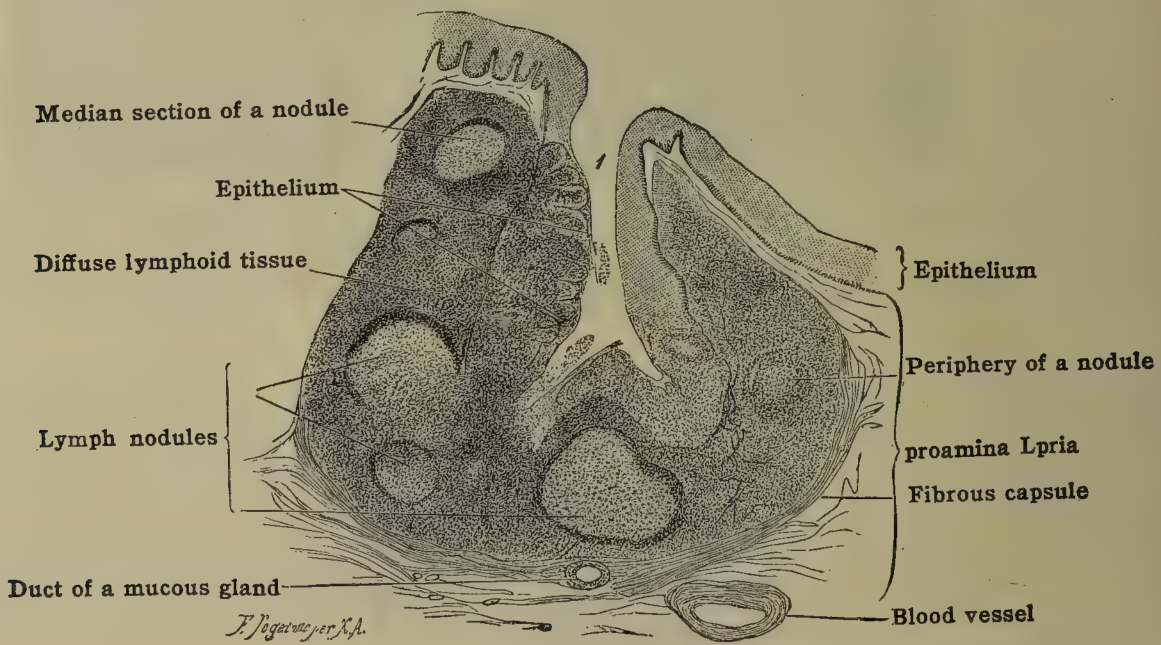


Fig. 943.—From a Section of the Lingual Tonsil of an Adult Man. × 20. 1, Pit (crypt) containing leucocytes which have infiltrated its epithelium on the left side; that on the right is almost intact. (Lewis and Stöhr.)

(fig. 943). The lingual follicles are collectively designated as the **lingual tonsil** [tonsilla lingualis]. The sulcus terminalis forms a fairly sharp boundary between the lymphoid mucosa of the root and the papillated mucosa of the body of the tongue (fig. 947).

The follicles vary from 34 to 102 in number, the average being 66 (Ostman), and are somewhat irregular in size and form. They are often arranged in more or less distinct longitudinal

rows, with corresponding folds of the mucosa (Jurisch). Between the lingual follicles and around the periphery of the lingual tonsil there are found smaller ordinary lymphoid nodules (without crypts) and indefinite masses of lymphoid tissue.

Glands.—The glands of the tongue are of three types—mucous, serous and mixed. The most numerous are those of the **mucous** type. They are spread over the entire surface of the root of the tongue, in the spaces between the lingual follicles, usually opening upon the surface but in many cases into the crypts. Anteriorly, they extend a short distance along the posterior portion of the lateral margin of the tongue, and also occupy small areas in and near the midline in front of the vallate papillæ.

In the immediate region of the vallate papillæ, and in the small lateral areas corresponding to the foliate papillæ (i. e., in the regions of the taste-buds), the mucous glands are replaced by the **serous** glands (of von Ebner), which have a watery secretion (fig. 941). Finally, on the inferior surface of the tongue, on either side of the frenulum near the apex, are the **anterior lingual glands** (gl. apicis linguæ; glands of Nuhn or Blandin). Each is about 15 mm. in length, and is composed of a group of racemose glands with about 5 very small ducts opening on the surface between the anterior portions of the plicæ fimbriatæ. The anterior lingual glands are deeply placed and are covered not only by the mucosa, but also by some of the longitudinal muscle-fibers. This gland is of the mixed type, though chiefly mucous. A retention cyst of this gland is called a ranula, as it resembles a frog's belly.

Muscles of the tongue.—A layer of fibrous connective tissue, the **lingual septum,** separates the halves of the tongue, extending in the median plane from the apex to the root, where it is

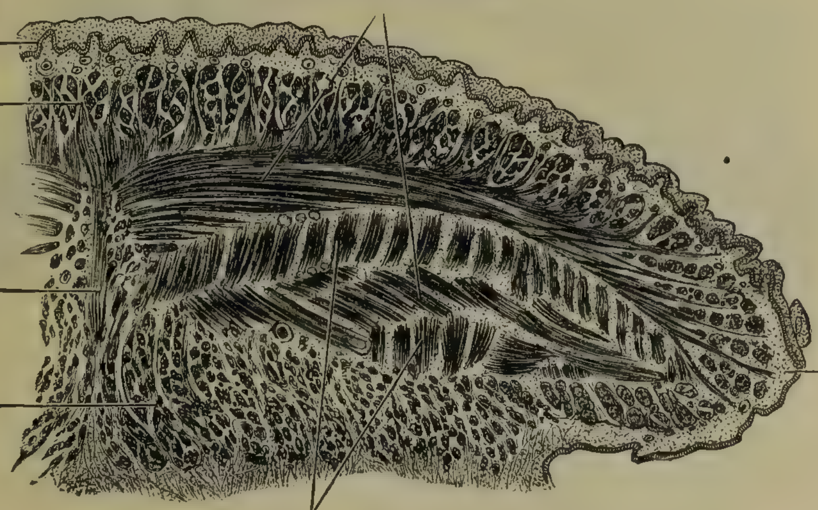


Fig. 944.—Transverse Section through the Left Half of the Tongue. (Magnified.) (From a preparation by Mr. J. Pollard, Middlesex Hospital Museum.)

attached below to the hyoid bone. The muscles of the tongue are classified as extrinsic and intrinsic. The **extrinsic muscles** (fig. 939) extend into the tongue from without. They are the hyoglossus, chondroglossus, genioglossus, styloglossus, and glossopalatinus (palatoglossus), all of which are described elsewhere (see Section V).

The attachments of the genioglossus can be felt behind the symphysis. Division of these muscles allows the tongue to protrude freely from the mouth; but when both are divided the tongue becomes unsteady and may easily fall back over the larynx during anesthesia or in sleep. Therefore, in operative procedures at least part of this attachment should be preserved if possible.

The intrinsic muscles.—The **longitudinalis superior** (or superficialis NK) (fig. 944) is a superficial longitudinal stratum extending from the base to the apex of the tongue, immediately beneath the mucosa of the dorsum, to which many of its fibers are attached. The **longitudinalis inferior** (or profundus NK) (fig. 944) is composed of two muscle-bands extending from base to apex on the inferior surface of the tongue, and is situated between the hyoglossus and the genioglossus, some of its fibers near the apex mixing with the styloglossus, while posteriorly some are attached to the hyoid bone. The **transversus linguæ** (fig. 944) consists of fibers which pass transversely, and is situated between the superior and inferior longitudinal muscles. The fibers arise from, or pass through, the septum linguæ, and are attached to the mucosa of the dorsum and lateral margins of the tongue. The **verticalis linguæ** (fig. 944) is composed of fibers which pass from the mucosa of the dorsum to the mucosa of the inferior surface of the tongue, interlacing with those of the other intrinsic and extrinsic muscles.

Vessels and nerves.—The **lingual arteries** furnish the principal blood-supply. The **lingual veins** carry the blood from the tongue to the internal jugular. The **lymphatics** form a network in the lamina propria, connected with a deeper network in the submucosa. The latter network forms plexuses around the lingual follicles. The efferent lymph-vessels from the tongue empty chiefly into the superior deep cervical lymph-nodes. (For details concerning the blood- and lymph-vessels see Sections VI and VII.) **The nerves** are motor and sensory. The **hypoglossal nerve** supplies the intrinsic and all the extrinsic muscles of the tongue except the glossopalatinus (palatoglossus), which is supplied from the pharyngeal plexus. The sensory nerves (fig. 945) are:—the **lingual nerve,** a branch of the mandibular division of the trigeminus, which, after joining with the chorda tympani from the facial, is distributed to the anterior two-thirds of the tongue and represents the nerve of touch; the **lingual branches of the glossopharyngeal** (nerve of taste), which are distributed to the root of the tongue, including also the vallate and foliate

papillæ; and the superior laryngeal branch of the vagus, which supplies a small area near the epiglottis.

Topography of the lingual nerve.—While the mouth is widely open, the pterygomandibular ligament can be seen and felt beneath the mucosa and just behind the last molar teeth. Here the lingual nerve is superficially placed. It can easily be exposed and divided to give relief from pain in lingual carcinoma, or blocked for local anesthesia. In lingual cancer the pain is often referred up the auriculotemporal nerve to the ear and side of the head.

Development.—The body of the tongue (anterior to the sulcus terminalis) is derived from the ventral region of the mandibular arch, and its epithelium is derived from the ectoderm of the oral sinus. The root of the tongue is covered with entodermal epithelium of the oral pharynx. For details concerning the development of the tongue, see p. 44.

Variations.—Of the manifold variations in the structure of the tongue, some have already been mentioned. Additional mucous glands sometimes occur along the margin of the tongue (completing Oppel's 'glandular ring'). A *forked* tongue (normal in some animals) is a rare congenital anomaly. Another rare variation is the so-called '*hairy*' tongue, due to hypertrophy of the filiform papillæ. While the V-shaped arrangement of the vallate papillæ is typical, the Y-form (two to four papillæ in the median line forming the stem of the Y) is nearly as frequent.

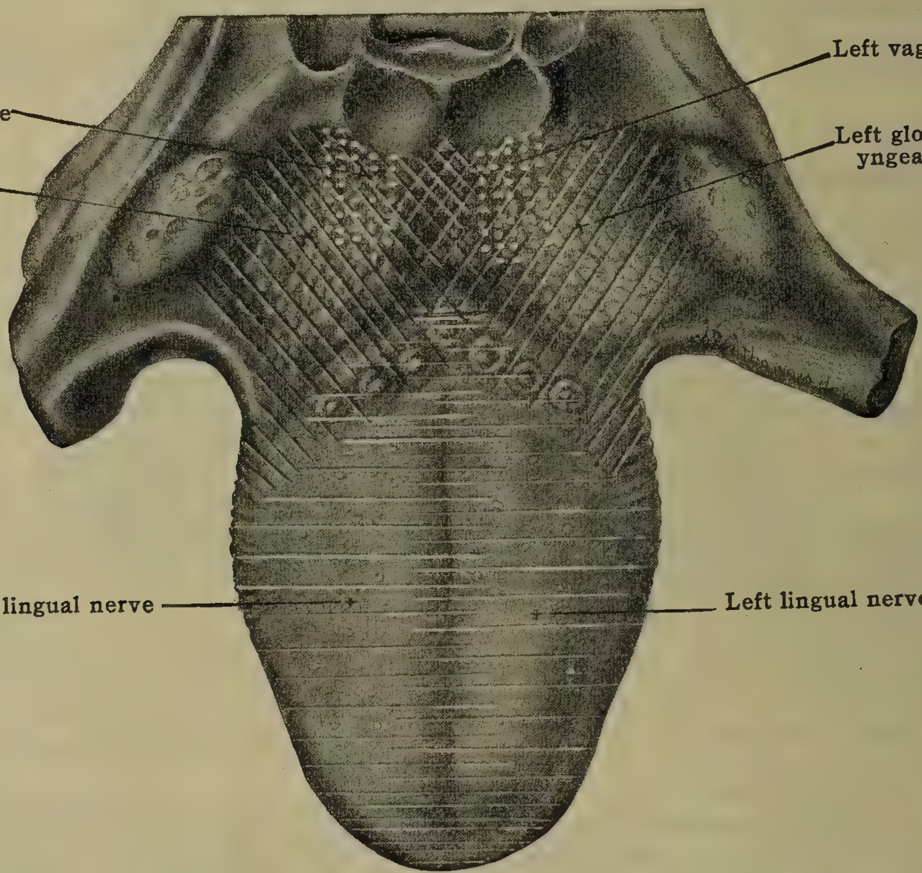


Fig. 945.—Schematic Representation of the Distribution of the Sensory Nerves in the Mucous Membrane of the Tongue. Areas of distribution according to R. Zander. White dotted area indicates vagus; oblique lines, glossopharyngeal; horizontal lines lingual.

Indeed, in some of the colored races the latter type seems to predominate. The sulcus terminalis and foramen cecum are often indistinct and sometimes absent. A persistent thyroglossal duct is rare.

In 'tongue-tied' individuals, the frenulum is abnormally short. When division of the frenulum is really required (which is not often), the scissors should be kept close to the bone in order to avoid injury to the blood vessels.

Comparative.—The rudimentary tongue of fishes contains neither glands nor intrinsic musculature. Among higher vertebrates, the tongue varies exceedingly in form and structure, but usually contains intrinsic musculature and mucous glands. The latter primitively form a ring around the margin and root of the tongue (Oppel). The serous glands are associated closely with the papillæ bearing taste-buds.

Among various mammals, the number of vallate papillæ varies from one to thirty, but the V- or Y-arrangement is typical. The region of the foliate papillæ ('marginal organ') is typcal for mammals, and is much better developed in some (e. g., rabbit) than in man. The mucosa of the root of the tongue is always different from that of the body. The lingual papillæ are especially well developed in the tongue of carnivora.

THE SALIVARY GLANDS

Numerous glands—labial, buccal, palatine and lingual—have already been mentioned, which pour their secretions into the mouth cavity. In addition to these there are three larger pairs, the salivary glands proper. They include the parotid, the submaxillary, and the sublingual (the latter really a group of glands).

THE PAROTID GLAND

The **parotid gland** [glandula parotis] is the largest of the salivary glands, varying from 15 to 30 gm. in weight. It is located below and in front of the ear in the retromandibular fossa (fig. 946), extending from the zygomatic arch above to the angle of the mandible below.

Form and relations.—The parotid is somewhat prismatic or wedge-shaped (figs. 946, 947), with three surfaces and three borders or angles. The *lateral* surface is covered by skin and superficial fascia, and in its lower part by the platysma. The *anterior* (anteromedial) surface overlaps the masseter and extends medialward in contact with the posterior border of the mandibular ramus and with the posterior aspect of the internal pterygoid muscle. An irregular 'pterygoid lobe' may extend forward. The *posterior* (posteromedial) surface is in contact with the sternomastoid muscle laterally, and with the styloid process and associated muscles medially. Between the sternomastoid and styloid process it touches the posterior belly of the digastric, and is in relation with the internal carotid and

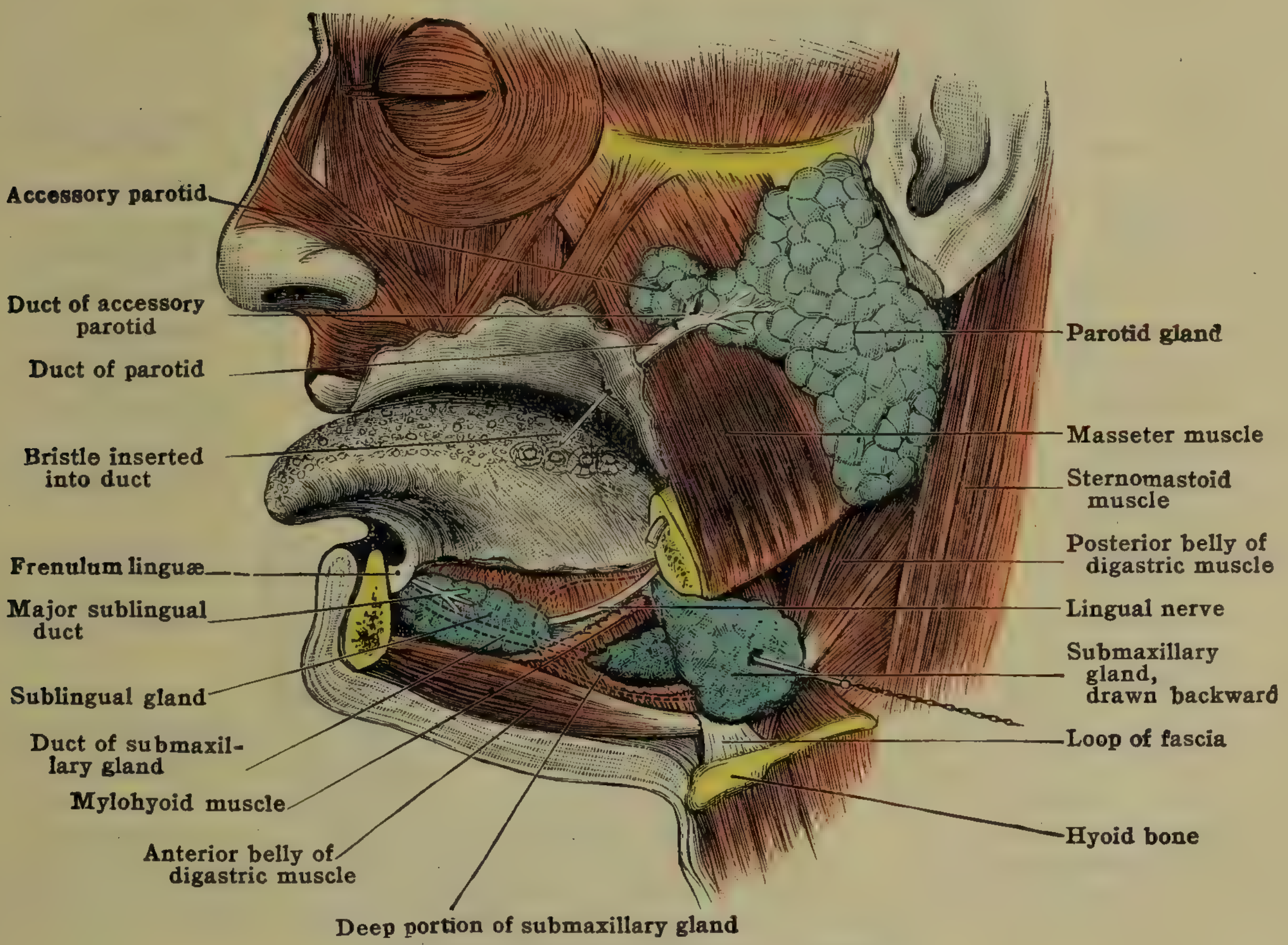


Fig. 946.—The Salivary Glands.

jugular vessels. The upper part of the posterior surface is in contact with the mastoid process. The various structures in contact with the parotid gland often make more or less distinct grooves upon its posterior and anterior surfaces.

Borders.—The *anterior* border usually extends from below obliquely upward and forward so as to give the whole superficial surface a triangular appearance. Near the upper end of the anterior border, the parotid duct leaves the gland, and just above this there is usually a small separate *accessory lobe* [gl. parotis accessoria], of variable form and size. The branches of the facial nerve also emerge from the anterior border. The *posterior* border extends along the anterior aspect of the sternomastoid muscle up to the mastoid process. The *medial* border is deeply placed (at the junction of the anterior and posterior surfaces), and approaches the wall of the pharynx. The medial border forms the apex of the wedge-shaped parotid mass, and is termed the *processus retromandibularis*.

The *upper extremity* of the parotid sends a process into the posterior part of the manibular fossa, behind the condyle of the mandible, and is related with the external auditory meatus. From the upper extremity emerge the superficial temporal vessels and the auriculotemporal nerve. The *lower extremity* is sepa-

rated by the stylomandibular ligament from the posterior end of the submaxillary gland.

Fascia.—As shown in fig. 948, the parotid gland is enclosed in a sheath (called the parotid fascia or aponeurosis) derived from the deep fascia of the neighborhood. The superficial layer of the sheath covers the lateral surface of the gland, while the deep layers correspond to the anterior and posterior surfaces of the gland. The sheath is very feeble or deficient at the medial angle. The superficial and the deep layers of the parotid sheath unite below to form a thick fascial band (stylomandibular ligament) extending from the angle of the mandible to the lower part of the styloid process. In general, the sheath is strong enough to cause very painful tension during inflammation of the parotid. The process in the mandibular fossa explains the pain associated with movements of the jaw in parotitis (mumps.) Pus or growths within the parotid are likely to burrow deeply toward the pharynx or pterygoid region, where the sheath is weakest.

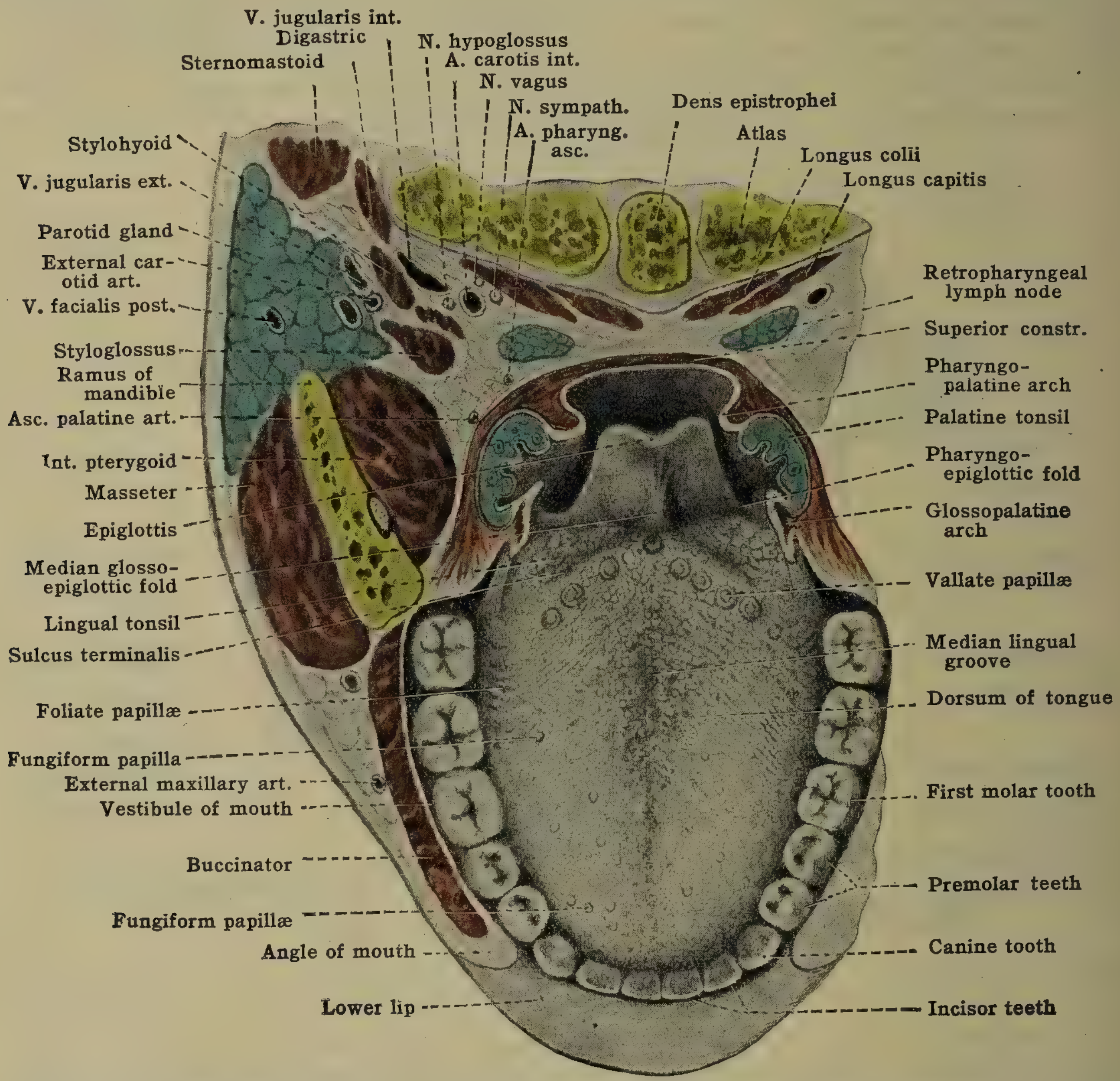


Fig. 947.—Horizontal Section through Head at Level of Rima Oris. (After Henle, modified.)

Contents.—Within the sheath, the parotid gland is in intimate relation with numerous important structures. Extending along the medial border, and partly embedded in the gland, is the external carotid artery, dividing above into the superficial temporal and internal maxillary (including the origins of the deep auricular and transverse facial); and the posterior facial (temporomaxillary) vein and branches. The auriculotemporal nerve passes through the upper part of the gland, while the facial nerve passes through it at a lower level, dividing into its temporofacial and cervicofacial divisions. Grégoire (Jour. de l'anat., etc. T. 48, 1912) and McWhorter (Anat. Rec., Vol. 12, 1917) have shown that the parotid is fundamentally divisible into two lobes, superficial and deep, between which lie the principal branches of the facial nerve. Finally, there are embedded in the gland two or three deep lymphatic nodes, which receive lymphatic vessels from the external auditory meatus, the soft palate and the posterior part of the nasal fossa; there are also several superficial nodes, which receive lymphatic vessels from the temple, eyebrows and eyelids, cheek and auricle.

Structure.—The parotid is a racemose gland of the serous type.

Duct, vessels and nerves.—The **parotid duct** (Stensen's) issues from the anterior border of the gland, crosses the masseter a finger's breadth below the zygoma, and turns abruptly medialward round the anterior border of the masseter: The duct is accompanied by the

transverse facial artery above and the infraorbital branch of the facial nerve below. It penetrates the fat of the cheek and the fibers of the buccinator muscle, between which and the mucous membrane it runs for a short distance before it terminates, sometimes on the summit of a little papilla, by a minute orifice. This opening is placed opposite the crown of the second upper molar tooth. The duct commences by numerous branches, which converge toward the anterior border of the gland. It receives in its passage across the masseter the duct of the accessory parotid gland. The canal is about the size of a crow-quill; length about 35 to 40 mm., diameter 3 mm. The wall of the duct is thick and tough, and consists of fibrous tissue intermixed with smooth muscle fibers. *Incisions* should be made with care in the parotid region. They should be made parallel with the principal structures, in order to avoid injury of Stensen's duct (causing a salivary fistula), or section of the facial nerve (causing palsy).

The **arteries** are derived from those lying in the gland substance and from the posterior auricular artery. The **veins** terminate in the posterior facial (temporomaxillary) trunk.

The nerves.—The parotid gland receives its secretory fibers from the otic ganglion, conveying impulses from the glossopharyngeal via the lesser petrosal and the auriculotemporal; its sensory supply is through branches of the fifth nerve; and its sympathetic supply from the carotid plexus. The **lymphatics** from the parotid gland terminate in the superficial and deep cervical glands, and especially in the deeper group of parotid nodes embedded in the substance of the gland.

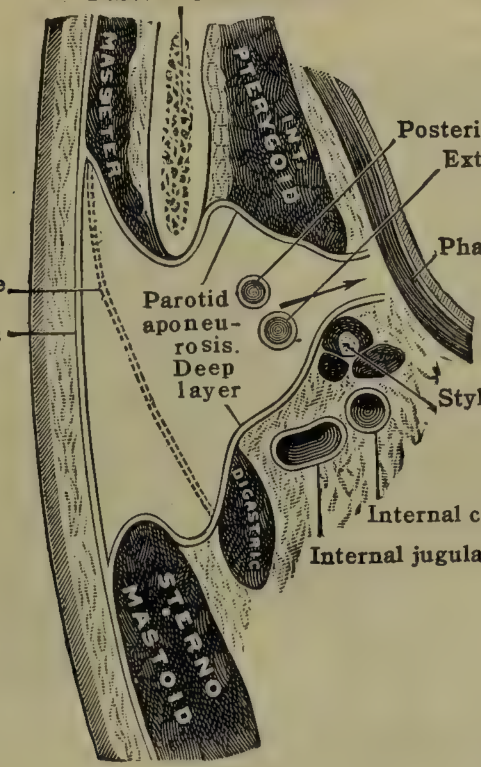


FIG. 948.—DIAGRAM OF HORIZONTAL SECTION SHOWING THE PAROTID COMPARTMENT AND RELATIONS. Arrow indicates opening in sheath. (From Woolsey after Testut.)

Variations.—The parotid is quite variable in size and in the form of its various processes, especially of the accessory lobe, as already mentioned. The lobulations are less distinct in infancy. Rarely the parotid is absent or rudimentary, the retromandibular fossa being filled with a fatty tissue enclosing the vessels and nerves normally found with the gland.

THE SUBMAXILLARY (SUBMANDIBULAR) GLAND

The **submaxillary gland** [glandula submaxillaris] (gl. submandibularis NK) weighs 7 to 10 grams, and is of about the form and size of a flattened walnut. It consists of a chief or superficial part, and a smaller deep process. The chief portion is located in the digastric triangle, and presents three surfaces—superficial, deep and lateral (figs. 933, 949).

Surfaces.—The *superficial* (inferolateral) surface is covered by skin, superficial fascia, platysma and deep fascia (which forms an incomplete capsule around the gland). It is crossed by the anterior facial vein and by cervical branches of the facial nerve. Several lymphatic glands, which receive vessels from the anterior facial region, lie upon or embedded in this surface.

The *lateral* surface is the smallest of the three. It is in contact with the submaxillary fossa of the medial surface of the mandible, and with the lower part of the internal pterygoid muscle. The posterior aspect of the gland is deeply grooved by the external maxillary (facial) artery and is separated from the parotid gland by the stylomandibular ligament. The *deep* (mediosuperior) surface is in contact with the lower surface of the mylohyoid, and behind this with the hyoglossus, stylohyoid and posterior belly of the digastric. Between this surface

and the mylohyoid muscle are the mylohyoid nerve and artery and the submental artery.

The submaxillary gland is usually palpable externally. It can also be felt internally, through the posterior part of the sublingual region in the floor of the mouth, especially if pressure is made from the outside.

The **deep process** (fig. 949) is a tongue-like extension which passes from the deep surface of the submaxillary gland around the posterior border of the mylohyoid muscle, and extends forward in company with the duct, under cover of (above) the mylohyoid, and in relation medially with the hyoglossus and genioglossus muscles. At its commencement, the deep process lies just below the submaxillary ganglion, and it often reaches the sublingual gland.

Structure.—The submaxillary is a racemose gland belonging to the mixed type, some of the acini being serous, others mucous or mixed.

The **submaxillary (submandibular or Wharton's) duct** springs from the deep surface of the superficial part of the gland associated with the deep process; it passes forward and inward and opens by a small orifice on the summit of a papilla [caruncula sublingualis] by the side of the frenulum of the tongue. It is crossed superficially by the lingual nerve. It lies at first between the mylohyoid and hyoglossus; next, between the mylohyoid and genioglossus; and lastly, under

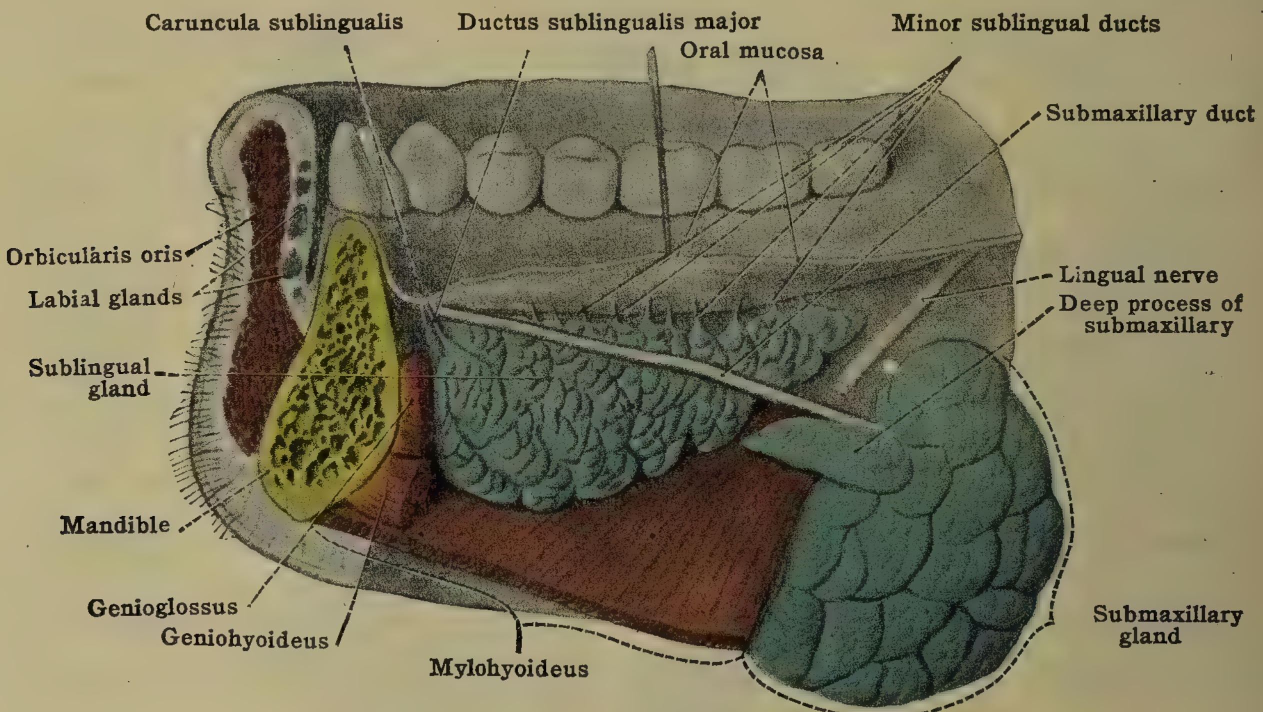


Fig. 949.—Medial View of the Submaxillary (Submandibular) and Sublingual Glands. (From Sobotta—McMurrich's Atlas.)

cover of the oral mucosa, between the genioglossus and the sublingual gland. The duct is about 5 cm. in length, and has comparatively thin walls. Salivary calculi are occasionally found in this duct.

Vessels and nerves.—The **arteries** to the gland are derived from the external maxillary (facial) and lingual, and they are accompanied by *veins* joining the anterior facial.

The nerves.—The submaxillary gland receives its secretory fibers from numerous small sympathetic ganglia situated on the submaxillary duct and in the hilus of the gland, these conveying impulses from the chorda tympani; its sensory branches probably come from the geniculate ganglion, and its sympathetic branches from the cervical sympathetic.

Variations.—Absence of the gland is a rare anomaly. A case is recorded (Turner) where the submaxillary was placed entirely under cover of the mylohyoid, being closely associated with the sublingual gland. The deep process is extremely variable in size, form and relations.

THE SUBLINGUAL GLAND

The **sublingual gland** [gl. sublingualis]—the smallest of the salivary glands (2 to 3 gm.) is in reality a group of glands forming an elongated mass in the floor of the mouth under the tongue (fig. 933). *Above*, it forms a distinct ridge, covered by a fold of mucosa (plica sublingualis) upon which its ducts open (fig. 942). It is flattened from side to side, its *lower* border resting upon the surface of the mylohyoid, its *lateral* surface in contact with the sublingual fossa of the mandible, and its *medial* surface with the geniohyoid, geniohyoglossus, lingual nerve, deep lingual artery and submaxillary duct (fig. 946). *Anteriorly* it approaches its fellow of the opposite side, while *posteriorly* it is often related with the deep process of the submaxillary gland. It has no distinct capsule, thus differing from the submaxillary and parotid glands. In *structure*, it is a racemose mixed gland, but predominantly mucous.

Ducts.—The *minor sublingual ducts* [ductus sublinguales minores], ducts of Rivinus, vary from five to fifteen or more in number, and open on minute papillæ along the crest of the plica sublingualis (fig. 942). The anterior portion of the gland often forms a *major* (*Bartholin's*) *duct* [ductus sublingualis major] which opens alongside the submaxillary duct on the *caruncula sublingualis* (figs. 942, 949).

Vessels and nerves.—The *arteries* are derived from the sublingual and submental, with corresponding *veins*. The *lymphatics* are tributaries of the superior deep cervical nodes.

Nerves.—The sublingual glands receive their secretory fibers from the submaxillary and associated sympathetic ganglia, conveying impulses from the chorda tympani; sympathetic branches come from the cervical sympathetic and sensory fibers probably from the geniculate ganglion, although this question needs further investigation.

Development of the salivary glands.—The salivary glands appear early as buds from the ectodermal epithelium of the oral sinus. For details, see p. 44.

Variations.—The duct of Bartholin is present in about half of the cases, and the corresponding anterior part of the gland may be more or less separate [gl. sublingualis major]. The number of ducts may reach thirty (Tillaux). Rarely processes from the gland may penetrate the mylohyoid, appearing on its lower surface in one or more places (Moustin). Most of the variations in this and the other salivary glands are due to developmental irregularities.

Comparative.—Oral glands are usually absent in the lower aquatic vertebrates. Mucous glands occur in all terrestrial vertebrates, but true salivary (digestive) glands appear only in mammals. Although great variations occur in the different species of mammals, those in man (excepting the anterior lingual) are typical for the order. The sublingual gland, however, often occurs as two separate glands, corresponding to the sublingualis major and minor. The parotid gland apparently has no representative in forms below mammals. In some mammals (e. g., monkey) it has two main lobes—a larger superficial and a smaller deeper lobe between which lies the facial nerve (Gregoire). Other oral glands (e. g., orbital, zygomatic) appear in some mammals.

THE TEETH

The **teeth** [dentes] are highly specialized structures developed in the oral mucosa as organs of mastication and also (in man) of speech. The adult indi-

Fig. 950.—Teeth of Adult, Lingual Surfaces. (Broomell and Fischelis.)

Fig. 951.—Teeth of Adult, Labial and Buccal Surfaces. (Broomell and Fischelis.)

vidual with perfect dentition has thirty-two teeth, arranged arch-like in the sockets (alveoli) of the maxilla and the mandible. Sixteen belong to the upper or maxillary arch, and sixteen to the lower or mandibular. The four central teeth in each dental arch are the *incisors*, the tooth next to these on each side is the *canine* (cuspid); behind these are the two *premolars* (bicuspids); and lastly the three *molars*. This relation of teeth is expressed by the following dental formula:

$$\mathrm{i}\,\frac{2}{2},\ \mathrm{c}\,\frac{1}{1},\ \mathrm{pm}\,\frac{2}{2},\ \mathrm{m}\,\frac{3}{3} = 32.$$

Forms.—Each tooth [dens] has a *crown* [corona dentis], the portion exposed beyond the gum, and covered with enamel (figs. 952, 953). The root [radix dentis] is the portion covered with cementum and embedded in the bony socket. At the line of union of crown and root is the slightly constricted *neck* [collum dentis]. The surface of the tooth directed toward the lip (or cheek) is termed the *labial*

(or buccal) surface [facies labialis; f. buccalis]; while that toward the tongue is the *lingual* surface [f. lingualis]. The crowns of the opposite arches meet at the

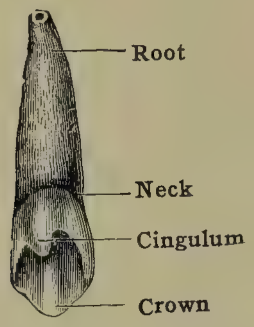


FIG. 952.—CANINE TOOTH, LINGUAL SURFACE.

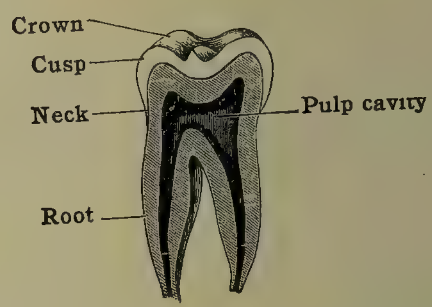


FIG. 953.—A MOLAR TOOTH IN SECTION.

masticating or occlusal surface [f. masticatoria]. The surfaces in contact with the adjacent teeth of the same arch [facies contactus] are, for the incisors and canines,

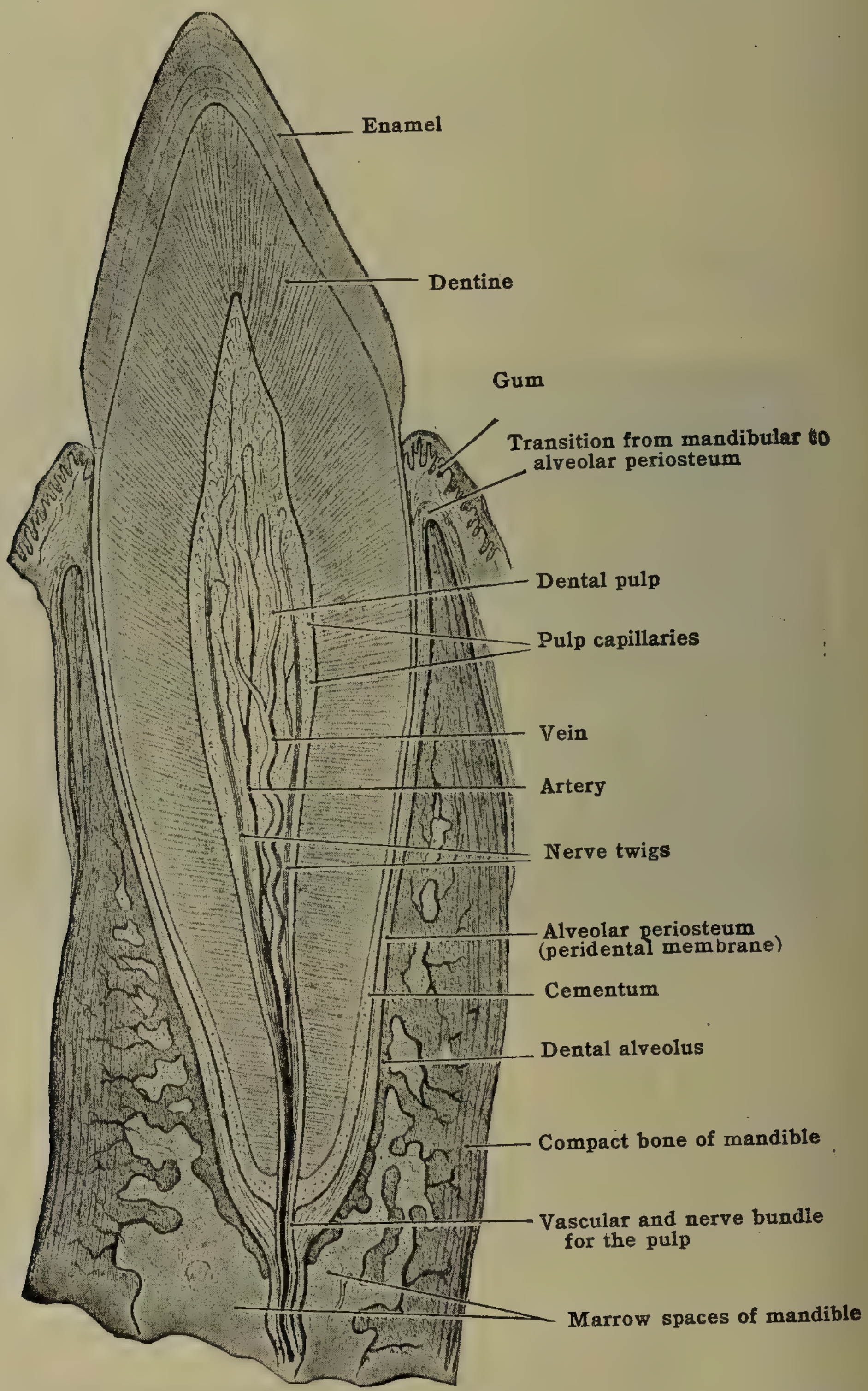


FIG. 954.—VERTICAL SECTION OF AN INFERIOR CANINE TOOTH, IN SITU. × 4. (From Toldt's Atlas.)

termed *medial* and *lateral*, while those for the premolars and molars are termed *anterior* and *posterior*.

Structure.—As shown in longitudinal section (figs. 953, 954), each tooth has a central *cavity* [cavum dentis] or pulp cavity, which is filled with *pulp* [pulpa dentis]. The pulp is a soft fibrous tissue richly supplied with vessels and sensory nerves which enter the *root canal* through the apical *foramen* [foramen apicis dentis]. The body of the tooth, both crown and root, is composed of a dense modified variety of bone called *dentine* [substantia eburnea]. It is yellowish in color. The striated appearance of the dentine is due to numerous fine canals, the *dentinal tubules* [canaliculi dentales]. These contain 'Tomes' fibrils,' which are long protoplasmic branches of the *odontoblasts,* a layer of cells on the surface of the pulp. At the outer surface of the dentine in the root are numerous small, irregular *interglobular spaces,* corresponding to Tomes' 'granular sheath' (fig. 954). The dentine of the crown is covered with a layer of white

FIG. 955.—CROSS-SECTION OF THE MEDIAL UPPER INCISOR, IN SITU. × 4. (From Toldt's Atlas.)

enamel [substantia adamantina], which is the hardest substance in the body. It is composed of numerous minute hexagonal *prisms* [prismata adamantina] which are arranged perpendicular to the surface and are of epithelial origin. In adult teeth, the enamel is often worn through in places, exposing the yellowish dentine. The dentine of the root is covered by a thin layer of *cementum* [substantia ossea], a layer of modified bone which is very thin at the neck, but becomes thicker toward the root apex (fig. 954). Surrounding the root is the *alveolar periosteum* (peridental membrane), a fibrous membrane connecting the cementum firmly with the bony lining of the socket. For further details of the minute structure of teeth, works on histology may be consulted.

The relations of the teeth and alveoli are well shown by the X-rays (fig. 956).

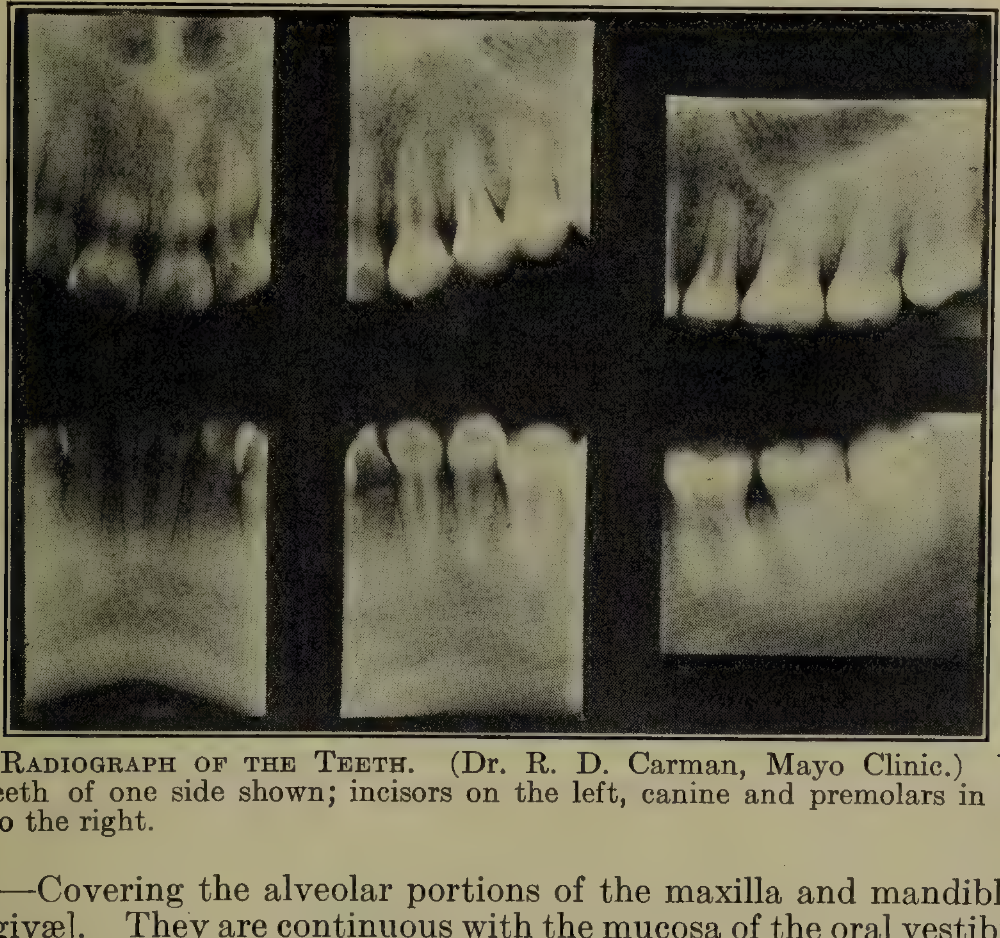


FIG. 956.—RADIOGRAPH OF THE TEETH. (Dr. R. D. Carman, Mayo Clinic.) Upper and lower teeth of one side shown; incisors on the left, canine and premolars in the center, molars to the right.

Gums.—Covering the alveolar portions of the maxilla and mandible are the **gums** [gingivæ]. They are continuous with the mucosa of the oral vestibule externally and of the palate or floor of the mouth internally. Like the mucosa of the mouth elsewhere, they are covered with stratified squamous epithelium. The lamina propria is especially thick and strong, and is firmly attached to the subjacent bone. Around the neck of each tooth, the epithelium of the gum forms an overlapping collar and the lamina propria is continuous with the alveolar periosteum (peridental membrane (fig. 954).

The incisors.—(Figs. 950, 951, 955.) The incisor teeth [dentes incisivi] are so named on account of their function in cutting the food. The *crown* has a characteristic chisel-shape. The *masticating* surface is narrow and chisel-edged. In recently erupted teeth, the cutting edge is elevated into three small cusps, which soon wear down, leaving a straight edge. These cusps correspond to three indistinct ridges on the labial surfaces. The lateral angle of the crown is usually more rounded than the medial. The *labial* surfaces are slightly convex, the *lingual* slightly concave. The *contact* surfaces are somewhat triangular. The *roots* of the incisors are single, though often longitudinally grooved, indicating traces of a division. They are somewhat conical, but flattened from side to side, especially the lower set, and are slightly curved lateralward.

The upper or **maxillary incisors** are much larger than the lower. They are lodged in the premaxilla, and are inclined downward and forward. They overlap the lower incisors in mastication, hence the masticating surface is worn off and rounded at its posterior edge, while the anterior edge becomes sharp and chisel-like. The lingual surfaces of the crowns terminate near the gum in a low, inverted V-shaped ridge, the basal ridge or *cingulum*. At the apex of the V, near the gum, there is often (especially on the lateral incisor) a small *lingual cusp*. The medial upper incisor is distinguished from the lateral by its much larger size.

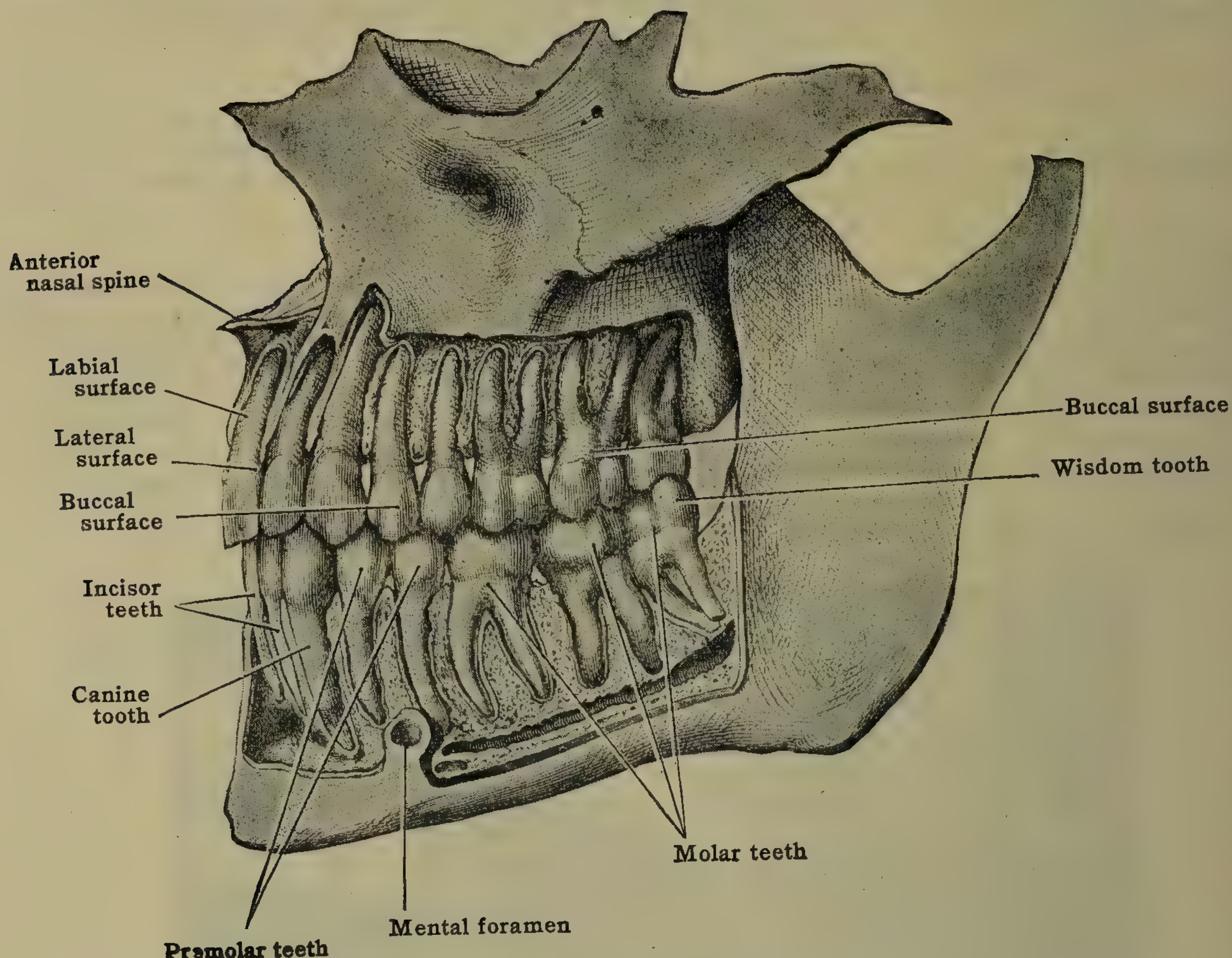


Fig. 957.—Dissection Showing the Roots of the Teeth. Teeth in Occlusion. ×1. (From Toldt's Atlas.)

The lower or **mandibular incisors** are smaller than the upper, the cutting edges being only about half as wide. Being overlapped by the upper set, the lower incisors have the masticating surface worn off anteriorly, leaving a sharp cutting edge posteriorly. The lower incisors are vertically placed, and the crown becomes narrower toward the neck. A cingulum is rarely visible. The medial lower incisor, unlike the upper, is slightly smaller than the lateral.

The canines.—(Figs. 950–952.) The canine teeth [dentes canini] so-called from their prominence in the dog-tribe, are sometimes termed the 'cuspids.' They are the longest of all the teeth. The *crown* is thicker and more conical than in the incisors. The *masticating* surface forms a median angular point, on either side of which the cutting edge slopes to the lateral angle. The medial limb of the cutting edge is usually somewhat shorter than the lateral, rendering the crown asymmetrical. The *labial* surface is convex, the *lingual* somewhat concave. The *root* is single, long, flattened from side to side and grooved on the sides as in the incisors. The canine root is usually slightly curved lateralward. The bony alveolar protuberances [juga alveolaria] are more prominent than those of any other teeth.

The **upper canine** slants forward and overlaps the lower, as in the incisors. The upper canine also presents a well-marked *cingulum*, and usually a distinct *lingual cusp* (fig. 952) below which a slight median ridge extends along the lingual surface. On the **lower canine**, these structures are poorly marked or absent. The lower canine is somewhat smaller than the upper, and its root is occasionally bifid.

The premolars.—(Figs. 950, 951, 957, 958.) The premolars [dentes premolares] are so named on account of their position in front of the molars. The *crown* presents on the masticating surface two prominent cusps, on account of which the premolars are often called 'bicuspids.' The *buccal* and *lingual* surfaces are convex especially from side to side, so that the crown

is somewhat cylindrical in form, with flattened, quadrilateral anterior and posterior *contact* surfaces. The *root* is (usually) single and more or less flattened anteroposteriorly, and usually somewhat curved backward.

The **upper premolars** are distinguished from the lower by a greater anteroposterior flattening of the crown and by a deep groove separating the cusps (excepting at their anterior and posterior margins) on the masticating surface. In the *first* upper premolar the lingual cusp and surface are decidedly smaller than the buccal; and the root is frequently bifid or double (occasionally even triple). In the *second* upper premolar the lingual cusp and surface are as large as the buccal; and the root, though deeply grooved, is rarely bifid.

In the **lower premolars,** the crowns are more cylindrical in form, and the cusps are united by a median ridge so that the masticating surface presents two small pits. The roots are more rounded and tapering, and rarely grooved. In the *first* lower premolar (like the corresponding upper) the lingual cusp and surface are much smaller than the buccal, the lingual cusp sometimes being rudimentary; while in the *second* they are more nearly equal. The second lower premolar is often slightly larger than the first, while in the upper premolar the converse is true. It should be noted, however, that the premolars are quite variable in all respects, and it is therefore often difficult to identify the individual isolated teeth.

The molars.—(Figs. 950, 951, 953, 957.) The molars [dentes molares] or 'grinders' are characterized by their large size, and by the presence of three to five masticating cusps (hence sometimes called 'multicuspids'). The *crowns* are massive, somewhat resembling rounded cubes, and the lingual and buccal surfaces present vertical grooves continuous with the fissures separating the cusps. The *pulp-cavity* (fig. 953) has slight extensions corresponding to the cusps, and also communicates with the canals of the *roots*, which are usually two or three in number, and more or less curved.

The **upper molars** are most easily distinguished from the lower by the presence of a triple root. The masticating surface is nearly square with rounded angles. They each have typically four cusps, separated by grooves resembling a diagonally placed H (fig. 880). The crowns of the upper molars are obliquely placed so as to slant downward and slightly lateralward.

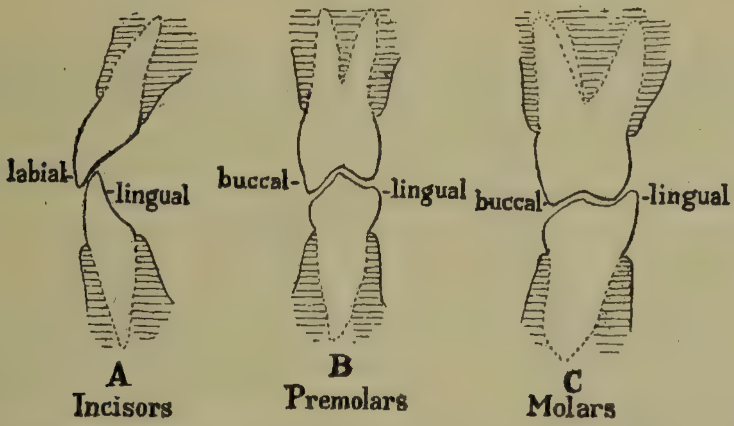


FIG. 958.—DIAGRAM SHOWING THE ARTICULATION OF THE TEETH. (Poirier-Charpy.)

Each upper molar has three roots, two buccal and one lingual or palatal. The roots (especially the buccal) end in more or less close relation with the floor of the maxillary antrum (of Highmore) (fig. 957). The buccal roots are flattened anteroposteriorly, and longitudinally grooved, and bent backward. The palatal root is more rounded, with a groove on the lingual surface, and usually bent medialward. Either of the buccal roots may fuse with the palatal, or there may be an extra fourth root.

As to the *individual* upper molars, the *first* has almost invariably four typical cusps (rarely only three, or with an additional fifth rudimentary). The *second* upper molar has only three cusps in about half of the cases (in Europeans), and four in the remainder. The *third*, or wisdom tooth [dens serotinus] is exceedingly variable in size and form. It has three cusps much more frequently than four, and its three roots are often more or less fused into a conical mass. It is usually much smaller than the other molars, and is absent in nearly one-fifth of all cases.

The **lower molars** have usually four or five cusps (two lingual, and two or three buccal) the fissures separating them being cross-shaped or stellate (fig. 947). The crowns incline upward and slightly medialward. They have each two roots, anterior and posterior, flattened anteroposteriorly, and usually somewhat curved backward. The roots, especially the anterior, may be longitudinally grooved. The anterior has two root-canals, the posterior usually only one. The apices of the roots of the lower molars, especially of the third, approach the mandibular (inferior dental) canal (fig. 957).

Of the *individual* lower molars, the *first* is usually slightly the largest, and has five cusps in the great majority of cases (variously estimated at from 60 to 95 per cent.), otherwise four. The four main cusps (two buccal and two lingual) are separated by a cruciform fissure, which bifurcates posteriorly to embrace the small fifth cusp (which is placed slightly to the buccal side) when present. The *second* lower molar has usually four cusps (75 to 85 per cent of cases), otherwise five, the fifth usually small or rudimentary. The roots are sometimes confluent. The lower *third* or wisdom tooth [dens serotinus], like the upper, is usually small and exceedingly variable. It has usually four or five cusps; but the number may be increased to six or seven, or reduced to three, two, or one. The roots are often short and fused into a conical mass, in which sometimes only a single canal is present.

The **dental arches.**—On comparing the upper and the lower dental arches, it is seen that the upper (fig. 938) forms an elliptical curve, while the lower (fig. 947) resembles a parabola. The upper arch is slightly larger (due chiefly to the slant of the teeth, as previously explained)

so that it slightly overlaps the lower when the teeth are in occlusion. Thus, as shown in fig. 957, the upper incisors and canines overlap the lower. The buccal cusps of the lower premolars and molars fit into the groove between the upper buccal and lingual cusps; while the upper lingual cusps correspond to the groove between lower buccal and lingual cusps. This arrangement favors a more perfect mastication (see fig. 958).

Moreover, when viewed from the side (fig. 957), it is seen that in general, the corresponding teeth of the upper and the lower arches are not opposite, but alternate with each other. This is due chiefly to the great width of the upper central incisor. The lower molars, however, especially the third, are wider (anteroposteriorly) than the upper, so that the two arches are nearly equal in length. The interdental line between the two arches is not straight, but slightly convex downward (fig. 957). In both arches, the crowns of the incisors and canines are taller than those of the premolars and molars.

Vessels and nerves.—The vessels and nerves of the teeth are distributed partly to the pulp and partly to the surrounding alveolar periosteum. The *arteries* are all derived from the internal maxillary. Those for the upper teeth are the posterior superior alveolar and the anterior superior alveolar (from the infraorbital). Similar branches to the lower jaw are given off by the inferior alveolar. They give off twigs to the gums (rami gingivales), the alveolar periosteum (rr. alveolares), and the pulp cavities (rr. dentales). A dental branch enters each root canal through the apical foramen, and breaks up into a rich peripheral capillary plexus under the odontoblast layer (fig. 954). From this plexus, the corresponding *veins* arise. There is a plexus of peridental *lymphatics*, which anastomose with those of the surrounding gums, and drain chiefly into the submaxillary nodes. Lymphatics have also been demonstrated in the pulp of the tooth (Schweitzer).

The nerves are sensory branches derived from the trigeminus. Those for the upper teeth are from the anterior, middle, and posterior superior alveolar (fig. 804); while those for the lower teeth are from the inferior alveolar (fig. 805). These nerves give numerous branches to the gums, alveolar periosteum (peridental membrane), and pulp cavities. The latter enter with the corresponding vessels, and their distribution within the tooth is a subject of controversy. They may be followed easily to a plexus under the odontoblasts; but whether they end freely, or in connection with the odontoblasts (which by some are considered as peripheral sensory cells), or send fine terminal branches out into the dentinal canals is still uncertain.

Development of the teeth.—The teeth represent calcified papillæ of the oral mucosa, the enamel being a derivative of the ectodermal epithelium, and the remainder of the tooth coming from the underlying mesenchyme. The early development of the teeth is described on p. 43.

Surrounding the entire developing tooth there is formed a strong, fibrous connective tissue membrane, the *tooth-sac*. The deeper part of this sac later becomes the *alveolar periosteum* (peridental membrane) around which the bony alveoli are formed. This bone may entirely surround the tooth-sac, excepting at the summit, where a foramen persists through which a process of connective tissue (*gubernaculum dentis*) connects the tooth-sac with the overlying gum (see fig. 184). Upon the inner surface of the tooth-sac, next to the root, the bony *cementum* is deposited upon the dentine. The root gradually elongates, and is usually not completed until long after the eruption. The remaining superficial portion of the tooth-sac undergoes pressure atrophy and absorption. The remnants of the enamel organ, however, persist and form a thin tough cuticle [cuticula dentis], *Nasmyth's membrane*, which is soon worn off when the crown is exposed at the surface.

From the remainder of the dental ridge, which lies on the lingual side of the deciduous teeth (fig. 44), the *permanent teeth* are later derived in a very similar manner. (Rudimentary indications of a *prelacteal* dental ridge have also been described.) The anlages of the permanent teeth therefore lie to the lingual side of the deciduous (fig. 960). From the posterior end of the dental ridge a process extends into the jaw behind the deciduous teeth, and from this process the permanent molars (which have no deciduous predecessors) are formed. At birth, although no teeth have yet been cut, there are present in the gums the anlages of not only all of the deciduous teeth, but also all of the permanent teeth, with two exceptions. Those of the second molars do not appear until six weeks after birth, and of the third molars not until the fifth year. The remnants of the dental ridges become broken up into small masses of epithelium, which persist for a variable time, forming the so-called 'glands' of Serres or Black.

The deciduous teeth.—The deciduous [dentes decidui], temporary or milk teeth are twenty in number (fig. 959), corresponding to the following formula:

$$\mathrm{di}\,\frac{2}{2},\ \mathrm{dc}\,\frac{1}{1},\ \mathrm{dm}\,\frac{2}{2} = 20.$$

The deciduous teeth (figs. 959, 960) are much smaller in size than the permanent teeth, and their necks are more constricted. The enamel of the crown-cap is thicker. In general, their form and structure otherwise are very similar to that already described in the case of the permanent incisors and canines. The molars, however, are different. Their cusps on the masticating surface are very sharp and irregular. There are usually three cusps on the first upper molar and four on the second; four cusps on the first lower molar and five on the second. The roots correspond to those of the permanent molars (three above and two below), but they are much more divergent, to allow room for the development of the corresponding subjacent permanent premolar teeth. The first molar is always considerably smaller than the second.

Calcification in the dentine and enamel of the teeth does not begin until the anlages of the crowns are well formed. The process of calcification follows that of the development of the tooth in general, beginning in the superficial portion of the crown and gradually spreading toward the root. Calcification in the *deciduous* teeth begins during the fifth fetal month, and at birth the crowns are nearly completed (fig. 962). Of the *permanent* set of teeth, only the first molar has begun to calcify at birth (fig. 963). Calcification of the other permanent teeth

begins as follows: incisors, first year; canines, third year; premolars, fourth and fifth years; second molars, fifth year; third molars, eighth or ninth years. There are, however, great variations in the time at which the calcification of the various teeth begins. As a rule, the calcification of the roots is not completed at the apices until some time after the crowns are

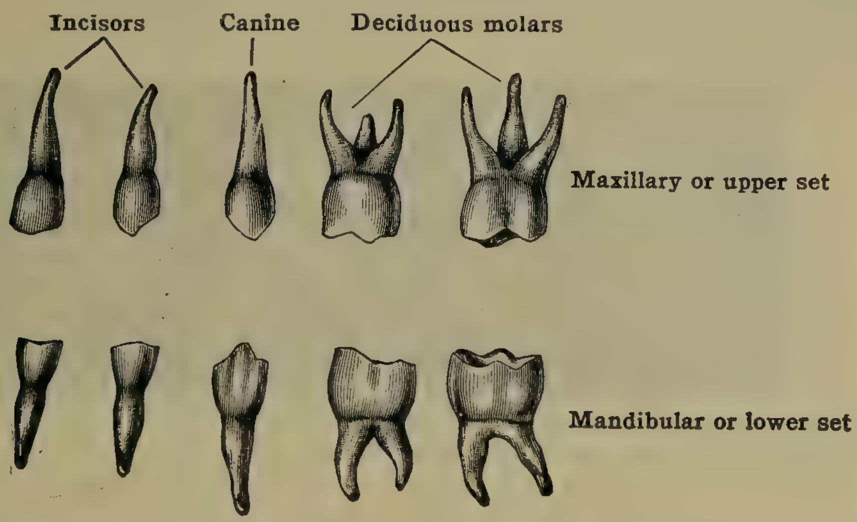


FIG. 959.—THE DECIDUOUS TEETH, EXTERNAL VIEW.

exposed in eruption. As shown by fig. 963, calcification in most of the teeth is completed between the tenth and twelfth years; but in the second molars not until the sixteenth year, and in the third molars at eighteen years or later.

Eruption of the teeth.—On account of pressure due to growth and expansion at the root of the tooth (and probably other obscure factors), the crowns are pushed toward the surface.

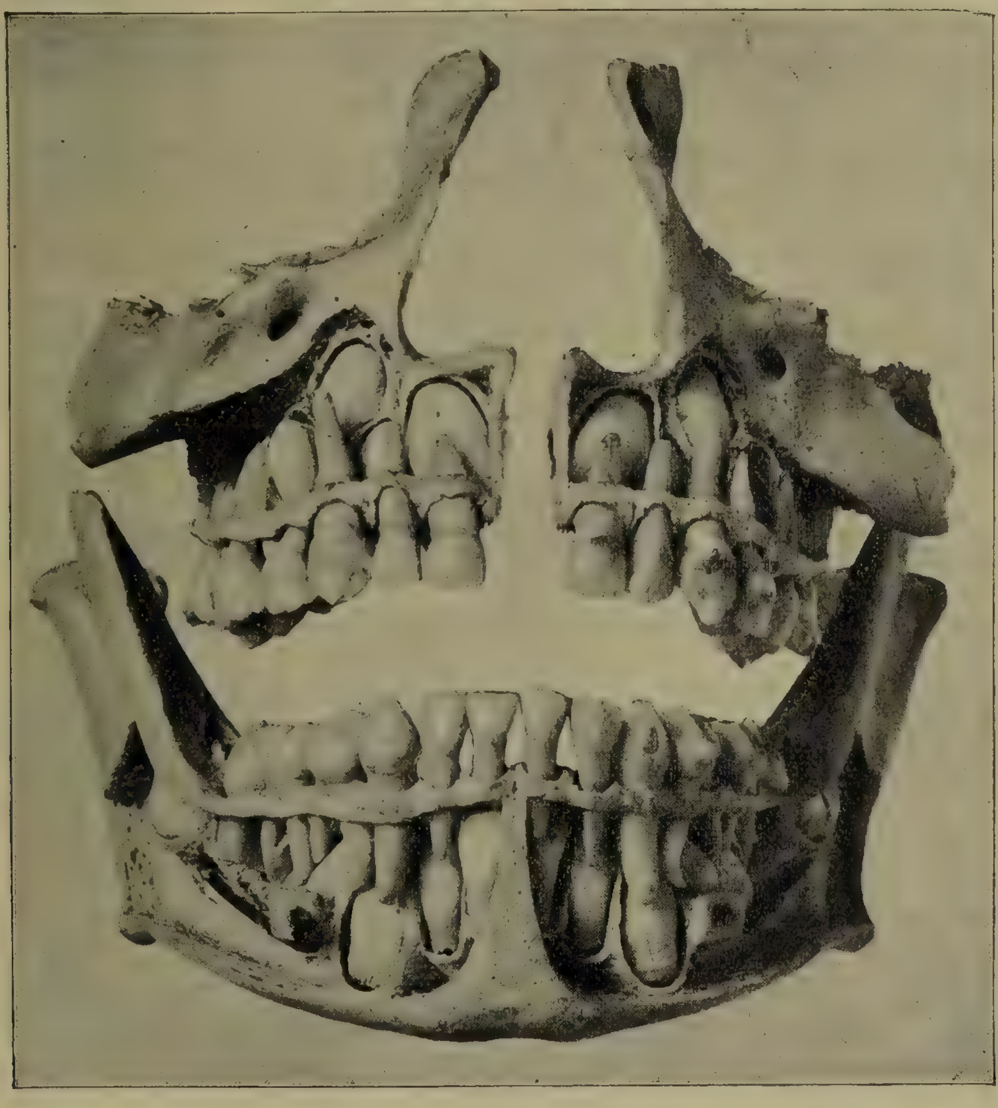


FIG. 960.—DISSECTION SHOWING BOTH DECIDUOUS AND PERMANENT TEETH AT ABOUT SIX YEARS. (Broomell and Fischelis.)

The overlying portion of the tooth-sac, together with corresponding portions of the temporary alveolar bone, are absorbed, and the crown is 'cut,' i. e., breaks through the surface of the gum in eruption. In the case of the permanent teeth, this is normally preceded by a shedding of the deciduous teeth. The latter have been loosened by the absorption of their roots, which is perhaps due largely to the activity of certain *odontoclasts* (like the osteoclasts of bone) which are found in the region of absorption.

Time and order of eruption.—The *time* of the eruption of the various teeth is subject to great variation, so that no two investigators agree upon it. Aside from the wisdom teeth, the time of eruption is most variable in the canines and premolars, and least variable in the first permanent molars (Röse). According to Röse, the eruption averages four and one-half months earlier in the male, and is also earlier in well-to-do and city children. But Boas and Bean find the eruption usually earlier in girls than in boys. The *order* in which the teeth appear is less

Fig. 961.—Growth of the Root and Pulp-cavity of the Upper First Molar, from the Fifth to the Ninth Year. (Broomell and Fischelis.)

variable. The average time at which the various deciduous and permanent teeth appear and are shed is indicated approximately in the following table. The lower teeth usually erupt before the corresponding upper teeth.

A. Deciduous Teeth

	Eruption Occurs	Shedding Begins
Medial incisors	7 (6–8) months	7th year
Lateral incisors	9 (7–12) months	8th year
First molars	14–15 months	10th year
Canines	18–19 months	10th year
Second molars	20–24 months	11th–12th year

B. Permanent Teeth

The approximate age (in years) at which the eruption of each of the permanent teeth has occurred in 50 per cent. of the individuals examined, which corresponds to the time of most

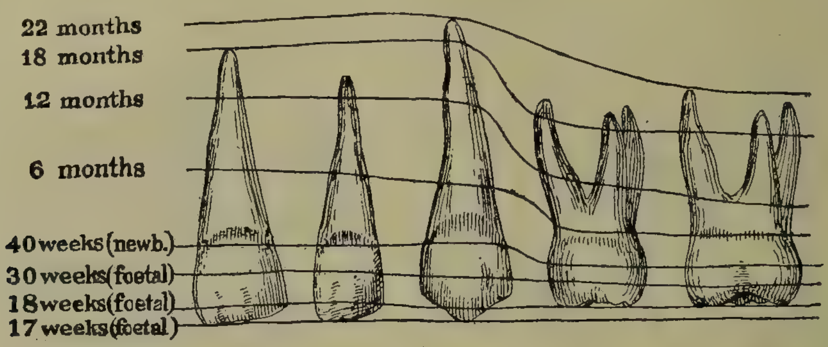


Fig. 962.—Showing the Extent of Calcification of Deciduous Teeth. (Peirce.)

rapid eruption, is given in the following table (observations of Bean upon 1445 school children at Ann Arbor, Michigan, and of James and Pitts on 4850 English children). The lower teeth, excepting the premolars, usually appear before the corresponding upper teeth.

	American		English
	Girls	Boys	
First molars	6.0	6.5	5.75– 6.25
Medial incisors	6.5	7.0	6.25– 7.50
Lateral incisors	8.0	8.5	7.50– 8.75
First premolars	10.0	11.0	9.75–10.50
Canines	10.5	11.5	10.25–11.75
Second premolars	10.0	11.5	10.75–12.00
Second molars	11.5	12.5	11.75–(12+)

The third molars (wisdom teeth) are extremely variable, usually erupting between the ages of 17 and 25, but sometimes later and occasionally failing to appear at all.

Loss of teeth.—Brekhus has shown that of the permanent teeth the first molar is usually the first to be lost (absent in 47 per cent. of college students, age 20 years). Among dispensary patients, at age of 40, 26 per cent. of the males have lost all the upper teeth, and 13 per cent. all the lowers; 43 per cent. of the females have lost all the upper teeth, and 21 per cent. all the lowers.

Variations.—The great variability of the teeth has already been emphasized, and numerous variations described in connection with the various individual teeth and their development.

The observations of James and Pitts show a range of 4 or 5 years in the date at which eruption occurs. Bean has shown that there is marked racial variation in this respect. In *number*, the teeth may be reduced, due to absence (oftenest of the third molar) or incomplete development with failure of eruption. An *increase* in the normal number is less common. It may be only apparent, due to the retention of a deciduous tooth. There may rarely, however, be a true extra third incisor or premolar, or a fourth molar. Aberrant teeth may occur either on the labial or palatal side of the dental arch. A third dentition appears rarely in old age. In *form*, there is much greater variation as before mentioned. All intermediate forms between

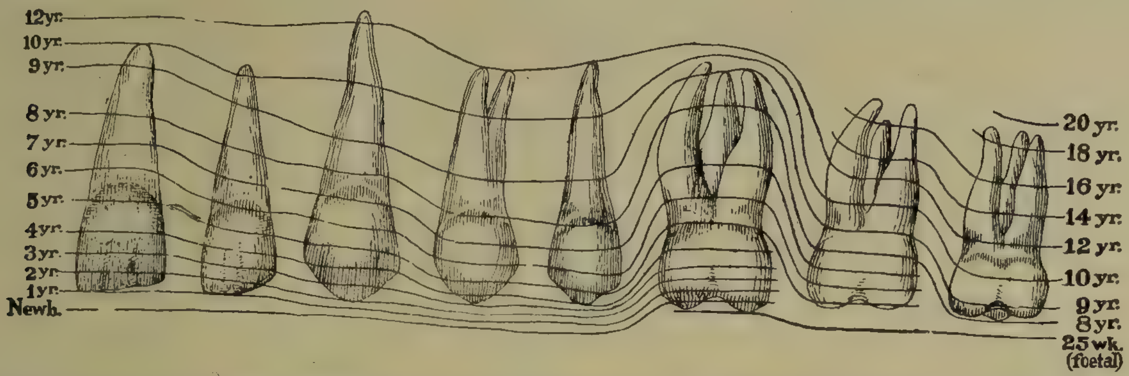


FIG. 963.—SHOWING THE EXTENT OF CALCIFICATION OF THE PERMANENT TEETH. (Peirce.)

rudimentary and fully developed teeth may occur. Fusion between neighboring teeth is sometimes found, and deformities in the dental arches necessarily accompany palatal defects involving the alveolar arches.

Comparative.—As the oral mucosa represents an invagination of the integument, so the teeth are morphologically equivalent to modified dermal papillæ. The close relationship between the teeth and the dermal appendages is clearly shown among many of the lower vertebrates, but most clearly in the Selachians (which include sharks and allied forms). In fig. 964, which illustrates a sagittal section through the lower jaw of a young dogfish, it is clearly evident that the external placoid scales or 'dermal teeth' are continuous with the equivalent oral teeth at the oral margin of the jaw. Both the dermal teeth and the oral teeth are composed of dentine

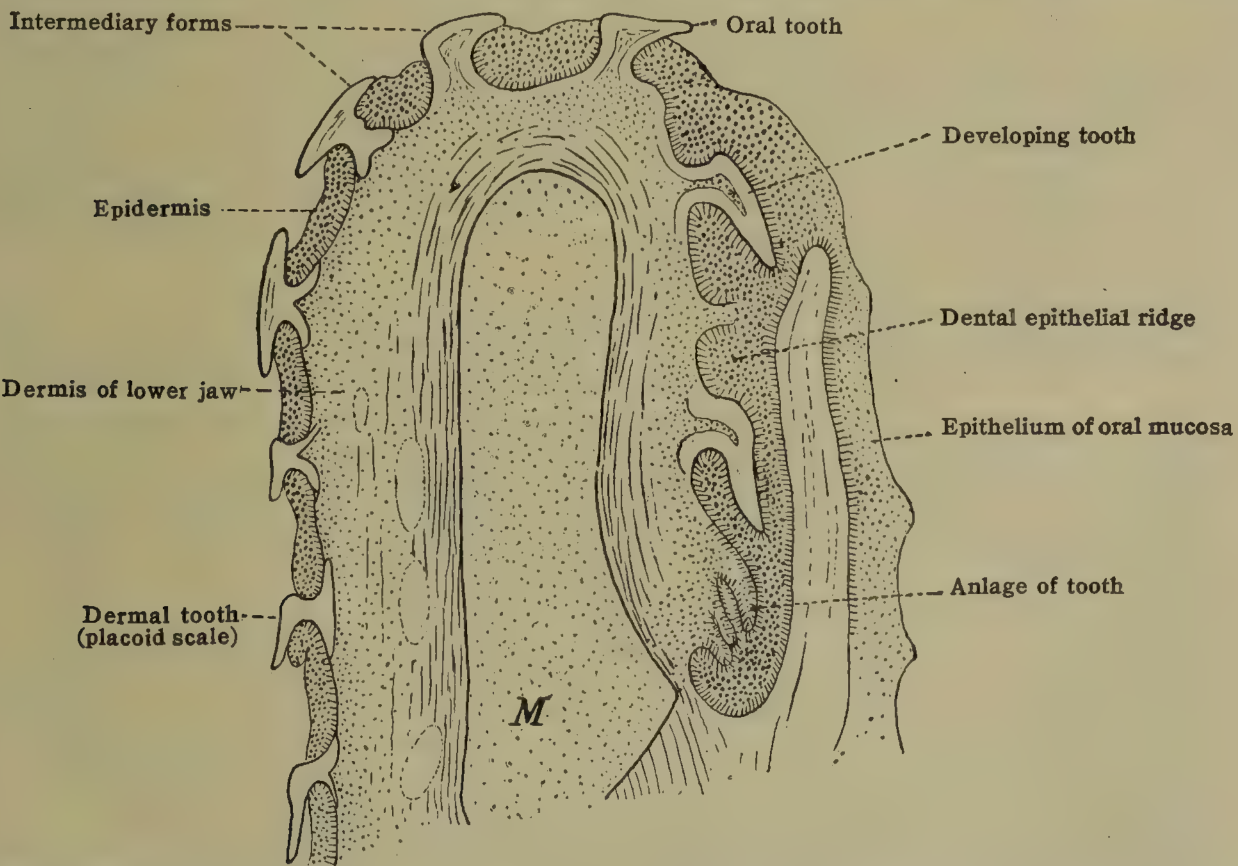


FIG. 964.—SECTION THROUGH LOWER JAW OF DOG-FISH, SHOWING THE DEVELOPMENT OF THE ORAL TEETH, AND THE TRANSITION TO DERMAL TEETH. M, mandible. (After Gegenbaur.)

which presents an enlarged base and a somewhat conical apex. The base is embedded in the fibrous lamina propria (often in bony plates) while the apex projects through the epithelium and is covered with a thin cuticular layer the 'enamel membrane.' True enamel is usually rudimentary or absent in the primitive teeth of lower vertebrates, and represents a secondary acquisition. The dentine is in all cases derived from the connective tissue, and the enamel from the epithelium.

The process of development of the primitive oral teeth is also illustrated in fig. 964. Just within the oral margin there is a shelf-like downgrowth of the ectodermal epithelium, forming a primitive germinal ridge. Along this ridge may be seen the anlages of several rows of teeth in various stages of development. As fast as the mature teeth at the oral margin are worn

off, new teeth pass up from below to replace them. Thus the primitive form of dentition is *polyphyodont*, with many sets of teeth developed successively throughout life. As we pass up the vertebrate scale there is a tendency to a reduction in the number of sets, although there is a wide variation among the various forms. In most mammals, as in man, the number of sets of teeth has been reduced to two, or *diphyodont* dentition, with only traces of an earlier (pre-lacteal) and also a later (post-permanent) set. In some mammals (monotremes, cetacea) the dentition has been reduced to a single set, *monophyodont*, while in birds all except rudimentary traces of dentition have been lost.

As may be further observed in fig. 964, the primitive teeth are of a recurved conical form, and serve primarily for grasping and holding the food. The specialization of the teeth for purposes of mastication is in general a secondary acquisition amongst higher vertebrates.

It is also noteworthy that the primitive teeth, as found among nearly all forms below the mammals, are practically alike in form, i. e., *homodont*. Among mammals, however, there is a marked specialization of the teeth, or *heterodont* dentition. The mammalian teeth are usually differentiated into four distinct classes, incisors, canines, premolars and molars, similar to those found in man.

The typical or complete mammalian dentition (found in mole, pig and young horse), however, contains a larger number of teeth than found in man, and is represented by the formula:

$$i\,\frac{3}{3},\ c\,\frac{1}{1},\ pm\,\frac{4}{4},\ m\,\frac{3}{3} = 44.$$

Thus it is probable that there has been a reduction in the incisors and premolars in the human species, and there has been considerable discussion of the question as to which teeth of the primitive series have been lost. This reduction in the number of teeth is probably correlated with the general reduction in the jaws, which are relatively much larger and stronger in the savage races and lower animals. The third molar, or wisdom tooth, is apparently now on the road to extinction, due to a continuation of the same evolutionary process.

THE PHARYNX

The **pharynx** is a vertical, tubular passage, flattened anteroposteriorly, and extending from the base of the cranium *above* to the beginning of the esophagus below. *Posteriorly*, it is in contact with the bodies of the upper six cervical vertebræ. *Laterally*, it is in relation with the internal and common carotid arteries, the internal jugular vein, the sympathetic trunk and the last four cranial nerves. *Anteriorly*, it communicates above with the nasal cavity, beneath this with the oral cavity, and below with the laryngeal cavity. The pharynx is correspondingly divided into three parts: the *nasal pharynx* [pars nasalis], which is exclusively respiratory in function; the *oral pharynx* [pars oralis], which is both respiratory and alimentary; and the *laryngeal pharynx* [pars laryngea], which is chiefly alimentary.

Size and form.—The average length of the pharynx is about 12 cm. (5 inches). It is wide at the nasal pharynx, with a slight constriction (isthmus) at the junction with the oral pharynx, and is again somewhat narrowed at the junction of oral and laryngeal pharynx (fig. 965). It is narrowest at the point where it joins the esophagus below. In sagittal section (fig. 934), it is evident that the anterior and posterior walls are closely approximated in the laryngeal pharynx, and have only a small space between them in the oral pharynx. The nasal pharynx, however, has a considerable anteroposterior depth, and is always kept open by its bony walls for respiratory purposes.

Structure.—The pharynx approaches the typical structure of the alimentary canal, yet differs from it in several important respects. The lining *mucosa* is continuous with that of the various cavities which open into the pharynx. Above, it is closely adherent to the base of the cranium, where it is thick and dark in color. It becomes thinner where it approaches the openings of the auditory tubes and choanæ; and below it is paler and thrown into longitudinal folds.

External to the mucosa, there is a characteristic fibrous membrane, the *pharyngeal aponeurosis* [fascia pharyngobasilaris], which is well marked above (fig. 969), but below it gradually disappears as a definite structure. Above, it is attached to the basilar portion of the occipital bone in front of the pharyngeal tubercle. Its attachment may be traced to the apex of the petrous portion of the temporal bone, and thence to the auditory (Eustachian) tube and medial lamina of the pterygoid process. It descends along the pterygomandibular ligament to the posterior end of the mylohyoid ridge of the lower jaw, and passes thence along the side of the tongue to the stylohyoid ligament, the hyoid bone, and thyroid cartilage.

External to the pharyngeal aponeurosis is a thick *muscular* layer, made up of various cross-striated muscles, as will be described later. Outside of the muscular layer is a thin fibrous tunica fibrosa, connected with the adjacent prevertebral fascia by a loose, areolar tissue. This loose tissue allows movement of the pharynx, and also favors the spreading of post-pharyngeal abscesses.

The **nasal pharynx** [cavum pharyngis, pars nasalis] (figs. 934, 965) belongs with the nasal fossa as a part of the respiratory rather than the digestive system. Its

anterior wall is occupied by the two *choanæ* (posterior nares), with the nasal septum between them. The *floor* is formed by the upper surface of the soft palate and is a direct posterior continuation of the floor of the nasal fossæ. Posteriorly, however, the floor presents a more or less narrowed opening, the *pharyngeal isthmus*, which communicates with the oral pharynx below.

The isthmus is bounded anteriorly by the uvula, laterally by the posterior (pharyngopalatine) arches. These slope backward and downward to the posterior wall of the pharynx, which forms the posterior boundary of the isthmus. The floor and isthmus change their form and position greatly during the action of the palatal muscles, as will be mentioned later.

The **lateral wall** of the nasal pharynx presents above and behind, corresponding to its widest point, a wide, slit-like lateral extension, the *pharyngeal recess* [recessus pharyngeus] or fossa of Rosenmueller (fig. 965). Below and in front of this recess, the greater part of the lateral wall is occupied by the aperture of the auditory (Eustachian) tube [ostium pharyngeum tubæ]. This is a somewhat triangular, funnel-shaped opening, with an inconspicuous *anterior lip* [labium anterius], a more distinct *posterior lip* [labium posterius], which presents posteriorly a rounded prominence (due to the projecting cartilage of the auditory tube), called the *torus tubarius*. On the lower aspect of the triangular aperture is a slightly rounded fold, the *levator cushion*, which is a prominence caused by the levator veli palatini muscle.

The prominence of the posterior lip facilitates the introduction of the Eustachian catheter, in connection with which the location of the aperture in the midlateral wall just above the level of the floor of the nasal fossa should be carefully noted. In early life the abundant lymphoid tissue around the pharyngeal orifice of the tube may form a 'tubal tonsil.' Enlargement of this tissue and of 'adenoids' (below mentioned) may cause deafness. Infections frequently ascend from the nasal pharynx through the auditory tube to the middle ear region.

A fold of mucosa descending from the posterior lip of the aperture to the lateral pharyngeal wall is the *plica salpingopharyngea* (due to the m. salpingopharyngeus). An inconspicuous *plica salpingopalatina* descends from the anterior lip to the soft palate.

The **posterior wall** (fig. 934) of the nasal pharynx slopes from below upward and forward, passing (above the level of the anterior arch of the atlas) into the *roof* or *fornix* [fornix pharyngis]. The *fornix* is attached chiefly to the basioccipital and basisphenoid bones, extending laterally to the carotid canal of the pyramid, and anteriorly to the base of the nasal septum. The mucosa of the fornix and to a certain extent also of the posterior wall, especially in children, is thrown into numerous and variable folds. These contain much lymphoid tissue, both diffuse and in the form of numerous characteristic lymphoid nodules, with cleft-like invaginations of the surface epithelium. This area constitutes the *pharyngeal tonsil* [tonsilla pharyngea] (fig. 965).

The pharyngeal tonsil is well developed in children (often abnormally enlarged, producing 'adenoids'), but usually, though not always, atrophied in the adult. Its lymphatic drainage is into the retropharyngeal nodes. According to Symington, the involution of the pharyngeal tonsil begins at 6 or 7 years, and is usually completed at 10 years. In the region of the pharyngeal tonsil and elsewhere, the mucosa presents numerous small racemose glands, especially thick in the palatal floor of the nasal pharynx.

In the lower portion of the pharyngeal tonsil, there is also found a median, small, inconstant blind sac, the *pharyngeal bursa*. More anteriorly a '*pharyngeal hypophysis*,' apparently derived from the lower end of Rathke's pouch, has also been described as constantly present (fig. 1164). The pharyngeal hypophysis may give rise to a tumor.

The **oral pharynx** [pars oralis] (figs. 934, 947, 965) is continuous *above* through the pharyngeal isthmus with the nasal pharynx and *below* with the laryngeal pharynx. Its *posterior* wall is related to the vertebral column. The *anterior* wall is deficient above, where there is a communication with the mouth cavity through the *isthmus faucium*. The faucial isthmus is bounded above by the uvula, laterally by the anterior (glossopalatine) arches, and below by the dorsum of the tongue in the region of the sulcus terminalis. Below the faucial isthmus, the anterior wall of the oral pharynx is formed by the root of the tongue, which has been described previously. The *lateral* wall of the oral pharynx on each side presents the *palatine tonsil*, enclosed in a somewhat triangular *tonsillar fossa* [sinus tonsillaris] limited anteriorly and posteriorly by the anterior and posterior palatine arches, and below by the root of the tongue.

The part of the vertebral column accessible to a straight instrument introduced through the mouth cavity and oral pharynx is somewhat restricted, extending from the second to the fourth cervical vertebræ. But if a finger is introduced, with the aid of an anesthetic, it is pos-

sible to examine the anterior aspects of the bodies of the upper four or five (in children, six cervical vertebræ.

The *palatine arches* (pillars) are folds of the mucosa formed at the sides of the free posterior border of the soft palate, as already mentioned in connection with that organ. The *anterior arch* [arcus glossopalatinus] extends from the soft palate downward and forward to the lateral margin of the tongue, just behind the papillæ foliatæ. It is a fold of mucosa due to the underlying glossopalatine muscle, and inconspicuous except when this muscle is in action, or when the tongue is depressed. It forms the lateral boundary of the faucial isthmus. The

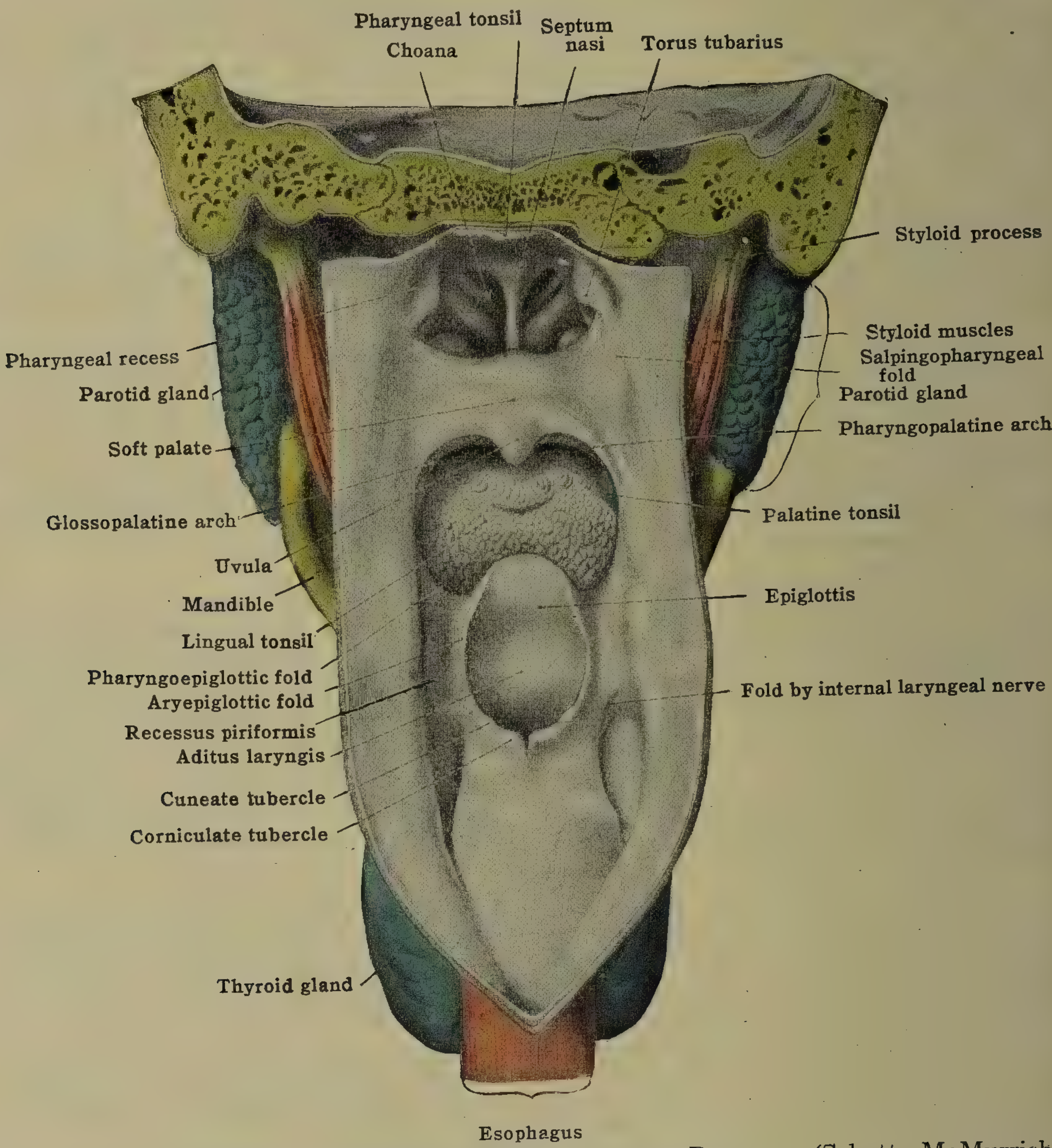


Fig. 965.—The Interior of the Pharynx, Viewed from Behind. (Sobotta-McMurrich.)

posterior arch [arcus pharyngopalatinus] is a more prominent fold which extends from the soft palate in the region of the uvula downward and backward to join the posterolateral aspect of the pharyngeal wall. It forms the lateral boundary of the pharyngeal isthmus, and encloses the pharyngopalatine muscle, whose action will be explained later.

The Palatine Tonsil

The **palatine tonsil** [tonsilla palatina] (figs. 947, 966, 967) is a flattened ovoidal body, usually visible through the mouth cavity and faucial isthmus, and located on each side of the oral pharynx. The tonsil is extremely variable in size, but in the young adult averages 20 to 25 mm. in height, 15 to 20 mm. in width (anteroposteriorly) and about 12 mm. in thickness. The weight averages 1.4 grams (Gundobin).

The **lateral** or attached **surface** of the tonsil is covered by a thin but firm fibrous *capsule*, which is continuous with the pharyngeal aponeurosis, and in contact with the superior constrictor muscle of the pharynx (fig. 947).

The tonsillar capsule is rather loosely connected with the constrictor muscle by connective tissue, so that the tonsil can readily be enucleated after an incision through the surrounding mucous membrane. Tonsillar abscesses may extend into this peritonsillar region, or may even spread through the pharyngeal wall into the adjacent retropharyngeal (prevertebral) space. Through the wall of the constrictor, the tonsil is in relation with the ascending pharyngeal and ascending palatine arteries, but is separated by a considerable space from the external and internal carotids. Rarely, however, the lingual or external maxillary may extend up higher than usual, so as to be in close relation with the lower aspect of the tonsil. Further lateralward, the palatine tonsil is in relation with the internal pterygoid muscle, and on the surface corresponds to a point somewhat above and in front of the angle of the mandible. The posterior border of the tonsil is thicker than the anterior, and forms a somewhat flattened surface in contact with the pharyngopalatine muscle (fig. 967).

The **medial** or free **surface** of the tonsil is covered with mucosa and presents a variable number (10 to 30) of small pits which are the openings into the tubular or slit-like *crypts* [fossulæ tonsillares]. These crypts are somewhat more numerous in the upper part of the tonsil, and are sometimes branched or irregular in form. Usually they end blindly in the substance of the tonsil, surrounded by lymphoid tissue in characteristic nodular masses (fig. 966).

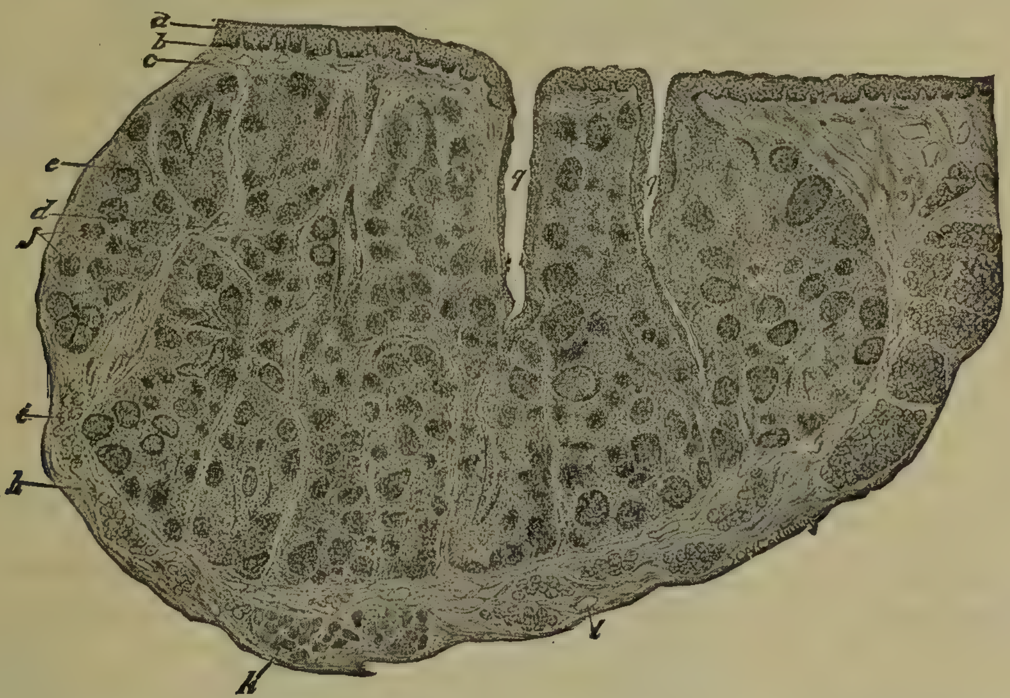


Fig. 966.—Vertical Section of a Human Palatine Tonsil. *a*, stratified epithelium, *b*, basement membrane. *c*, lamina propria. *d*, trabeculæ. *e*, diffuse lymphoid tissue. *f*. nodules. *g*, crypts. *h*, capsule. *i*, mucous glands. *k*, striated muscle. *l*, blood vessel. (From Radasch.)

The lymphocytes normally migrate through the stratified squamous epithelium lining the crypts (occasionally eroding passages of considerable size), and escape into the pharyngeal and mouth cavities, where they form the so-called *salivary corpuscles*. Around the periphery of the palatine tonsil, in the capsule, are many mucous glands (fig. 966), similar to those described in connection with the lingual and pharyngeal tonsils. The ducts of the mucous glands sometimes enter the crypts, but usually pass to the surface around the margins the palatine of tonsil.

Tonsillar plicæ and fossæ.—Connected with the tonsil are certain important folds and fossæ. The *plica triangularis* (fig. 967) is a fold of variable extent and appearance, placed just behind the anterior arch, wider below and narrower above. According to Fetterolf, it is a prolongation of the tonsillar capsule, covered with mucosa. It may be adherent to the anterior part of the medial surface of the tonsil, or it may be free, in which case it covers a recess called the *anterior tonsillar fossa*. Occasionally there is a similar plica and fossa at the *posterior* border of the tonsil. Above the tonsil there is similarly a semilunar fold and a *supratonsillar fossa* [fossa supratonsillaris], that is also inconstant and exceedingly variable in size and shape. Killian found a supratonsillar fossa or canal in 41 of 105 cadavers.

Tonsillar vessels.—The *arteries* to the tonsil (figs. 528, 967) include the *anterior* tonsillar (from the dorsalis linguæ); the *inferior* tonsillar (from the external maxillary); the *posterior* tonsillar (from the ascending pharyngeal) and the *superior* tonsillar (from the descending palatine). These pierce the capsule and supply the gland. The *veins* form a plexus around the capsule and empty into the lingual vein and the pharyngeal plexus. The *lymphatic* relations of the palatine tonsil are important. *Afferent* vessels have not yet been satisfactorily demonstrated. There is an extensive lymphatic plexus in the capsule and around the lymph follicles within the tonsil. *Efférent* lymphatic vessels pass chiefly to the upper deep cervical lymphatic nodes. One of these, located just behind the angle of the mandible, is so closely connected with

the tonsil, and so constantly enlarged following tonsillar infection, that it has been called the *tonsillar lymph-gland* (Wood). There are also communications with the submaxillary and superficial cervical lymphatic nodes. The tonsillar lymphatic vessels connect also with those of the lingual tonsil in the root of the tongue.

The innervation of the palatine tonsil is from the middle and posterior palatine nerves, and from the tonsillar branches of the glossopharyngeal, forming a plexus, the *circulus tonsillaris*.

The tonsillar ring.—The two palatine tonsils, together with the lingual tonsil below and the pharyngeal tonsil above, form an almost complete ring of characteristic tonsillar tissue surrounding the pharynx and known as Waldeyer's 'tonsillar ring.' It is a highly specialized development of the diffuse lymphoid tissue which is found widespread in the mucosa of the alimentary and respiratory tracts. It may be noted that the 'tonsillar ring' corresponds to the anterior limit of the embryonic foregut, hence the epithelium is of endodermic origin. The tonsillar apparatus is generally assumed to be a protective mechanism, belonging to the lymphatic system, but its exact function is still somewhat uncertain.

Development of the tonsil.—For the development of the palatine tonsil in the floor of the second branchial pouch, see p. 45. The later fetal development of this tonsil is subject to

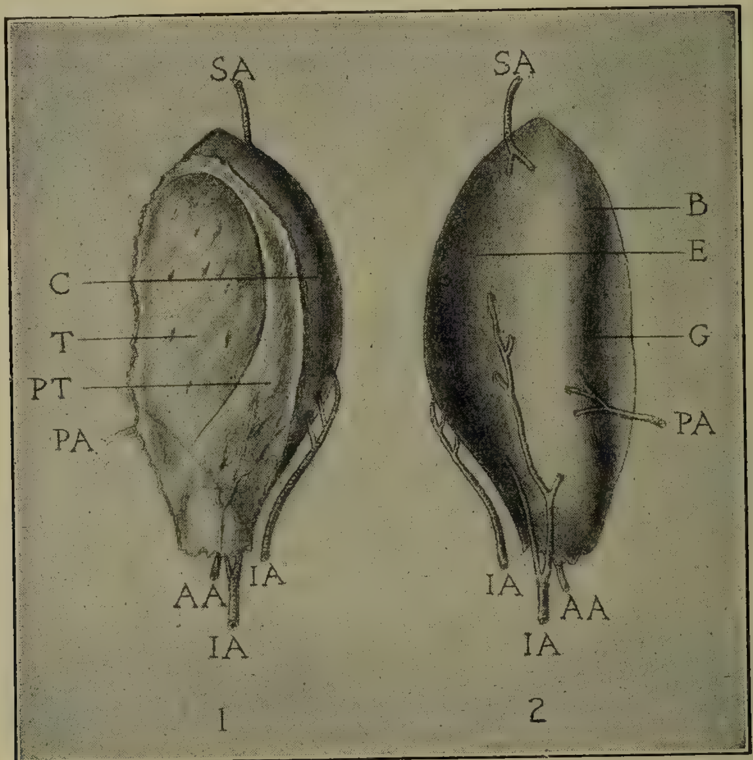


FIG. 967.—THE LEFT PALATINE TONSIL, SHOWING THE ARTERIAL SUPPLY.

1, Medial aspect. 2, posterolateral aspect. E, lateral surface. B, posterior surface. T, medial surface. G, groove for pharyngopalatine muscle. C, capsule. PT, plica triangularis. Arteries: AA, anterior tonsillar (from dorsal lingual); PA, posterior tonsillar (from ascending pharyngeal); SA, superior tonsillar (from descending palatine); IA, inferior tonsillar (anterior from dorsal lingual; posterior from tonsillar branch of internal maxillary). (Fetterolf: Amer. J. Med. Sc., 1912.)

considerable individual variation. The supratonsillar fossa is a remnant of the upper part of the primitive sinus tonsillaris, which may be transformed into a canal by growth of adenoid tissue around it. It is inconstant and quite variable in size and extent. A portion of the sinus may likewise persist anteriorly (anterior tonsillar fossa) between the tonsil and the plica triangularis, but this portion is usually obliterated by fusion of the plica with the tonsil. The occasional retrotonsillar fold and fossa are said to arise secondarily (Hammar).

Variations in the tonsil.—The palatine tonsil, like the lingual and pharyngeal tonsils, is an exceedingly variable organ. Many of the variations are developmental in origin, as above indicated, and are therefore *congenital*. Furthermore, the tonsils, like all lymphoid structures, are subject to marked *age-variations* (see p. 46). Though fairly well formed at birth, they are yet somewhat undeveloped. They rapidly increase in relative size and complexity, however. After the age of puberty, they usually undergo certain retrogressive changes, become smaller in size, and in old age become almost entirely atrophied and lost. They are also markedly subject to inflammatory hypertrophy, especially in children. Variations in the relations of the *blood-vessels* were mentioned above. The comparative anatomy of the tonsils is discussed later.

The laryngeal pharynx [pars laryngea] (fig. 934) is the lower portion leading from the oral pharynx above into the esophagus below (at the level of the lower border of the cricoid cartilage, usually opposite the sixth cervical vertebra). It is wide above and narrow below (fig. 965). Its *posterior* wall is continuous with that of the oral pharynx and in relation with the vertebræ. Its *lateral* walls are attached to the hyoid bone and the medial surface of the thyroid cartilage. *Anteriorly* it is in relation with the larynx (fig. 965). In the median line above is the epiglottis, below which is the superior aperture of the larynx.

Still lower is the posterior wall of the larynx, containing the arytenoid and lamina of the cricoid cartilage. Laterally are the pharyngoepiglottic folds, and below these on each side an elongated fossa, the *recessus piriformis*, bounded laterally by the medial surface of the thyroid cartilage. The *mucosa* of the laryngeal pharynx is similar to that of the oral pharynx, and contains racemose mucous glands, which are especially numerous in its anterior wall.

Muscles of the pharynx and soft palate.—These muscles (figs. 968–970), which are here grouped together for convenience of description, are chiefly sphincter-like constrictors in function. They include the constrictors of the faucial isthmus (mm. glossopalatini), the constrictors of the pharyngeal isthmus

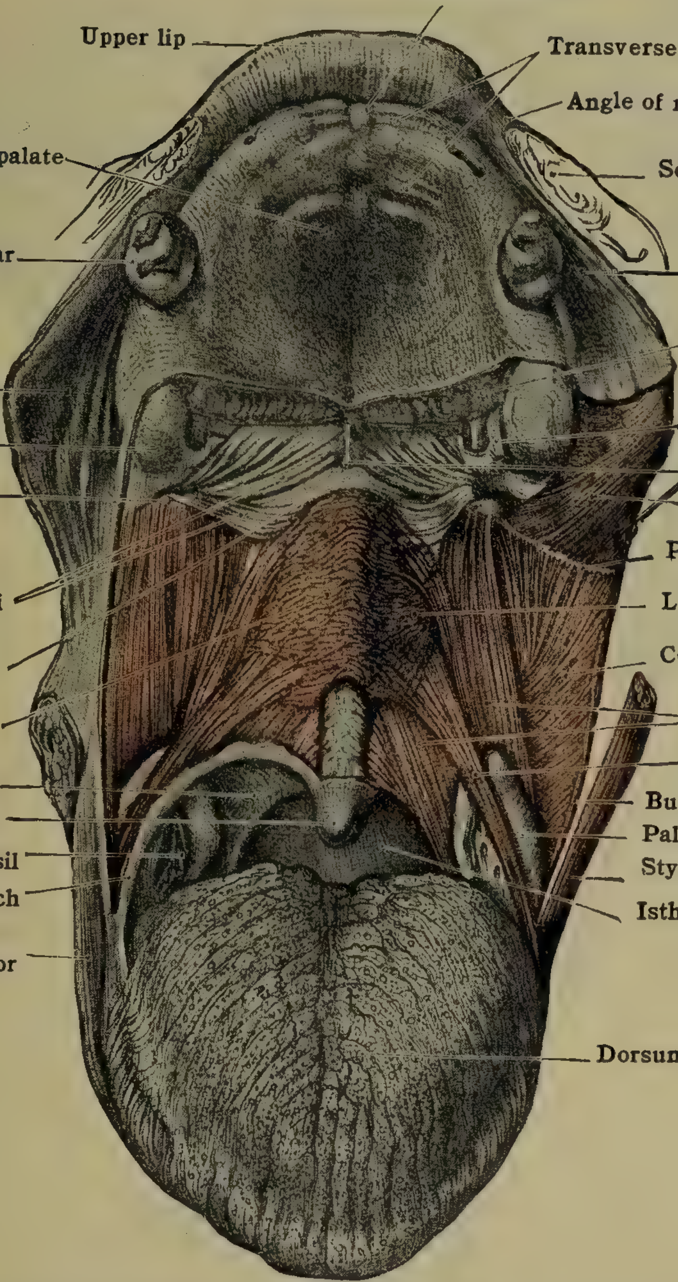


Fig. 968.—The Muscles of the Soft Palate and the Palatal Arches as Seen from in Front. (After Toldt, 'Atlas of Human Anatomy,' Macmillan Company.)

(mm. pharyngopalatini), the three pharyngeal constrictors, and also the levator and the tensor veli palatini, the m. uvulæ and the stylopharyngeus. The stylopharyngeus and pharyngopalatine muscles form an incomplete longitudinal layer within the more circularly arranged constrictors of the pharynx.

The muscles are arranged in layers either behind or in front of the palatal aponeurosis, and in a horizontal section of the soft palate the following layers are met with from behind forward: (1) The mucous membrane on the pharyngeal surface; (2) the posterior layer of the pharyngopalatinus (palatopharyngeus); (3) the m. uvulæ; (4) the levator veli palatini; (5) the anterior layer of the pharyngopalatinus; (6) the palatal aponeurosis with the tensor veli palatini; (7) the glossopalatinus (palatoglossus); and (8) the mucous membrane on the oral aspect.

The **glossopalatinus** (palatoglossus) is a cylindrical muscle extending between the soft palate and the lateral border of the tongue. *Origin.*—From the oral surface of the palatal aponeurosis. *Insertion.*—(1) The superficial layer of muscles which covers the side and adjacent part of the under surface of the tongue; (2) the transversus linguæ. *Structure.*—At its origin the muscle forms a thin sheet, but the fibers, passing lateralward, quickly concentrate to form a cylindrical bundle, which passes downward beneath the mucous membrane of the pharynx and in front of the palatine tonsil, forming the glossopalatine arch of the fauces. It reaches the side of the tongue at the junction of its middle and posterior thirds, and some of its fibers continue forward to join with those of the styloglossus and hyoglossus, while the majority pass

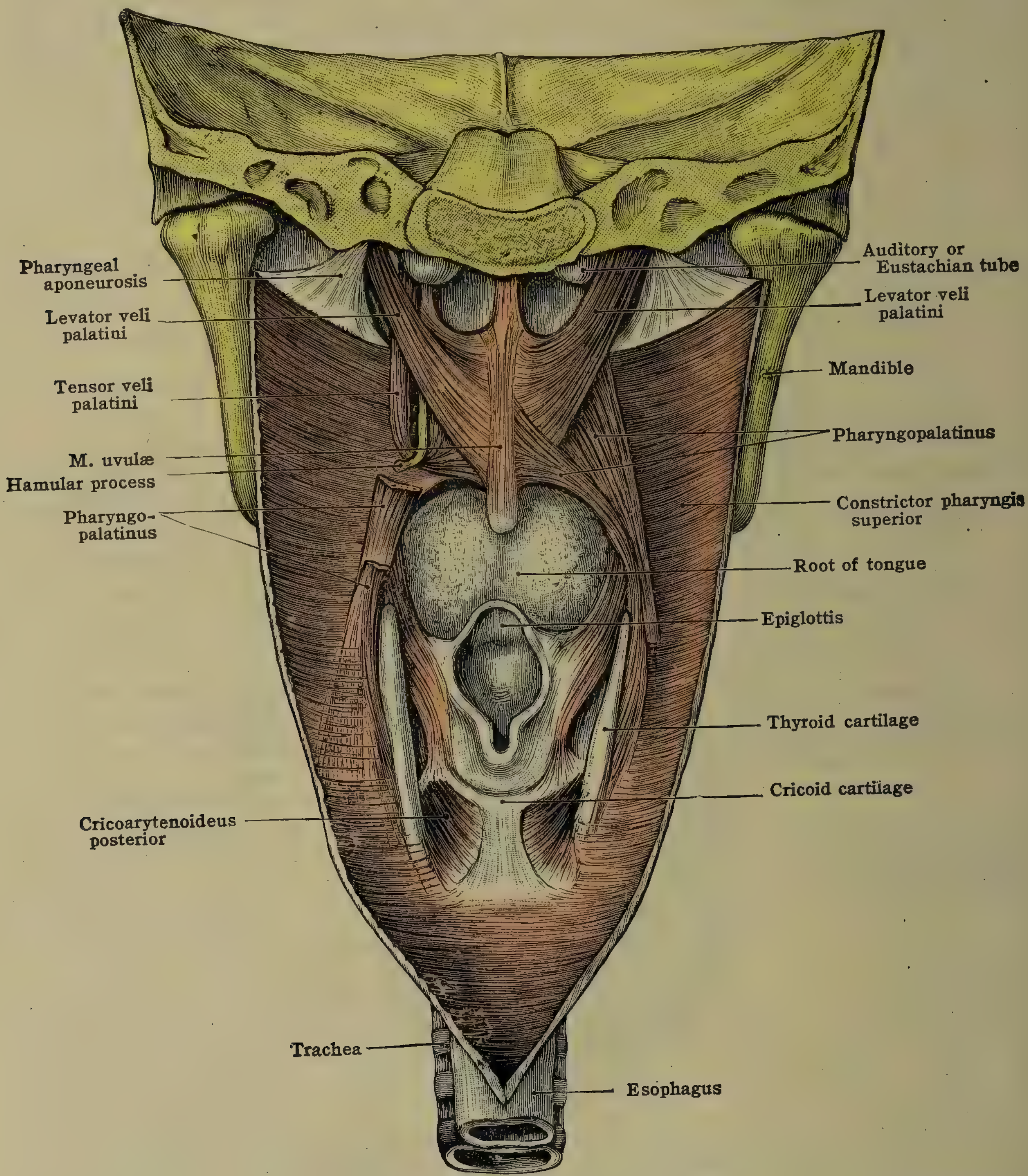


Fig. 969.—View of Muscles of Soft Palate, as Seen from Behind, Within the Pharynx. (Modified from Bourgery.)

medially to become continuous with the transversus linguæ. *Nerve-supply.*—From the pharyngeal branches (plexus) of the vagus. *Action.*—(1) To draw the sides of the soft palate downward; (2) to draw the sides of the tongue upward and backward. The combination of these actions tends to constrict the faucial isthmus. (The origin and insertion of the glossopalatinus as given above are often described as reversed.)

The **pharyngopalatinus** (palatopharyngeus)—named from its attachments—is a thin sheet. *Origin.*—(1) From the aponeurosis of the soft palate by two heads that are separated by the insertion of the levator veli palatini; (2) by one or two narrow bundles from the lower part of the cartilage of the auditory (Eustachian) tube (*salpingopharyngeus*). *Insertion.*—(1) By a narrow fasciculus into the posterior border of the thyroid cartilage near the base of the superior cornu; (2) by a broad expansion into the fibrous layer of the pharynx at its lower part. *Structure.*—The upper head of the muscle consists of scattered fibers which blend with the opposite muscle across the middle line; the lower head is thicker, and follows the curve of the posterior

border of the palate. The two heads with the fasciculus from the auditory (Eustachian) tube form a compact muscular band in the posterior palatine arch; the fibers mingle with those of the stylopharyngeus, at the lower border of the superior constrictor, and then expand upon the lower part of the pharynx. *Nerve-supply.*—From the pharyngeal branch (plexus) of the vagus. *Action.*—(1) Approximates the posterior arches of the fauces; (2) depresses the soft palate; (3) elevates the pharynx and larynx. (The origin and insertion above given are often described as reversed.)

The **inferior constrictor** [m. constrictor pharyngis inferior] (m. laryngopharyngeus NK) is thick and strong. It *arises* from the thyroid cartilage immediately behind the oblique line and superior tubercle (thyropharyngeus), and from a tendinous arch extending between the inferior tubercle of the thyroid and the cricoid cartilage and also from the lateral surface of the cricoid cartilage (cricopharyngeus) (fig. 970). The fibers spread backward and medialward, the lowest horizontally, while those above ascend more and more obliquely, and are *inserted* into the fibrous raphé of the pharynx. Some of the lowest fibers are continuous with the muscu-

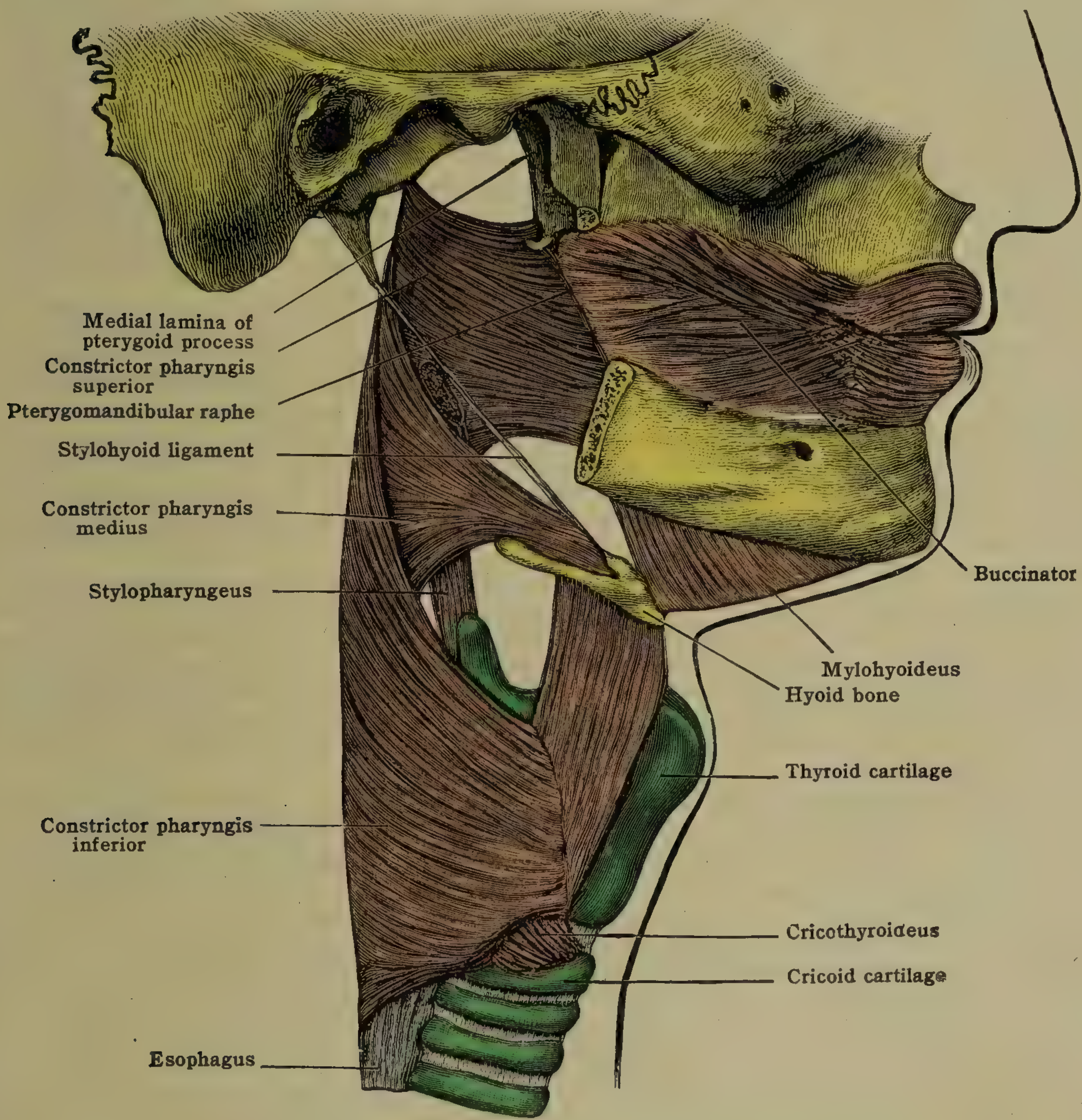


Fig. 970.—The Muscles of the Pharynx, Lateral View.

lar fibers of the esophagus, and the upper overlap the middle constrictor (fig. 970). The *nerve-supply* of all three constrictors is from the pharyngeal plexus (chiefly through vagus fibers derived from the accessory nerve).

The **middle constrictor** (m. hyopharyngeus NK) is a fan-shaped muscle that *arises* from the lesser cornu of the hyoid bone and from the stylohyoid ligament (chondropharyngeus), and from the whole length of the greater cornu (ceratopharyngeus). The diverging fibers are *inserted* into the median raphé, and blend with those of the opposite side. The lower fibers of the muscle descend, beneath the inferior constrictor, to the lower part of the pharynx; the upper overlap the superior constrictor, and reach the basilar process of the occipital bone, while the middle fibers run transversely (fig. 970). The glossopharyngeal nerve passes downward above its upper border, the stylopharyngeus passes between it and the superior constrictor, and near its origin it is overlapped by the hyoglossus and crossed by the lingual artery.

The **superior constrictor** (m. cephalopharyngeus NK) is quadrilateral in shape, pale, and thin (figs. 405, 970). It *arises* from the lower third of the hinder edge of the medial lamina of the pterygoid process and its hamular process (pterygopharyngeus), from the pterygomandibular ligament (buccopharyngeus), from the posterior fifth of the mylohyoid ridge of the mandible (mylopharyngeus), and from the side of the root of the tongue (glossopharyngeus).

The fibers pass backward to be *inserted* into the median raphé, the highest reaching the pharyngeal tubercle. The Eustachian tube and the levator veli palatini are placed above the superior arched border, and the space (*sinus of Morgagni*) between this and the basilar process, devoid of muscular fibers, is strengthened by the pharyngeal aponeurosis, this portion of it being semilunar in shape (fig. 969).

The **stylopharyngeus** *arises* from the base of the styloid process internally (figs. 526, 939). It passes downward and medialward to reach the pharynx between the superior and middle constrictors. Its fibers spread out as it descends beneath the mucous membrane. At the lower border of the superior constrictor some of its fibers join fibers of the pharyngopalatinus (palatopharyngeus), and are *inserted* into the posterior border of the thyroid cartilage (fig. 970); the remainder blends with the constrictors. The *nerve-supply* of the stylopharyngeus is from the glossopharyngeal nerve.

The **levator veli palatini**—named from its action on the velum of the soft palate—is somewhat rounded in its upper, but flattened in its lower, half. *Origin.*—(1) The inferior surface of the petrous portion of the temporal, anterior to the orifice of the carotid canal; (2) the lower margin of the cartilage of the auditory (Eustachian) tube. *Insertion.*—The aponeurosis of the soft palate; the terminal fibers of the muscles of each side meet in the middle line in front of the m. uvulæ. *Structure.*—Its origin is by a short tendon; the muscle then becomes fleshy and continues so to its insertion. *Nerve-supply.*—From a pharyngeal branch (plexus) of the vagus. *Action.*—(1) To raise up the velum of the soft palate, and bring it in contact with the posterior wall of the pharynx; (2) to narrow the pharyngeal opening and (possibly) to widen the isthmus of the auditory (Eustachian) tube.

The **tensor veli palatini**—named from its action on the velum of the soft palate—is a thin, flat, and narrow sheet. *Origin.*—(1) The scaphoid fossa of the sphenoid; (2) the angular spine of the sphenoid; (3) the lateral side of the membranous and cartilaginous wall of the auditory (Eustachian) tube. *Insertion.*—(1) Into the transverse ridge on the lower surface of the horizontal plate of the palate bone; (2) the aponeurosis of the soft palate.

Structure.—Its belly is muscular as it descends between the pterygoideus internus and the internal pterygoid plate. On approaching the hamular process it becomes tendinous. A bursa is interposed between the hamular process and the tendon. The belly of the muscle is at nearly a right angle with its tendon. *Nerve-supply.*—From the mandibular division of the trigeminus through the tensor veli palatini branch of the otic ganglion. *Actions.*—(1) Tightens the soft palate; (2) opens the auditory (Eustachian) tube during deglutition.

The **musculus uvulæ** is so named by reason of its position in the uvula. *Origin.*—(1) From the aponeurosis of the soft palate and tendinous expansions of the two tensores veli palatini. *Insertion.*—Into the uvula. *Structure.*—The muscle consists of two narrow parallel strips lying on each side of the middle line of the palate. *Nerve-supply.*—From the pharyngeal branches (plexus) of the vagus. *Action.*—To draw up the uvula.

Development of the muscles.—According to W. H. Lewis, the tensor veli palatini is a derivative of the mandibular arch (probably split off from the pterygoid mass); the levator veli palatini and m. uvulæ come with the facial musculature from the hyoid arch; the glossopalatine, stylopharyngeus and pharyngeal constrictors probably from the third visceral arch, in a premuscle mass visible in a 9 mm. embryo. The adult innervation of the pharyngeal muscles does not agree entirely with this, however. The pharyngeal muscles (as above stated) are innervated chiefly from the vagus, whereas if derived from the third arch their innervation from the glossopharyngeus would be expected.

Process of swallowing.—In the act of swallowing, practically all of the muscles of the mouth, tongue, palate and pharynx are involved. By compression of the lips and cheeks, together with elevation of the tongue, the food is forced backward through the faucial isthmus into the oral pharynx. Constriction of the faucial isthmus by the glossopalatine muscles assists in preventing a return to the mouth. By the action of the levator and tensor veli palatini, and pharyngopalatine muscles, the soft palate is retracted and tightened, with constriction of the pharyngeal isthmus, so as to prevent the passage of the food upward into the nasal pharynx. The pharynx is drawn upward by the stylopharyngeus, and the pressure produced by the pharyngeal constrictors (the contraction beginning above and extending downward) forces the food downward through the laryngeal pharynx and into the esophagus. Passage of the food into the larynx is prevented by constriction of the superior aperture of the larynx.

Vessels and nerves.—The vessels of the tonsil and the motor nerves of the various muscles have already been mentioned. In general, the *arteries* to the pharynx are derived chiefly from the ascending pharyngeal, the ascending palatine branch of the external maxillary, and the descending palatine and pterygopalatine branches of the internal maxillary. The *veins* form a venous plexus between the pharyngeal constrictors and the pharyngeal aponeurosis, and also an external plexus, communicating with the pterygoid plexus above and with the posterior facial or internal jugular vein below. The *lymphatic* vessels pass chiefly to the deep cervical nodes, those from the upper portion ending partly in the retropharyngeal nodes. The *nerves* of the pharynx, both motor and sensory, are derived chiefly from the glossopharyngeal, vagus (and accessory), by way of the pharyngeal plexus.

The development of the pharynx.—For the development of the pharynx, including the branchial arches and pouches, and the pharyngeal tonsils, see p. 45.

Variations.—Variations in the palatine and pharyngeal tonsils and in the pharyngeal bursa have already been mentioned. Remnants of the visceral clefts may persist as aberrant diverticula or as 'branchial fistulæ' connected with the pharynx. Many additional *muscles* have been described, chiefly longitudinal muscles arising from the base of the cranium either by splitting of those normally present, or as separate slips. A detailed description of these may be found in Poirier-Charpy's work. Abnormally extensive fusion of the posterior arches of the palate with the walls of the pharynx may produce a congenital stenosis of the pharyngeal isthmus.

Comparative.—The pharynx is not distinctly separated from the mouth cavity in the lower vertebrates. It is the region containing the branchial or visceral clefts and is thus both

respiratory and alimentary in function. The *nasal* pharynx, including the apertures of the auditory tubes, becomes distinct along with the nasal cavity when the palate is formed (from the reptiles upward). In the air-breathing vertebrates, the laryngeal aperture appears in the ventral wall of the pharynx just anterior to the beginning of the esophagus. Of the *tonsils*, the *pharyngeal* are the most primitive, being present in the roof of the pharynx in amphibia, well developed in reptiles, birds, and mammals (Killian). The *palatine* tonsils, on the other hand, are characteristic of mammals, being rarely absent, however (e. g., rat, guinea pig). From the embryological point of view, Hammar has classified the palatine tonsils in the various mammals under (1) the primary type (including rabbit, cat, and dog), in which the tonsil is formed from the embryonic tonsillar tubercle (described above under development of tonsil); and (2) the secondary type (including pig, ox, sheep and man), in which the tonsillar tubercle disappears and the tonsil is developed from the wall of the surrounding tonsillar sinus. Typical epithelial crypts (highly branched in the ox) are found only in the secondary type. The tonsil may form a single (lymphoid) lobe (cat, pig, rabbit) or may develop typically two lobes (ox, sheep, man), separated by the intratonsillar fold. There are great variations among different species as to relative size, number and character of folds, crypts, etc. The intimate relation of the epithelium with the underlying lymphoid tissue is characteristic and constant.

THE ESOPHAGUS

The **esophagus** [œsophagus] (figs. 971, 972) is that segment of the alimentary canal which extends from the pharynx to the stomach. It is a constricted

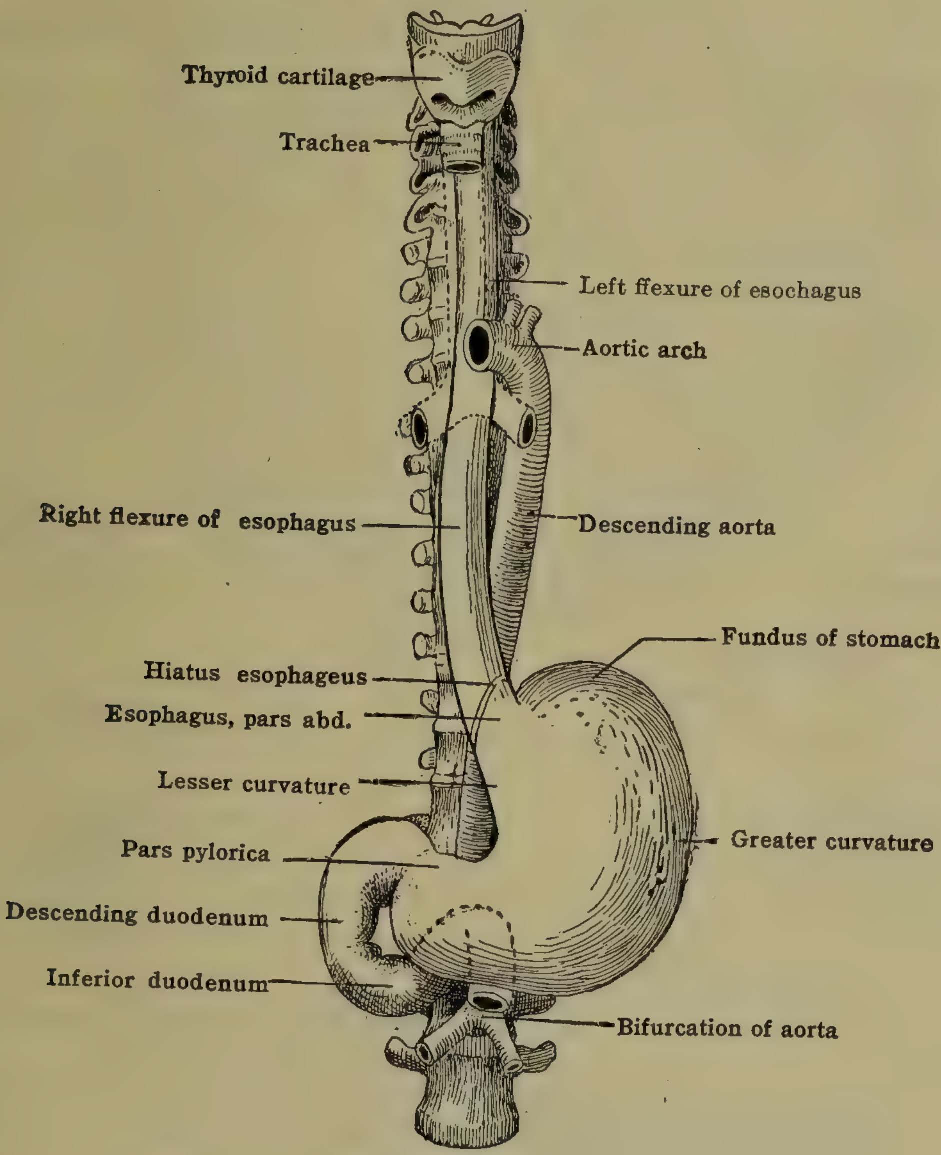


FIG. 971.—THE ESOPHAGUS AND STOMACH. (Testut.)

portion of the canal, being narrowest at its commencement opposite the lower border of the cricoid cartilage. It is again somewhat contracted at the aortic arch or tracheal bifurcation, and at its passage through the diaphragm, opposite the tenth or eleventh thoracic vertebra (figs. 971, 972). It has three parts—cervical, thoracic and abdominal.

In its course downward the esophagus follows the curve of the vertebral column until it finally passes forward in front of, and slightly to the left of, the aorta to gain the esophageal opening in the diaphragm. In addition to this curve it presents two lateral curvatures, one convex toward the left side at the root of the neck and in the upper part of the thorax, and the other concave toward the

left in the lower part of the thorax where it leaves the vertebral column. It lies in the middle line at its commencement (usually opposite the sixth cervical vertebra), and again, at a lower level, opposite the fifth thoracic vertebra.

The following average measurements *in situ* (range in parenthesis), were observed by v. Hacker on male cadavers (females slightly less): Teeth to cricoid level, 14.9 (14–16) cm.; total esophagus, 25.0 (23–30) cm.; cricoid to tracheal bifurcation, 10.4 cm.; tracheal bifurcation to cardia, 14.6 (12–17) cm. The average width is about 2.0 cm.; but at the upper end only 1.3 cm., and near the lower end (hiatus esophageus), 1.6 cm.

After death the esophagus is somewhat flattened from before backward, but it is more rounded during life. It is closed except during the passage of food, etc. The *peristaltic movements* of the esophagus can readily be observed by means of the Rœntgen-rays. Solids often

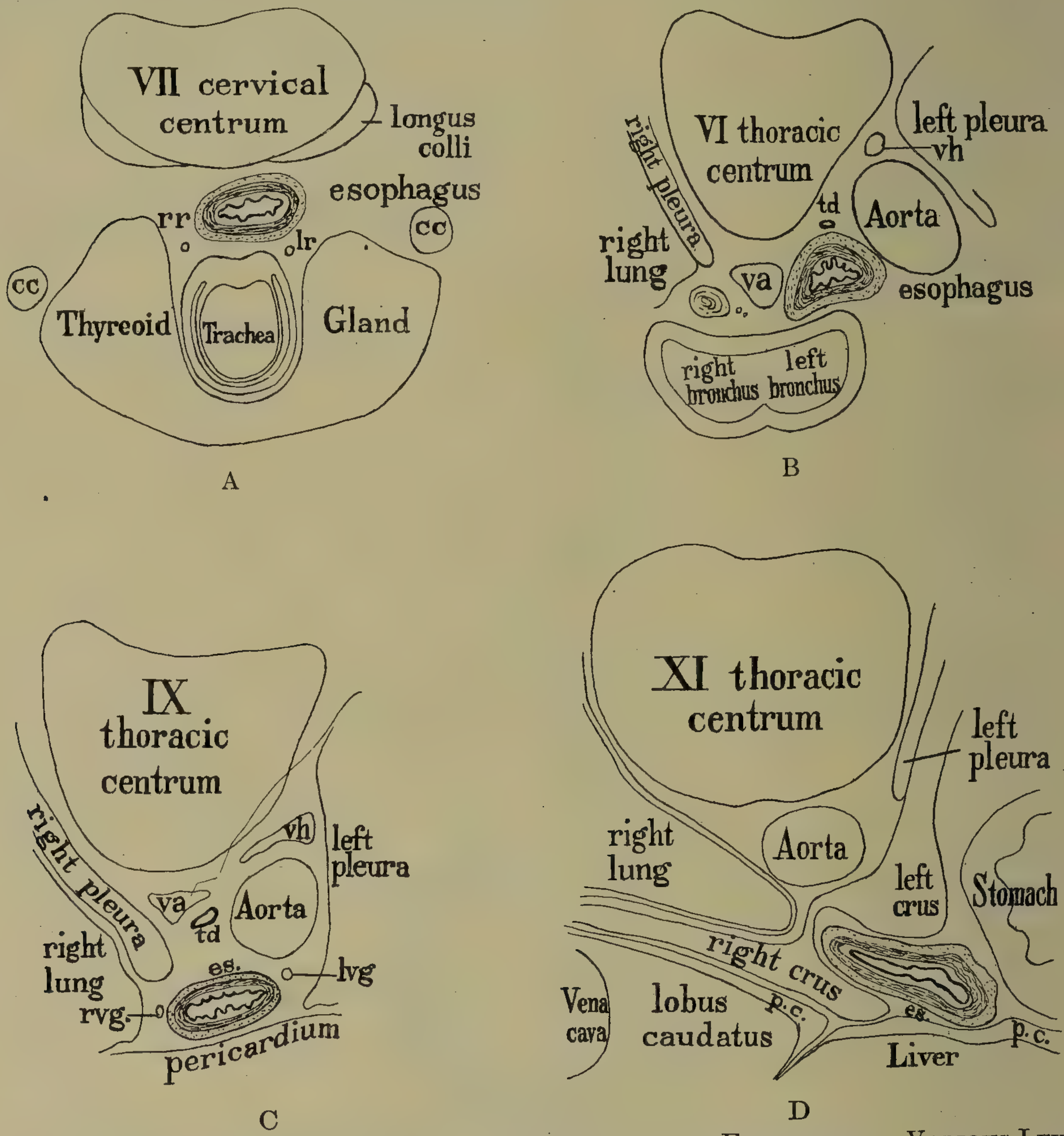


Fig. 972.—Cross sections Showing the Relations of the Esophagus at Various Levels.

lodge a short time at the level of the arch of the aorta, but pass quickly through the cardiac orifice. A swallow of liquid, on the other hand, is usually detained at the lower end of the esophagus (probably by sphincteric action of the cardia) for about seven seconds before passing into the stomach (Pfahler).

Cervical portion.—The esophagus in this region has anteriorly the trachea, the posterior portion of the left lateral lobe of the thyroid gland, and the left recurrent nerve, branches of the inferior thyroid artery, and the carotid sheath. *Posteriorly,* it rests upon the vertebral column, the longus colli muscles, and prevertebral fascia. *On its right side* are placed the right carotid and right recurrent nerve; and *on the left side* the left inferior thyroid vessels, left carotid artery, left subclavian, and the thoracic duct. The recurrent nerves pass upward on each side to gain the interval between the trachea and esophagus. The left nerve, as already described, lies in front of the tube, and the right along its right border.

Surgical approach.—To expose the esophagus in the neck an incision is made on the left side, much as for the higher ligature of the common carotid, but carried lower down. The depressors of the hyoid are drawn medially or divided, and the pretracheal fascia is opened. The overlapping thyroid gland and trachea are displaced medially, while the carotid sheath is retracted laterally. The tracheal rings are the best guides to the esophagus. The recurrent nerve must be avoided.

Thoracic portion.—The esophagus descends in the thorax through the superior and the posterior mediastina. In the *superior mediastinum* its anterior relations are the trachea, with the deep cardiac plexus in front of its bifurcation, the left subclavian and carotid arteries crossing its left border obliquely, the left recurrent nerve, and the arch of the aorta. To the *left* are the left carotid and subclavian arteries, the end of the arch of the aorta, and the left pleural sac. To the *right* it is in relation with the right vagus nerve and the right pleural sac. *Posteriorly*, it rests upon the vertebral column, the left longus colli muscle, and it overlaps the thoracic duct. As it enters the *posterior mediastinum* it passes behind the bifurcation of the trachea (or left bronchus) and the right pulmonary artery, resting posteriorly on the vertebral column and thoracic duct. In the posterior mediastinum it has *anteriorly* the pericardium, which separates it from the left atrium and a portion of the diaphragm; *posteriorly* it rests upon the vertebral column, accessory hemiazygos and hemiazygos veins, the right aortic intercostal arteries, the thoracic duct, and the descending aorta. To the *right* is the right pleural sac, the vena azygos, which it partly overlaps, and (below) the thoracic duct. To the *left* in the upper part is the descending thoracic aorta, and, below, the left pleural sac is separated from it by a little areolar tissue. It is surrounded by the esophageal plexus formed by the vagus nerves, and, as they emerge from the lower part of the plexus, the left vagus lies in front of the esophagus and the right vagus behind. All of these relations may be important in esophageal growths and ulcerations, or in the passage of instruments.

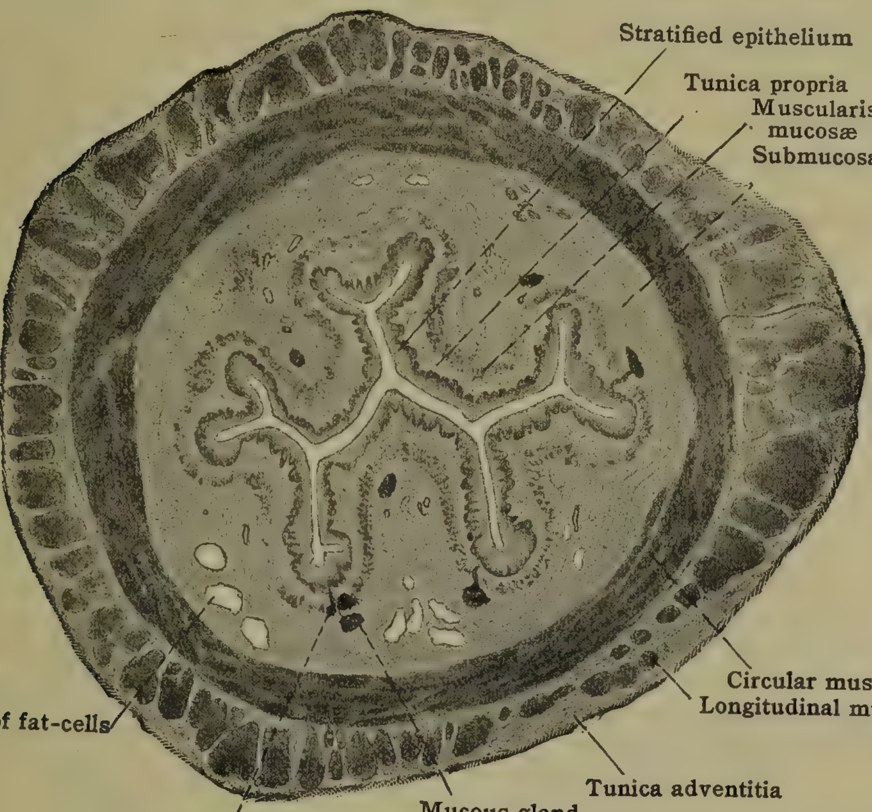


Fig. 973.—Transverse Section of the Upper Third of the Human Esophagus. × 5. (Lewis and Stöhr.)

Abdominal portion.—The terminal portion of the esophagus lies below the diaphragm, at the level of the xiphoid process, just to the left of the midline. *Anteriorly* is the left lobe of the liver; to the *left* the left lobe of the liver and the fundus of the stomach; to the *right* the caudate (Spigelian) lobe of the liver; and *posteriorly* the decussating fibers of the crura of the diaphragm and the left inferior phrenic artery. The abdominal portion (*antrum cardiacum*) is very short, usually not more than 2 cm. (⅘ inch) in length (see figs. 972, 978). According to Reich, this portion of the esophagus is functionally a part of the stomach. The so-called cardiac sphincter of the stomach is formed by the circular muscle layer of the esophagus, together with the adjacent fibers of the diaphragm.

Structure.—The thick-walled esophagus presents the four typical tunics of the alimentary canal (fig. 973). The mucosa and the muscularis are the most important, the submucosa and the external fibrosa being accessory layers. The **mucosa** (fig. 973) is thick and strong, of reddish color in its upper portion and more grayish below. It presents deep longitudinal folds to allow for distention, and when empty the lumen is therefore stellate in cross-sections. The lamina propria presents numerous papillæ, and is limited externally by a *muscularis mucosæ*. This is a comparatively thick layer (except at the upper end) and is composed of smooth muscle-fibers, longitudinally arranged.

The submucosa (fig. 973) is a thick, very loose fibrous layer connecting the mucosa with the muscularis. It contains numerous vessels and nerves, and *mucous glands*. The latter [gl. œsophageæ] are of the racemose type, and are variable in number. There are also two sets of *superficial* glands, confined to the lamina propria, and resembling the fundus glands of the stomach. The upper set (Rüdinger-Schaffer glands) are found in 70 per cent. of cases, occurring above the level of the fifth tracheal ring. The lower set (esophageal cardiac glands) form a ring around the esophagus just above the cardiac aperture. A few small lymph nodes also occur in the submucosa, often around the ducts of the mucous glands.

The **muscularis** (fig. 973) is a thick reddish tunic with two distinct layers, approximately equal in thickness. The fibers of the *inner* layer are arranged circularly and are continuous

with the inferior constrictor above and with the oblique fibers of the stomach below. The fibers of the *outer* layer are longitudinal and commence above as three flattened bands: a strong anterior band arising from the ridge on the back of the cricoid cartilage, and two lateral bands blending with the fibers of the stylopharyngeus and the pharyngopalatine. These all unite into a continuous layer which below passes into the muscular coat of the stomach. The upper third or fourth of the esophagus contains exclusively cross-striated muscle fibers, like those of the pharynx. Below this, there is a zone of intermingled smooth and cross-striated fibers. The lower third of the esophagus muscle is usually composed exclusively of smooth fibers.

Around the muscular coat is a thin loose *fibrous* layer [tunica adventitia] connecting the esophagus with neighboring structures.

Vessels and nerves.—The *arterial* supply of the esophagus is derived from the inferior thyroid, the esophageal branches of the aorta, the intercostals, the inferior phrenic and the left gastric arteries. Branches pierce the wall and supply the various coats. The *veins* accompany the arteries. They form on the outer surface of the esophagus a venous plexus opening into the gastric coronary vein below and the azygos and thyroid veins above (thus establishing a communication between portal and systemic veins). There are also numerous *lymphatics* in the esophagus arising chiefly in the mucosa and draining into the lower deep cervical, posterior mediastinal and superior gastric nodes (fig. 647). The *nerves* form two sympathetic plexuses, the submucous and the myenteric, from which the walls are supplied as will be described later for the stomach and intestine. Branches are received from the sympathetics, and from the vagus, including the recurrent nerve.

Development.—The embryonic esophagus is at first relatively very short, but lengthens rapidly in connection with the descent of the stomach. It is relatively longer in the newborn than in the adult (Kolster). The upper end is still high in children, corresponding to the higher vertebral level of the larynx. The primary longitudinal folds of the mucosa appear early (third month) and at the lower end seem to participate in the rotation of the stomach (F. P. Johnson). The superficial esophageal glands appear about the fourth month (78 mm.), the deep glands at 240 mm. (Johnson). Of the muscular layers, the circular appears first (at about 10 mm.), the longitudinal slightly later (embryo of 17 mm.).

Variations.—Usually a bundle of smooth *muscle* connects the esophagus with the left bronchus [m. bronchoœsophageus], and another similarly with the left mediastinal pleura [m. pleuroœsophageus]. More rarely there are similar bands connecting with the trachea, pericardium, etc. Pouch-like *dilations* or diverticula of the esophagus may occur, especially in the upper part of its posterior wall or at the lower end. According to C. R. Robinson, the latter include (1) *ampulla phrenica*, just above the diaphragm, and (2) *antrum cardiacum*, in the abdominal portion of the esophagus. *Diverticula* also occur, some of which may be derived from the embryonic vacuolization of the epithelium previously described, as may likewise the occasional congenital *atresia*. Abnormal *strictures* of the esophagus may occur, oftenest at the upper end, at the left bronchus, and near the lower end. Finally, the esophagus may be in part either double or absent, and may communicate by fistula with the trachea.

Comparative.—The *length* of the esophagus varies with the length of the neck, being shortest in fishes and amphibia where the esophagus is not well marked off from the stomach. *Mucous glands* are absent in fishes, but occur typically in all higher forms. They are found best developed toward the lower end of the esophagus, except in mammals, where they are usually more numerous at the upper end. Some birds (duck, chick) have a well developed *tonsil* at the upper end of the esophagus. *Dilations* may occur normally, as in the crop of birds, which is richly supplied with glands. The *musculature* of the esophagus is primitively entirely smooth (Oppel) as found in amphibia, reptiles and birds. A secondary replacement by cross-striated muscle is found to a variable extent in the majority of mammals and fishes.

THE ABDOMEN

The **abdomen** proper includes that part of the body situated between the thorax and the pelvis. It is limited *above* by the diaphragm; *below*, by the brim of the true pelvis; *behind*, by the vertebral column, diaphragm, quadratus lumborum and psoas muscles, and by the posterior portions of the ilia. *At the sides* it is limited by the anterior parts of the ilia and the posterior portions of the muscles which compose the anterior abdominal wall, viz., the transversus, internal oblique, and external oblique. *In front*, besides these muscles, there are the two recti and pyramidales muscles. In a broad sense, the term abdomen is also used to include the pelvis, with which it is directly continuous below.

Abdominal regions.—For purposes of description, it is customary to divide the ventra surface of the abdomen, by means of two horizontal and two vertical lines, into nine regions (fig. 974). A complete uniformity in the use of the boundary lines marking these regional subdivisions has not as yet been attained, although the variations in the schemes used are not marked as concerns the main features. It should be borne in mind that the boundary lines used should be converted into planes, carried through the whole depth of the abdomen and defined on the dorsal as well as the ventral surface. The relations defined are only approximate, owing to the wide range of variation in the position of the abdominal contents. The nine regions or subdivisions may be outlined as follows: The upper horizontal (infracostal) line or plane passes through the lowest point of the tenth costal cartilages. This lies about 3 to 5 cm. above the umbilicus, and passes dorsally through the second or third lumbar vertebra. The lower horizontal line and plane pass through the level of the anterior superior iliac spines, and dorsally about 2.5 cm. below the promontory of the sacrum. Cunningham has proposed that this line be passed through the tuberculum cristæ, therefore in a plane slightly higher than the interspinous plane. For the longitudinal lines and planes it has been cus-

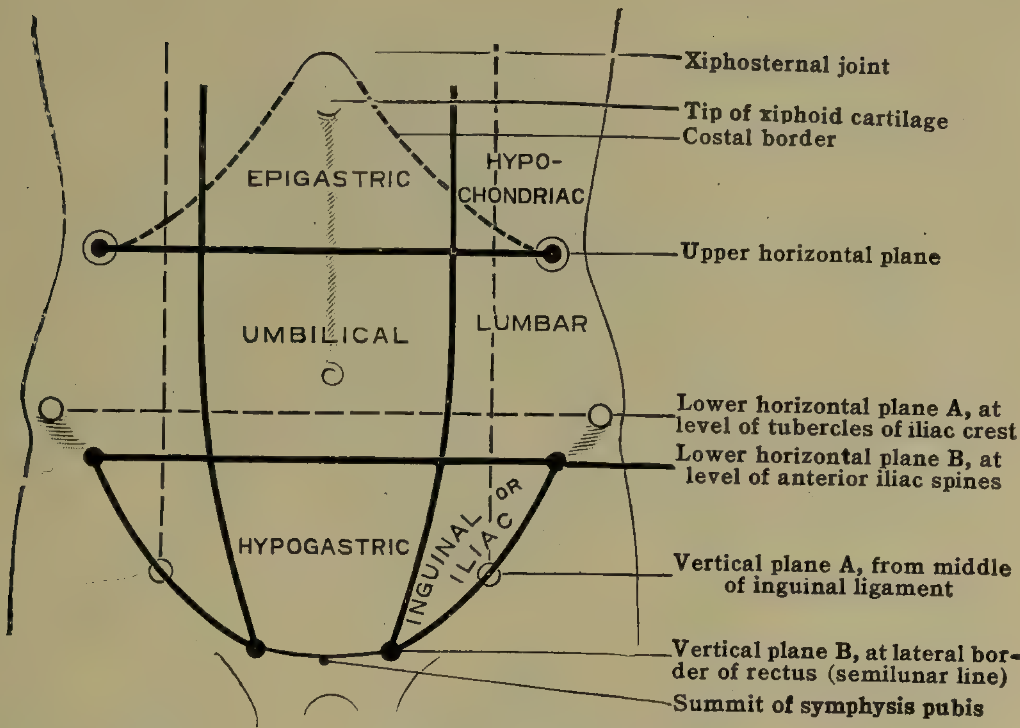


Fig. 974.—Diagram of the Abdominal Regions. Old method in broken lines. New method (BNA) in solid lines.

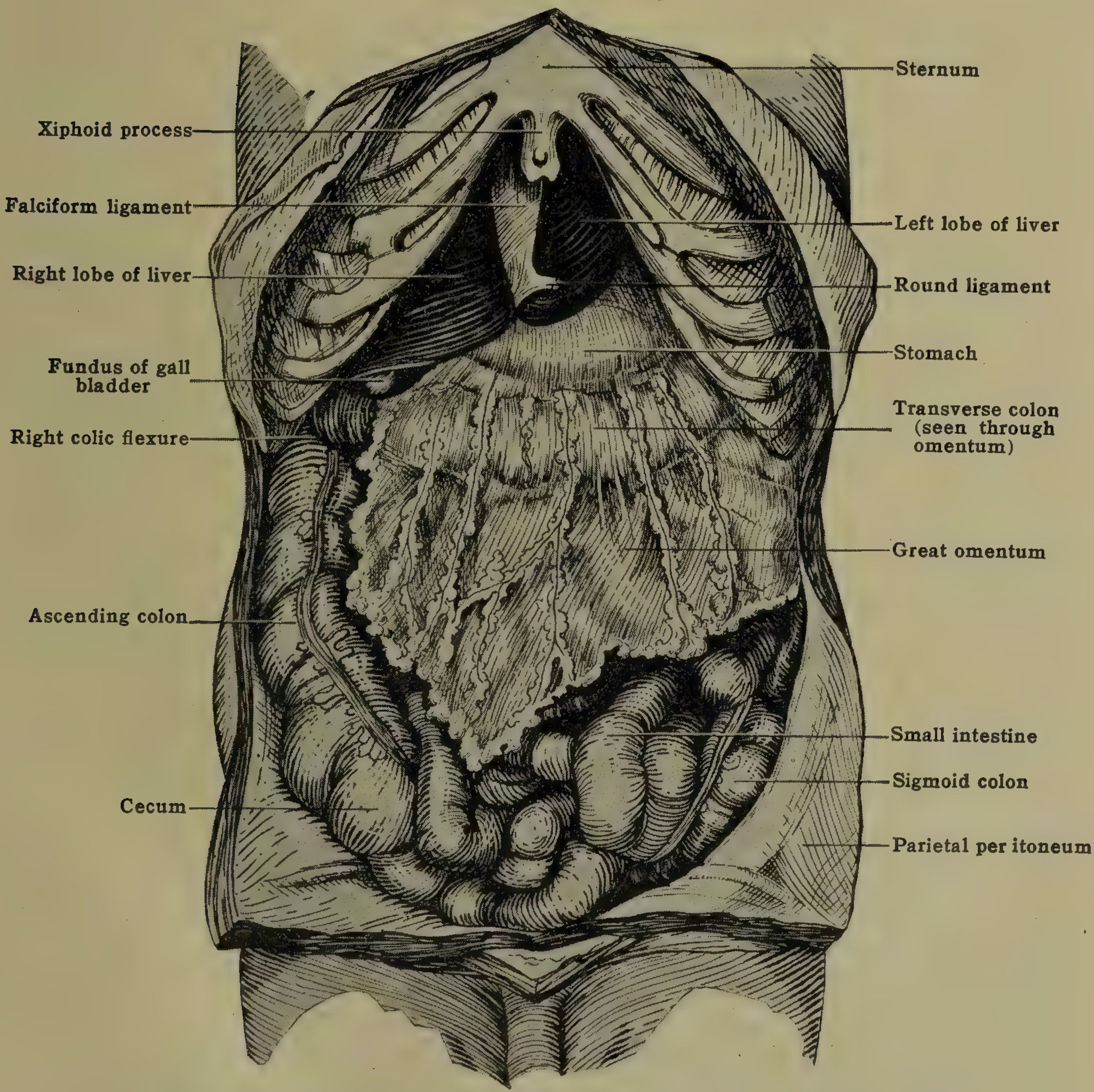


Fig. 975.—Abdominal Viscera in Situ. Ventral view. (After Toldt.)

tomary to run vertical lines from the middle of the inguinal ligaments. The preferable plan (BNA) is to use for this purpose the semilunar lines (lateral margin of the rectus muscle) extending from the costal border to the pubic spine on each side. This leaves on each side an inguinal region which includes the whole of the inguinal canal. The boundary lines here indicated may be made intelligible by a reference to fig. 974. The regions thus outlined are known as the right and left hypochondriac and epigastric regions, found above the upper horizontal line; the right and left lumbar and the umbilical regions, found between the two horizontal lines; the right and left inguinal (or iliac) and the hypogastric regions, found below the lower horizontal lines. According to the BNA, the lumbar regions are termed 'lateral abdominal.' A median vertical line is sometimes drawn in the linea alba, separating the right and left halves of the abdomen.

Another plane of topographic importance is represented by Addison's *midepigastric or transpyloric line* (fig. 1003). This is drawn horizontally through a point midway between the umbilicus and the sternoxiphoid junction, and is also midway between the symphysis pubis and the suprasternal notch. The *sternoxiphoid plane,* drawn horizontally at the sternoxiphoid junction, corresponds to the disk between the ninth and tenth thoracic vertebræ. The *umbilical plane* crosses about the disk between the third and fourth lumbar vertebræ (somewhat lower in corpulent subjects).

For further details concerning the topography of the abdominal wall, see fig. 1003.

On laying open the abdomen from the front, the general form of the space is seen to be an irregular hexagon, the sides of which are formed as follows (fig. 975): The upper two by the margins of the costal cartilages meeting at the xiphoid cartilage; the two lateral sides by the edges of the lateral boundary; and the two lower by the two inguinal ligaments which extend to the pubes.

In this irregular hexagon the following organs can be observed in their normal position. Above, on the right side, the liver can be seen, extending from the right across the epigastric region. Below the liver, and lying to the left side, is the anterior surface of the stomach; from the lower border of the stomach the omentum extends downward, and shining through it can be seen the middle part of the transverse colon. On each side and beneath the irregularly folded omentum are exposed the coils of the small intestine in the umbilical and hypogastric regions; in the right iliac fossa appears a part of the cecum, above which the ascending colon extends in the lumbar region; and on the left side are the descending colon and the sigmoid colon.

Viscera behind the linea alba.—From above downward there are the following;—(1) *Above the umbilicus*—the left lobe of the liver, the stomach, the transverse colon, part of the great omentum, the pancreas, and celiac (solar) plexus. (2) *Below the umbilicus*—the rest of the great omentum, covering in the small intestines and their mesentery. In the child, the bladder occupies a partly abdominal position; and in the adult, the same viscus, if distended, will rise out of the pelvis and displace the above structures, raising the peritoneum until, if distended half way to the umbilicus, there is an area of nearly 5 cm. (2 in.) safe for operations above the symphysis. The gravid uterus also rises behind the linea alba.

General morphogenesis.—Before taking up the various individual organs included in the abdominal and pelvic portions of the alimentary canal, a brief consideration of their general morphology is desirable. The primitive canal, as already described in the early embryo (in the section on Developmental Anatomy), and as found in the lower vertebrates is a comparatively straight, simple tube extending ventral to the body axis from mouth to anus. In the abdominal region (and primitively throughout the whole trunk), the canal lies within the body-cavity (celom), which is lined by parietal peritoneum. The visceral peritoneum is reflected from the mid-dorsal line as a double layer, the *primitive dorsal mesentery* [mesenterium commune] (fig. 976), within which the vessels and nerves pass to the walls of the canal. Within the dorsal mesentery are also the spleen and pancreas. In the anterior (upper) region of the abdomen there is also a similar primitive *ventral* mesentery, which contains the liver.

The relations above mentioned are indicated diagrammatically in fig. 976, which represents a comparatively early stage in the development of the intestinal canal. The liver is already somewhat separated from the diaphragm (with which it was intimately associated in the earlier septum transversum) (fig. 1030). The ventral mesentery (mesogastrium ventrale NK) persists in the form of (1) the lesser omentum, connecting the stomach with the liver; and (2) the falciform ligament, connecting the liver with the ventral body-wall.

The stomach undergoes a rotation on its longitudinal axis so that its anterior border (lesser curvature) is turned to the right, and its posterior border (greater curvature) to the left (fig. 977). Thus the dorsal mesentery of the stomach [mesogastrium dorsale] bulges to the left and forward, carrying with it the spleen and pancreas. The portion of the mesentery corresponding to the pancreas, and that from the spleen to the root of the mesentery, become fused with the posterior body-wall (fig. 979). The portion of the primitive mesogastrium between the stomach and spleen persists as the *gastrolienal ligament* (pars gastrolienalis NK), while the lower portion arches forward and downward as an extensive fold, the *great omentum* (figs. 977, 980). The upper part of the dorsal layer of the great omentum soon fuses with the transverse mesocolon; while the lower portion later fuses with the adjacent ventral layer of the great omentum, converting this part of the omentum into the single apron-like fold found in postnatal life (figs. 975, 977, 980). The part of the great omentum extending from the greater curvature to the transverse colon forms the adult *gastrocolic ligament* (pars gastromesocolica NK). The portion of the peritoneal cavity left behind the stomach is termed the *bursa omen-*

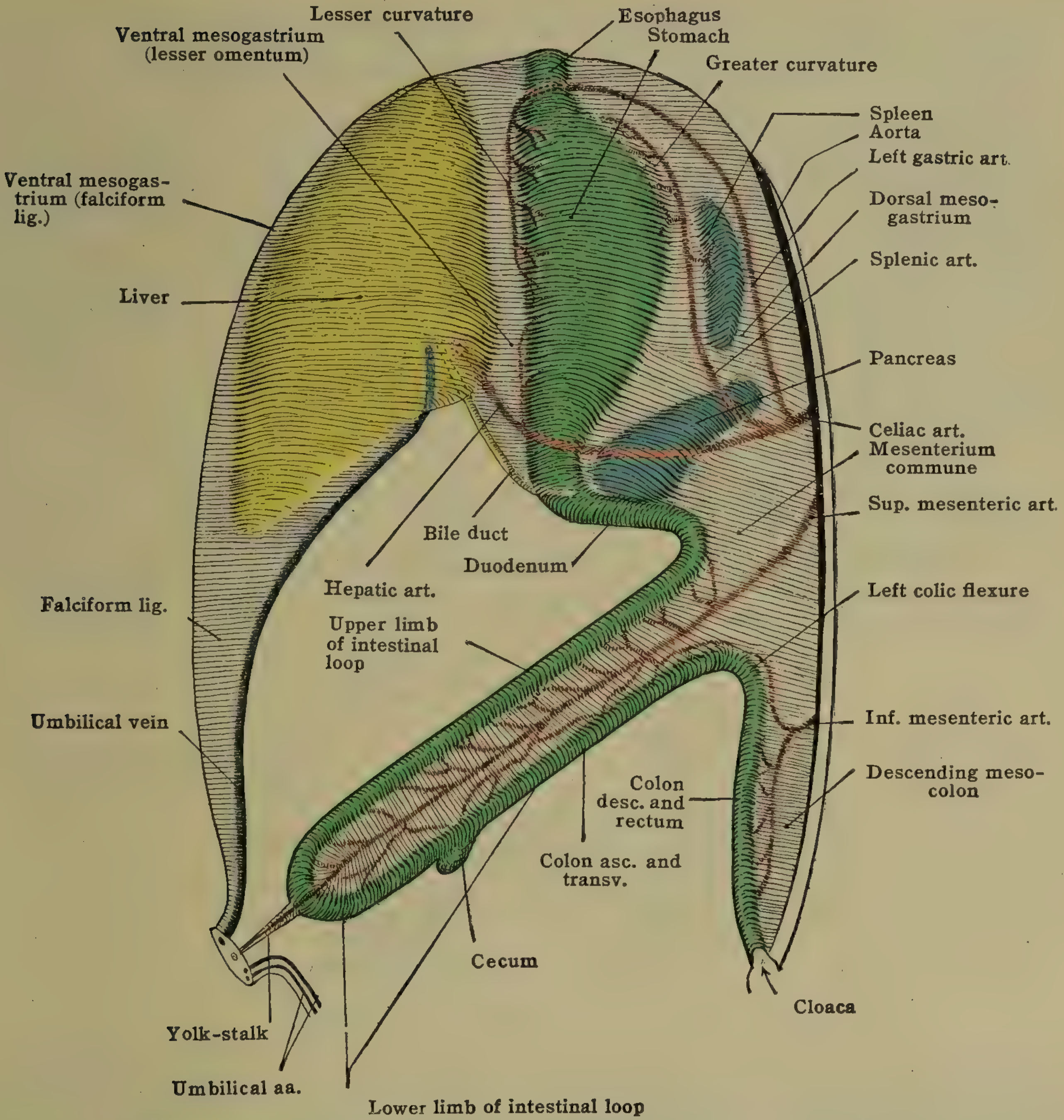


FIG. 976.—DIAGRAMMATIC REPRESENTATION OF AN EARLY STAGE IN THE DEVELOPMENT OF THE ALIMENTARY CANAL AND THE PERITONEUM (side view). (After Sobotta-McMurrich.)

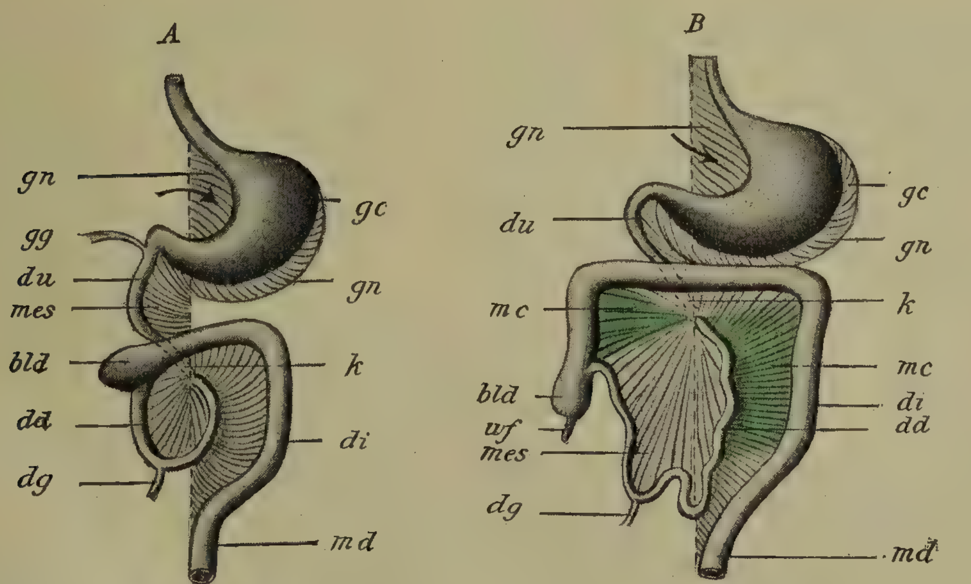


FIG. 977.—DIAGRAMS ILLUSTRATING THE DEVELOPMENT OF THE PERITONEAL STRUCTURES. A, EARLIER STAGE; B, LATER STAGE. Areas of obliteration in green.

bld, cecum. dd, small intestine. dg, yolk-stalk. di, descending colon. du, duodenum. gc, greater curvature of the stomach. gg, bile duct. gn, dorsal mesogastrium. k, point where the loops of the intestine cross. mc, mesocolon. md, rectum. mes, mesentery. uf, vermiform process. (McMurrich, after Hertwig.)

talis, or lesser sac, the remainder of the peritoneal cavity being the greater sac. The two sacs communicate through the *epiploic foramen* (of Winslow) (figs. 979–981).

Along with the pancreas, the duodenum becomes adherent to the posterior wall. The remainder of the intestine forms a loop (figs. 976, 977), the upper portion of which forms the jejuno-ileum, the lower portion the large intestine. The intestinal loop rotates around the superior mesenteric artery as an axis, so that the cecum and ascending colon are carried over to the right side of the body-cavity, where (with the corresponding portion of the primitive mesentery) they become adherent to the posterior body-wall (figs. 977, 978). The mesentery of the transverse colon persists (though becoming fused partly with the great omentum). The descending colon becomes displaced to the left side, and (together with its mesentery) becomes adherent to the posterior wall of the abdomen (figs. 977, 978). The mesentery of the sigmoid colon usually persists (in part), while that of the rectum is obliterated. Through these modifications of the peritoneum, and through unequal growth in the different regions, the simple primitive intestinal tube is transformed into the complicated adult canal. The details of the transformation will be more fully discussed later, with the development of the intestines.

Under certain rare conditions, the developmental process is modified so as to produce a *situs inversus*, which may be partial or complete, involving both thoracic and abdominal viscera. In this case, the viscera are transposed, the right and left sides being reversed.

THE PERITONEUM

The **peritoneum** is a serous membrane which lines the body-cavity from the diaphragm to the pelvic floor, and invests or covers to a varying extent the viscera

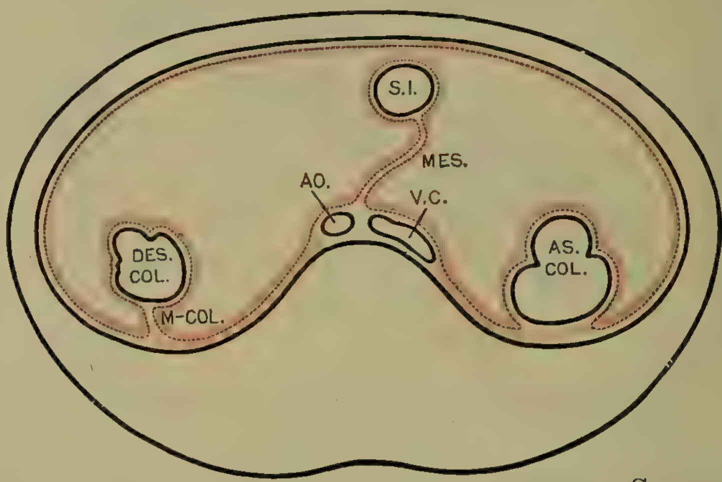


Fig. 978.—Diagram of Cross-section of the Abdomen, Showing the Peritoneal Relations at the Level of the Umbilicus. *AO*, aorta. *AS. COL.*, ascending colon. *DES. COL.*, descending colon. *MES.*, mesentery. *M. COL.*, descending mesocolon. *SI*, small intestine. *V.C.*, vena cava inferior. Peritoneum red; dotted lines indicate sites of obliteration of the primitive mesentery.

of the abdominal cavity. It may be regarded as a closed sac, the inner surface of which is smooth, while the outer surface is rough and is attached to the tissues which surround it. In the male subject the peritoneum forms actually a closed sac; but in the female its wall exhibits two minute apertures at the openings of the Fallopian tubes. The part lining the walls of the abdomen is termed the *parietal* peritoneum; that which is reflected onto the viscera is the *visceral* peritoneum. The disposition of the peritoneum in the adult may be studied first by noting its arrangement as made evident in transverse sections of the abdomen at certain levels.

The first section to be described shows the peritoneum in its simplest relations. This is a transverse section through the body, at about the level of the fourth lumbar vertebra, and therefore about the site of the umbilicus (fig. 978).

Starting on the inner surface of the anterior abdominal wall, the peritoneum covers the transversalis fascia and the anterior abdominal muscles; then, passing to the left, it lines the side of the abdomen, until it reaches the descending colon. This it covers, as a rule, in front and on the sides, though occasionally it forms a mesocolon. Then it passes over the bodies of the vertebræ with the large vessels upon them, and leaves the back of the abdomen to run forward and enclose the small intestine, returning again to the spine. The two peritoneal layers thus form the mesentery, having between them a middle layer [lamina mesenterii propria] containing the terminal branches of the superior mesenteric vessels. It then passes over the right half of the posterior abdominal wall, covering the ascending colon in front and at the sides only (unless there be a mesocolon), and then passes on to the side and front of the abdomen to the point from which it was first traced. The areas of peritoneal reflection from the posterior wall are well shown in fig. 981.

In tracing the peritoneum in a transverse section of the body opposite the stomach (fig. 979), at a level about the first lumbar vertebra, its course becomes more complicated and difficult to follow.

In the section already described, the peritoneum as a simple closed sac can be readily understood; but at the level now exposed the serous membrane has been so introverted (in connection with the primitive rotation of the stomach, as explained above) that there appear to be two connected sacs, known respectively as the greater and the lesser sac of the peritoneum. The *lesser sac* [bursa omentalis] is situated behind the stomach, so that on first opening the abdomen no trace of it is seen. The vestibule [vestibulum bursæ omentalis] is the portion which lies just behind the lesser omentum, and communicates with the greater sac through the epiploic foramen. The extensions upward and downward will be described later, in the sagittal section. In general, the lesser sac is limited *anteriorly* by the liver, stomach, and omenta; *posteriorly* by the posterior abdominal wall and the transverse mesocolon (fig. 980).

The **epiploic foramen (foramen of Winslow)** (figs. 979–983) is situated just below the liver, and will readily admit one or two fingers. It is bounded *superiorly* by the caudate lobe of the liver; *inferiorly*, by the duodenum (pars superior); *posteriorly*, by the vena cava; and *anteriorly* by the right margin of the lesser omentum, containing the root-structures of the liver (bile-ducts, hepatic artery and portal vein). Through the epiploic foramen, the greater sac communicates with the lesser sac or omental bursa which extends to the left.

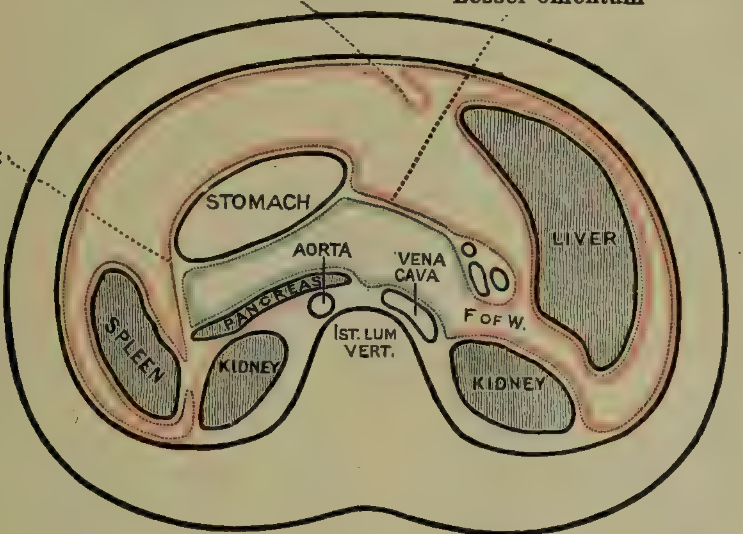


FIG. 979.—DIAGRAM OF CROSS-SECTION OF THE ABDOMEN, SHOWING THE PERITONEAL RELATIONS AT THE LEVEL OF THE EPIPLOIC FORAMEN OF WINSLOW (F. of W.). Peritoneum of greater sac in red; lesser sac (bursa) blue; dotted lines indicate site of obliteration.

The peritoneum may now be traced in a transverse section of the body at the level of the epiploic foramen (fig. 979), which is opposite the last thoracic or first lumbar vertebra. Starting at the front of the abdomen and going to the right, the peritoneum is seen to line the anterior abdominal wall, and to be reflected over the falciform ligament and ligamentum teres. It then passes backward over the side of the abdomen, and covers the front of the right kidney. It then extends on to the vena cava, when it enters the epiploic foramen and becomes a part of the lesser sac. Then it passes along the lesser sac, over the aorta and pancreas, which separate it from the vertebral column. Next it approaches the gastric surface of the spleen near the hilus. Here it meets with another layer of peritoneum, and helps to form the phrenolienal and gastrolienal ligaments. Leaving the spleen, it passes forward and runs to the greater curvature of the stomach, forming the inner layer of the gastrolienal ligament. It now continues to the right, covering the posterior surface of the stomach, and leaves its medial border (lesser curvature) to form the posterior layer of the lesser omentum. At a slightly higher level, it passes upward and to the right to the liver. In this transverse section it merely passes around the right (free) margin of the lesser omentum, where it forms the anterior boundary of the epiploic foramen. Here it encloses the hepatic vessels and bile-duct, continuing to the left as the anterior layer of the lesser omentum. Then passing to the left it again reaches the stomach at the lesser curvature, and extends over its anterior surface to the greater curvature. It then forms the outer layer of the gastrolienal ligament, and once more reaches the spleen. It now passes around the spleen to the region behind the hilus, where it is reflected onto the left kidney as the outer layer of the phrenolienal (lienorenal) ligament. The peritoneum then passes along the side and front of the abdomen to the point from which it started. In this section the liver is so divided as to appear separated from all connection with the other viscera and the abdominal wall, and to be surrounded by peritoneum. At a slightly higher level, its peritoneum would join with that of the lesser omentum medially and that of the falciform ligament anteriorly, in accordance with the location of the liver in the primitive ventral mesogastrium (fig. 976).

The course of the peritoneum in a **longitudinal** (midsagittal) **section of the body** will now be considered (fig. 980).

Starting at the umbilicus and passing downward, the peritoneum is seen to line the anterior abdominal wall. For some little way above the pubis the peritoneum is loosely connected with the abdominal wall, and the distended bladder can detach it to some extent.

On reaching the pubis it is reflected onto the upper surface of the bladder, covering it in the male as far back as the base of the trigone. Thence it is reflected onto the rectum, which it covers in front and at the sides on its upper part. Between the bladder and rectum it forms in the male the **rectovesical pouch** [excavatio rectovesicalis]. In the female the peritoneum is reflected from the bladder onto the uterus, forming the **vesicouterine pouch** [excavatio vesicouterina]. It then covers the uterus and extends so far down in the pelvis as to pass over the upper part of the vagina behind. Thence it extends to the rectum as the **rectouterine pouch**, or pouch of Douglas [excavatio rectouterina; cavum Douglasi]. The membrane has now been traced back to the posterior pelvic wall.

Following it upward, the sigmoid colon will be found to be completely covered by peritoneum, a mesocolon attaching the gut to the abdominal wall. A little higher up in the median

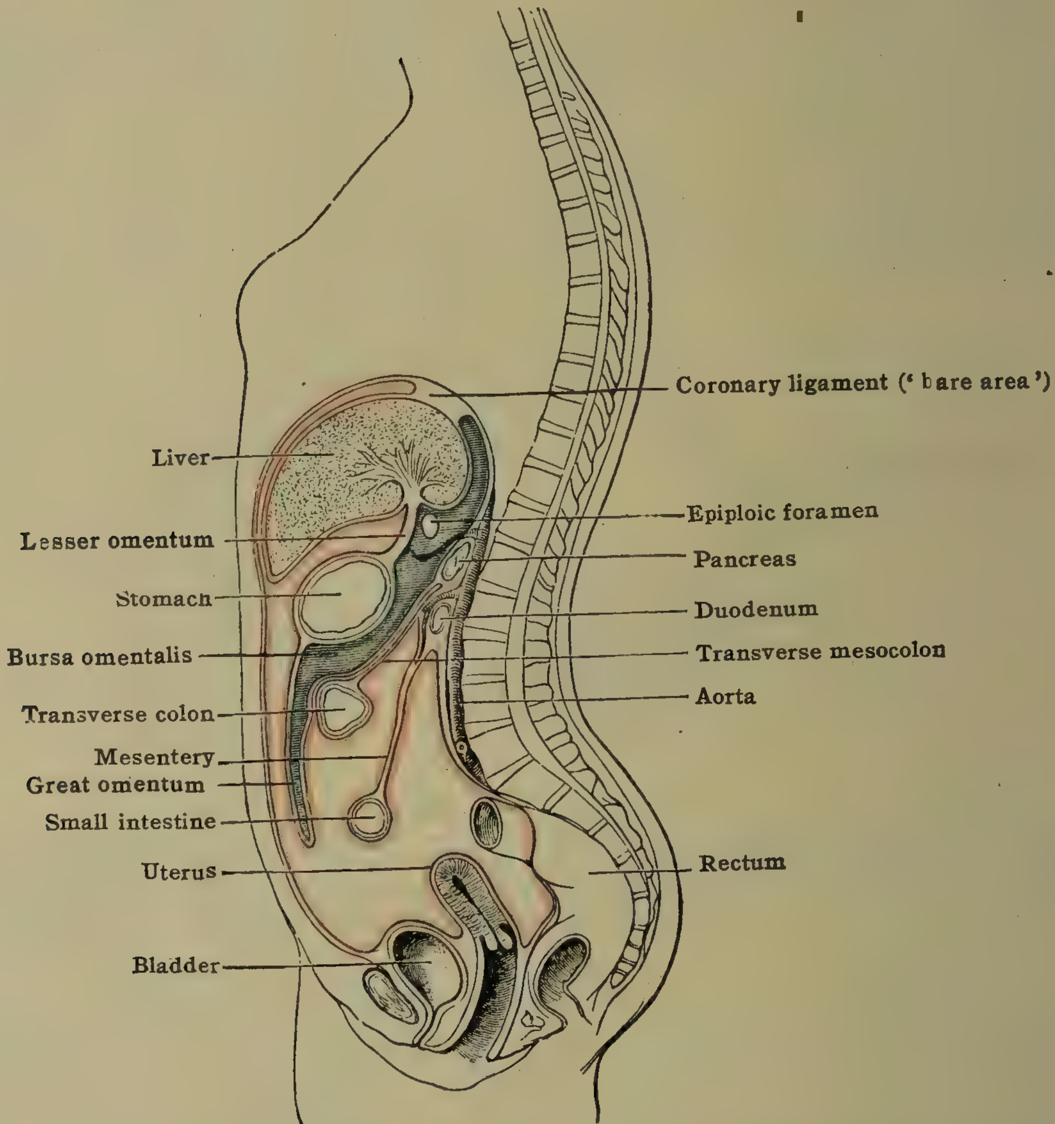


FIG. 980.—DIAGRAM OF A SAGITTAL SECTION OF THE TRUNK, SHOWING THE RELATIONS OF THE PERITONEUM. Greater sac in red; lesser sac (bursa) in blue; dotted lines indicate sites of obliteration.

line the peritoneum passes forward, to enclose the small intestine, and, returning to the spinal column, forms the mesentery (fig. 980). It now passes over the third part of the duodenum to the pancreas, from which point it again passes forward to form the lower layer of the transverse mesocolon. It invests the transverse colon below and partly in front, and then leaves it to pass downward, forming the posterior layer of the great omentum. Then it returns and forms the anterior layer of the great omentum. Between the colon and stomach it forms the anterior layer of the gastrocolic ligament. On reaching the greater curvature of the stomach it goes over the anterior surface, and at the upper border (lesser curvature) forms the anterior layer of the lesser omentum, which extends between the stomach and the liver. It next invests the inferior surface of the liver in front of the porta hepatis (transverse fissure), and, turning over the anterior border of the liver, covers its upper surface. At the posterior part of the upper surface it leaves the liver and goes to the diaphragm, forming the anterior layer of the coronary ligament. It covers the anterior part of the dome of the diaphragm, and, once more reaching the anterior abdominal wall, can be followed to the umbilicus, where the description began. This completes the boundary of the greater sac. On reference to the diagram (fig. 980) the student might be led to suppose that the two sacs are quite separate. This, of course, is not the case, since they communicate through the epiploic foramen (foramen of Winslow), as shown in the transverse section (fig. 979).

The peritoneum has been traced in this sagittal section only so far as it concerns the greater sac. It now remains to follow upon the same section (fig. 980) such part of the membrane as

forms the lesser sac [bursa omentalis]. The peritoneum here will be seen to cover the posterior surface of the stomach; thence from the lesser curvature it runs upward to the liver, forming the posterior layer of the lesser omentum. It reaches the liver behind the porta hepatis, and covers the posterior surface of the caudate lobe. It is now reflected onto the diaphragm, forming the posterior layer of the coronary ligament. This portion of the bursa behind the liver is the *recessus superior*. The peritoneum now goes downward over the posterior part of the diaphragm to the vertebral column, separated from the latter by the great vessels. It passes over the anterior surface of the pancreas, and then extends forward, to form the upper layer of the transverse mesocolon. It then covers the upper aspect of the transverse colon, and, descending, forms the inner layers of the great omentum. (The inner layers of the great omentum are

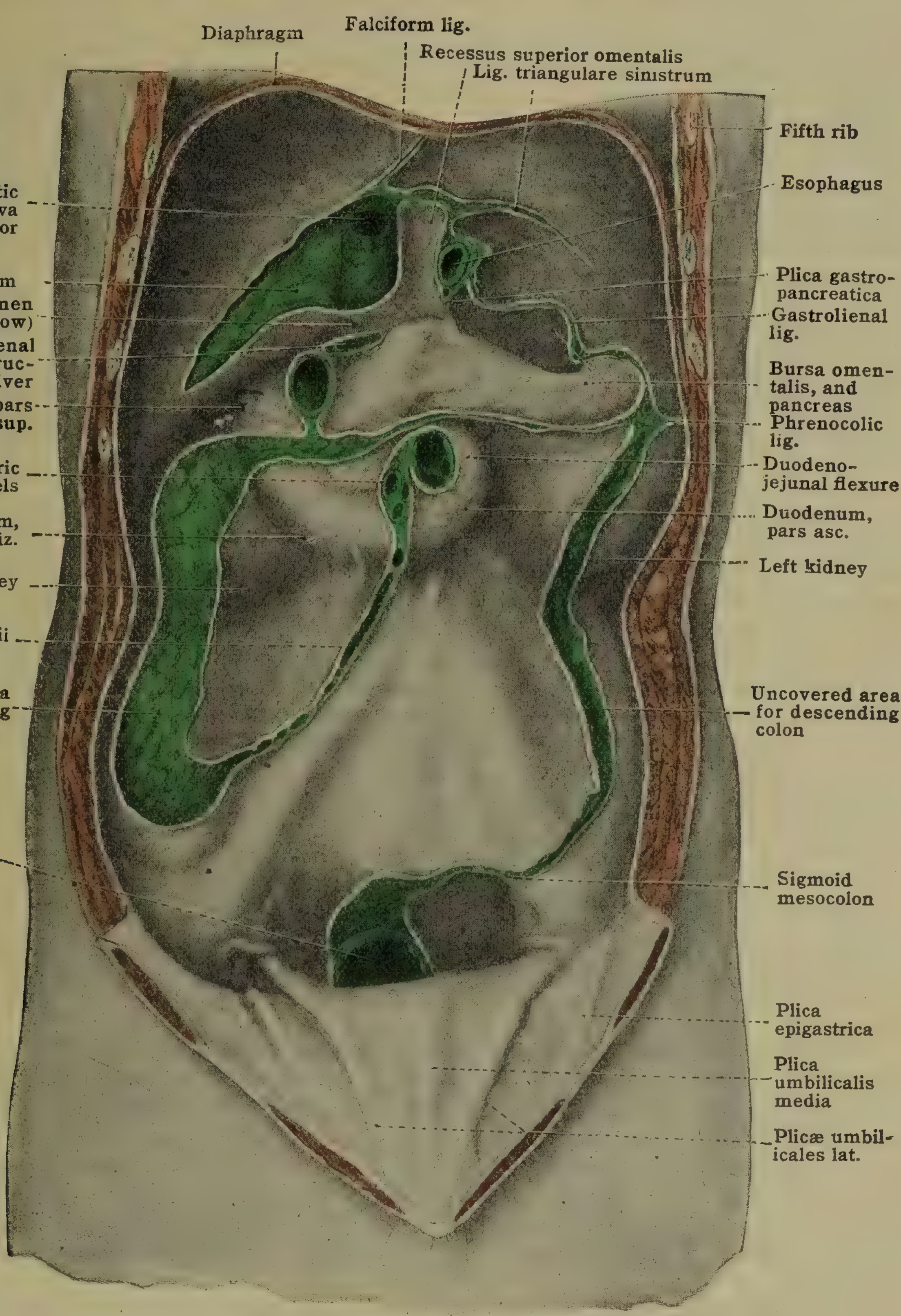


FIG. 981.—REFLECTIONS OF THE PERITONEUM ON THE POSTERIOR ABDOMINAL WALL. (From Rauber-Kopsch, modified.)

usually fused in the adult, however, thus obliterating this portion of the lesser sac.) It now ascends, and, arriving at the greater curvature of the stomach, passes onto its posterior wall, where the description began. The general relations of the greater and the lesser sac are also evident in fig. 981 showing the lines along which the parietal peritoneum is reflected from the posterior abdominal wall as the visceral peritoneum, forming the various mesenteries and covering the various abdominal organs.

The precise manner in which certain organs—such as the liver, the cecum, the duodenum, and the kidneys—are invested by peritoneum is described in the accounts of those viscera. To such accounts the reader is referred for a description of the many 'ligaments' (such as those of the bladder and liver) which are formed by the peritoneum.

The **bursa omentalis** (lesser sac) has already been described during development and as it appears in transverse and midsagittal sections of the adult (figs. 978, 979, 980). The general relations of the bursa are also well shown in figures 981 and 982.

The portion of the bursa behind the lesser omentum, adjacent to the epiploic foramen, is the *vestibulum bursæ omentalis*. From the vestibulum, the *recessus superior* extends upward behind the caudate lobe of the liver. A slight fold, the *plica gastropancreatica*, crosses the posterior wall below the recessus superior. The lower portion of the bursa is termed the *recessus inferior;* and the left extremity forms the *recessus lienalis*.

The **lesser omentum** [omentum minus] consists of a double layer of peritoneum extending between the stomach and the liver (figs. 980, 982, 983). If the two anterior layers of the great omentum are traced upward, they are seen to enclose the stomach, and then join together again at the lesser curvature to form the lesser omentum (fig. 980). It is connected *above* with the liver at the porta hepatis (transverse fissure) and the fissure for the ductus venosus; *below*, with the lesser curvature of the stomach and the first part of the duodenum; the *left* extremity joins the esophagus; the *right* border is free, forming the anterior boundary of the epiploic foramen (see fig. 983).

The lesser omentum is divided into two parts. The portion of the lesser omentum connecting the lesser curvature of the stomach with the fissure of the ductus venosus is the *gastrohepatic ligament* [lig. hepatogastricum]. The portion connecting the portal fissure of the liver with the first part of the duodenum, and enclosing the root-structures of the liver, is called the *hepatoduodenal ligament* [lig. hepatoduodenale]. Within this portion, near the right free border, are the root-structures of the liver; the bile-ducts on the right, the hepatic artery on the left, and the portal vein behind them (figs. 979, 983).

The great omentum.—As is evident from its development (figs. 977, 980), the great omentum [omentum majus] is formed of four layers of peritoneum, though usually this is quite impossible to demonstrate in an adult, the inner layers having become adherent. The great omentum acts as an apron (fig. 975), protecting the intestines and providing them with a heat-economizing covering of fat. It is nearly quadrilateral in shape, and is variable in extent. In fig. 980 the great omentum is shown to be connected with the greater curvature of the stomach, on the one hand, and the transverse colon, on the other. Originally it extended backward above the transverse colon and mesocolon to the posterior abdominal wall. The line along which it fuses with the transverse colon and mesocolon during development is shown in fig. 980. Superiorly it forms the gastrocolic ligament and is continuous with the gastrolienal, and (on the left) with the phrenocolic ligaments (fig. 983).

Mr. Lockwood has made some investigations on the lengths of the transverse mesocolon and great omentum in thirty-three cases. In twenty, under the age of forty-five, only one subject had a great omentum long enough to be drawn beyond the pubic tubercle; in five, the omentum reached as far as the pubes. In the cases beyond forty-five years it was exceptional to find an omentum that could not be pulled beyond the lower limits of the peritoneal cavity.

The **gastrosplenic ligament** [lig. gastrolienale] (pars gastrolienalis mesog. dors. NK) connects the left portion of the stomach with the spleen, continuing the layers of peritoneum which enclose the stomach (fig. 979). It is continuous below with the great omentum.

The **gastrocolic ligament** [lig. gastrocolicum] (pars gastromesocolica NK) is that portion of the great omentum extending from the greater curvature of the stomach to the transverse colon. Superiorly it is continuous with the gastrosplenic ligament, and on the left it terminates in the phrenocolic ligament (figs. 980, 983).

The gastrophrenic and phrenocolic ligaments.—As the peritoneum passes from the diaphragm to the stomach it forms a small fold just to the left of the esophagus. This is the gastrophrenic ligament. A strong fold of the membrane also extends from the diaphragm (opposite the tenth and eleventh ribs) to the left colic (splenic) flexure, and is known as the phrenocolic (costocolic) ligament [lig. phrenicocolicum] (plica phrenocolica NK). (See figs. 981, 983.)

Reflections of peritoneum.—The reflections of the peritoneum upon the posterior abdominal walls are well shown in fig. 981. As previously explained under 'general morphogenesis' (p. 1232), they represent chiefly transposed attachments of the primitive dorsal mesentery. The *coronary ligament* (with enclosed ('bare area') represents a persistent portion of the primitive intimate relation

between the liver and diaphragm (septum transversum). From the coronary ligament, the *falciform ligament* (mesohepaticum ventrale NK) extends forward and downward along the anterior abdominal wall to the umbilicus, representing a portion of the primitive ventral mesogastrium (figs. 976, 981).

Upon the lower part of the anterior abdominal wall appear certain peritoneal folds of variable size (fig. 981). In the midline, the *plica umbilicalis media* extends from the umbilicus to the apex of the bladder, and encloses the urachus (median umbilical ligament), a fibrous remnant of the embryonic allantoic stalk. Lateral to this median fold there appears on each side the *plica umbilicalis lateralis*, enclosing a fibrous cord (lateral umbilical ligament) representing the obliterated umbilical artery of prenatal life. Still more laterally on each side is a small, inconstant fold, the *plica epigastrica*, enclosing the inferior epigastric vessels.

Corresponding to these peritoneal folds, three peritoneal fossæ appear on each side in the lower part of the abdominal wall. Between the median and the lateral umbilical plica is the *fovea supravesicalis.* Between the lateral umbilical and the epigastric plica is the *fovea inguinalis medialis;* while just lateral to the epigastric plica is the *fovea inguinalis lateralis.* The lateral inguinal fovea corresponds to the abdominal inguinal ring.

Within the pelvis, the peritoneal floor presents on each side two or three distinct transverse folds, forming corresponding fossæ. The most anterior is a somewhat variable fold, the *transverse vesical fold* [plica vesicalis transversa] (fig. 1126) extending from the bladder laterally to the pelvic wall. Behind this is the *ureteral fold* in the male, or the *broad ligament* [lig. latum uteri] in the female. Posterior to the bladder is the *sacrogenital fold* in the male (enclosing a part of the seminal vesicle and ductus deferens), and the *rectouterine* fold in the female.

Corresponding to these folds, three pairs of pelvic peritoneal fossæ are described. Beside the bladder, and anterior to the ureteral fold (or broad ligament) on each side, is the *paravesical fossa,* crossed by the transverse vesical fold. Between the ureteral fold (or broad ligament) and the sacrogenital (or rectouterine) fold is the *paragenital fossa.* Behind the sacrogenital (rectouterine) fold is the *pararectal fossa,* which in front of the rectum communicates with the opposite fossa through the rectovesical fossa [excavatio rectovesicalis] in the male or the rectouterine (rectovaginal) fossa [excavatio rectouterina] or pouch of Douglas in the female.

Other peritoneal folds and relations will be described later in connection with the stomach, duodenum, jejunoileum, cecum, appendix, etc.

The peritoneal spaces.—The peritoneum presents certain potential spaces, determined by its various reflections from the parietes and abdominal viscera. In these spaces collections of fluid such as abscesses or extravasations from hollow viscera or blood vessels may collect and become shut off by adhesions or overflow in various directions into neighboring spaces. The transverse mesocolon and great omentum together form a shelf transversely placed, which divides the greater sac into two main divisions—supraomental and infraomental (figs. 980, 981, 983).

The supraomental region, in which the various forms of subphrenic abscess are found, contains the following fossæ (Barnard, Brit. Med. Jour., Feb. 15, 1908). (1) **Right subphrenic,** between the right lobe of the liver and the diaphragm, bounded toward the median line by the falciform ligament, and behind by the coronary ligament. It communicates below with (2) the **subhepatic fossa** or right renal pouch (Morison), which is bounded above by the visceral surface of the liver, and below by the mesocolic shelf and right kidney. It extends from the right lateral abdominal wall across the median line under the left lobe of the liver, and on its posterior aspect lie the upper pole of the right kidney, epiploic foramen, and anterior surface of small omentum. (3) The **left subphrenic,** also known as the anterior perigastric fossa, lies between the left dome of the diaphragm above, and the left lobe of the liver, stomach, spleen and omentum below. It is bounded on the right by the falciform ligament. (4) The **omental bursa** may be regarded as a diverticulum from the subhepatic fossa with which it communicates by the epiploic foramen. Abscesses in this sac are rare, but occasionally laceration of the pancreas or acute hemorrhagic pancreatitis gives rise to a collection of pancreatic juice and blood in the lesser sac, known as a pancreatic pseudo-cyst (Jordan Lloyd).

The **infraomental region** is subdivided in its abdominal part into (1) **right** and (2) **left compartments** by the attachment of the root of the mesentery to the spine, descending from the duodenojejunal flexure downward into the right iliac fossa. These fossæ communicate with the supraomental regions in the neighborhood of the hepatic and splenic flexures of the colon respectively, and below with (3) **the pelvis.** The deepest level of the peritoneum lining the pelvis constitutes in the male the rectovesical, and in the female the rectovaginal fossa (pouch of Douglas). The **mesentery** extends obliquely from above on the left, downward and to the right from the 2nd to the 4th lumbar vertebra. Because of this oblique attachment, an abscess developing from a ruptured appendix which lies in the pelvis may be directed upward and to the left.

It should be noted that with a patient in the supine position, owing to the contour of the psoas muscles and the anterior convexity of the lumbar spine, any fluid above the pelvic brim will tend to gravitate into the subphrenic spaces across the flexures of the colon which lie far back in the loins. This is undesirable in view of the great absorbing power of the subphrenic lymphatics, and may be obviated by propping the patient in a half-sitting position.

Minute anatomy.—The peritoneum, like all serous membranes, consists of two layers: a lining layer composed of simple squamous epithelium (mesothelium), and an underlying layer of fibrous connective tissue. The latter is highly elastic, and denser in the parietal than in the visceral layer. It often contains fat. In mesenteries and similar structures, the connective tissue is usually very scanty, except surrounding the vessels and nerves. Ruptures often occur in the omenta, which thus become fenestrated in structure. The visceral peritoneum is usually closely attached to the organs for which it forms the outer serous tunic, but the parietal peritoneum is often loosely attached to the adjacent wall by a fatty subserous layer [tela subserosa]. Smooth muscle occurs frequently in the various peritoneal folds.

The peritoneal cavity contains normally a very slight amount of watery fluid, which serves to lubricate the smooth peritoneal surface and thus to eliminate friction between adjacent surfaces during the movements of the alimentary canal.

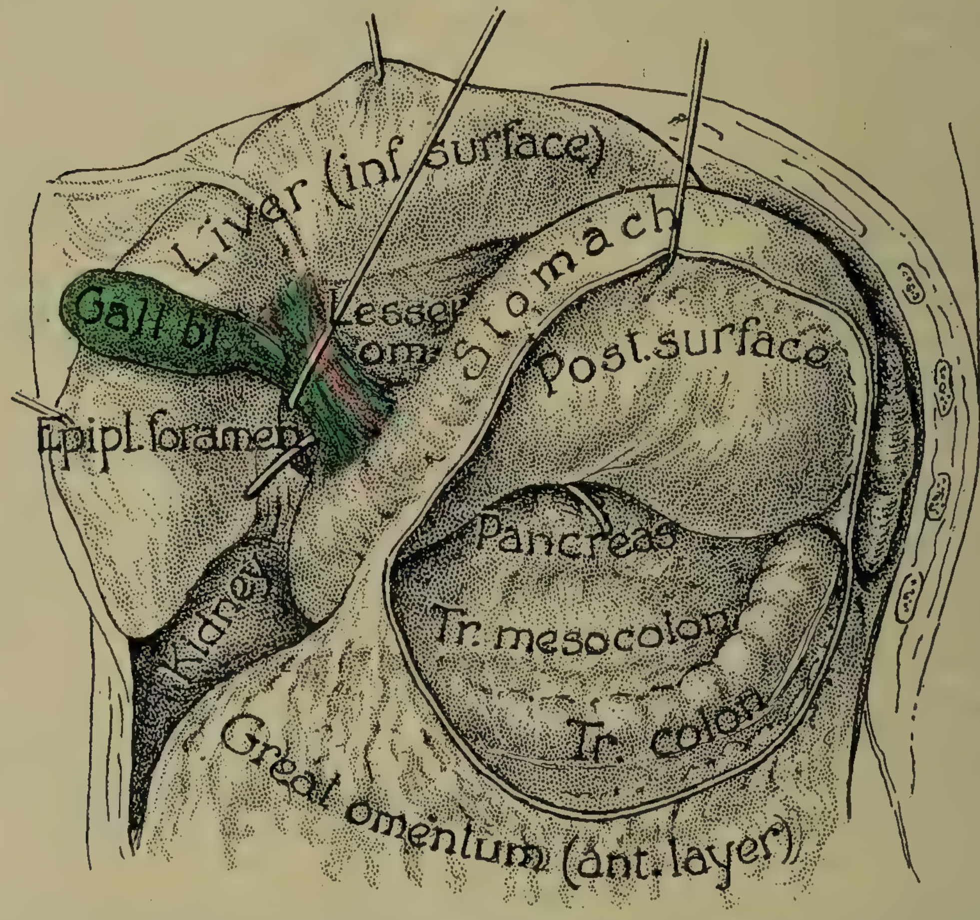


Fig. 982.—Gastric Region. Liver elevated and omental bursa opened by section along the gastrocolic ligament. Probe passed through the epiploic foramen. (After Hertzler.)

Vessels and nerves.—The peritoneum is in general somewhat sparsely supplied with *blood-vessels* from various adjacent trunks. *Lymph-vessels* also occur, but they probably do not connect directly with the peritoneal cavity. They communicate with the lymphatics of neighboring regions. The *nerves* are also comparatively scarce. They are partly of sympathetic origin (vasomotor), and partly sensory nerves from the intercostal (7th to 12th) and lumbar nerves. The sensory nerves are more frequent in the parietal peritoneum and end in the connective tissue, either freely or in special end-organs (varying from simple end-bulbs to Pacinian corpuscles).

Development.—The principal features in the development of the peritoneum have already been mentioned in the section on Developmental Anatomy (p. 57) and in the remarks on the general morphogenesis of the peritoneum (p. 1232). Further details will be included later under the development of the intestine, etc.

Variations.—Variations in the form and relations of the peritoneum are exceedingly common, and are frequently of developmental origin. Variations in the form and relations of the various abdominal organs necessarily involve corresponding modifications in the peritoneum. The diaphragm may be incompletely formed, leaving the peritoneal cavity in communication with the pleural, or more rarely the pericardial cavity. The primitive dorsal mesentery of the intestine [mesenterium commune] may rarely persist unmodified, or the various secondary changes may be inhibited at any stage. Thus the stomach or the intestinal loop may fail, either wholly or partly, to undergo the characteristic rotation. The adhesions of the various mesenteries may be incomplete, or they may be more extensive than usual. For example, the sigmoid mesocolon may be more or less completely obliterated by adhesion, and numerous unusual peritoneal pockets or ligamentous bands may be formed in this way in various localities. Variations thus due to extensions of the normal developmental process are sometimes difficult to

distinguish from pathological adhesions caused by peritonitis. Membranous bands, probably due to developmental disturbances, are frequent in the pyloric region and especially along the cecum and ascending colon ('Jackson's membrane').

Comparative.—As previously mentioned, the celom or primitive body-cavity in vertebrates extends throughout the trunk region. In the cyclostomata, this primitive relation persists, the pericardial cavity remaining in communication with the general body-cavity. In all higher forms, however, the pericardial cavity becomes entirely separated. In amphibia the lungs lie in the general (pleuroperitoneal) body-cavity; in the reptiles and birds, they are partially separated; but a complete separation of the pleural cavities with the formation of the definite, muscular diaphragm occurs generally only in mammals.

The formation in the peritoneal cavity of a complete dorsal mesentery, and an incomplete ventral mesentery (in the hepatic region) is typical for all classes of vertebrates. Slight modifications in the form of the mesenteries depend chiefly upon the different degrees of complexity in the development of the various parts of the intestinal tract. The marked changes associated with extensive secondary adhesions of the primitive peritoneal structures are found only among the higher mammalia, especially in man and the anthropoids, associated with the assumption of erect posture.

THE STOMACH

The **stomach** [ventriculus; gaster] is a dilation of the alimentary canal succeeding the esophagus. In the stomach the food is mixed with the gastric juice

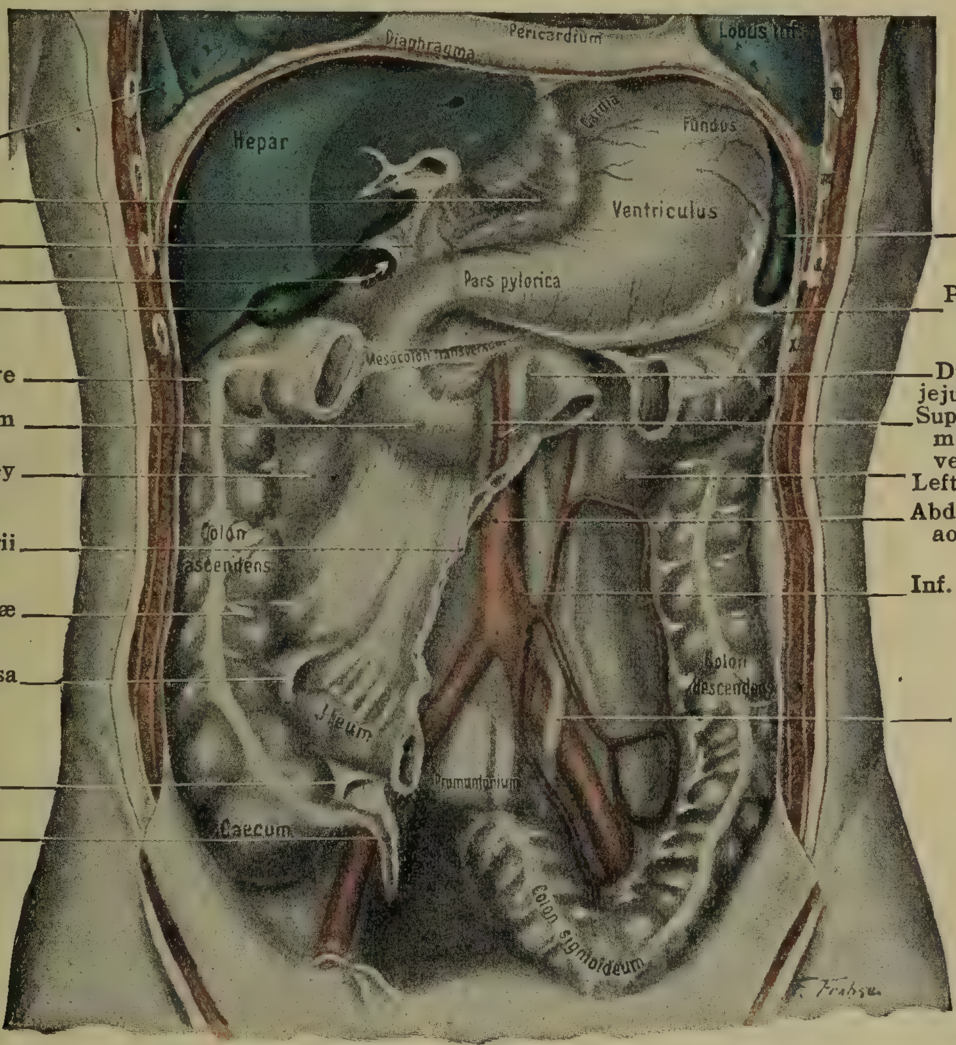


FIG. 983.—ABDOMINAL VISCERA, ANTERIOR VIEW, AFTER REMOVAL OF A PART OF THE LIVER AND INTESTINES. (Rauber-Kopsch.)

and reduced to a viscid, pulpy liquid, the chyme [chymus], which undergoes a certain amount of digestion and absorption before passing into the duodenum.

The stomach (figs. 983–988) is a somewhat J-shaped sac located in the upper left side of the abdominal cavity. It presents a *body* [corpus ventriculi], with an enlarged upper end or *fundus*, on the right side of which is the *cardia*, the aperture communicating with the esophagus. The body of the stomach is extremely variable in form, as will be explained later, but is in general divisible into a more expanded upper two-thirds, the *cardiac portion* [pars cardiaca], which is nearly vertical, and a more constricted lower third, the *pyloric portion* [pars pylorica], which curves toward the right. The junction of the cardiac and pyloric portions forms the *gastric angle*. The pyloric portion presents a variable dilation, the *antrum pylori*, succeeded by a short constricted *pyloric canal* (Jonnesco) (fig. 989). At the lower end of this canal the *pylorus* forms the aperture leading into

the duodenum, and contains a thick sphincter derived from the circular fibers of the muscular layer. The stomach has two borders and two surfaces. The medial border forms the *lesser curvature* [curvatura ventriculi minor], which is concave (except near the pylorus) and gives attachment to the lesser omentum. The lateral (or lower) border forms the *greater curvature* [curvatura ventriculi major], which is convex, and gives attachment to the great omentum. The curvatures separate the *anterior surface* [paries anterior] (p. ventricranialis NK), which faces forward and upward, from the *posterior surface* [paries posterior] (p. dorsocaudalis NK), which is placed backward and downward.

As a result of careful and extensive researches upon the anatomy of the stomach, with especial reference to the form of the living stomach shown by the Röntgen-rays Forssell divides the organ into *saccus digestorius* and *canalis egestorius* (fig. 984). The saccus, is divided into fornix, corpus and sinus. The sinus corresponds roughly to the antrum pylori above mentioned. The canalis egestorius is the constricted pyloric canal, whose primary function is to regulate the passage of food from the digestive sac.

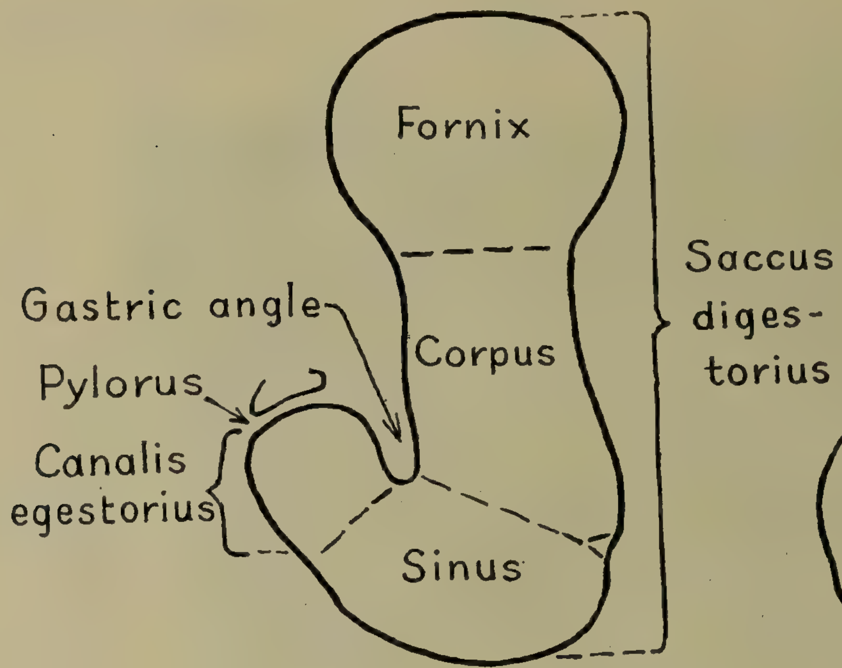


Fig. 984.—Diagram of the Parts of the Stomach, According to Forssell.

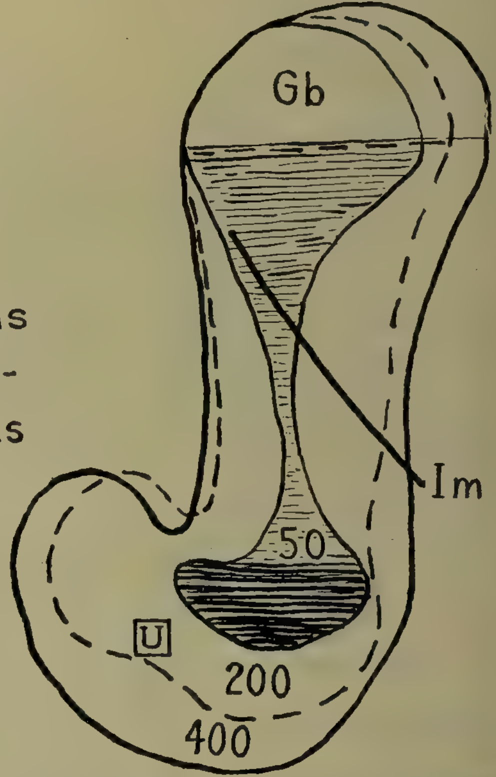


Fig. 985.—Changes in the Form of the Stomach. (Forssell.) Outlines as shown by the Röntgen-rays during upright posture after ingestion of 50, 200 and 400 cc. of bismuth mixture. Gb, gas bubble. U, umbilicus. Im, infracostal margin.

Form.—The form of the stomach varies especially with the amount of contents (fig. 985). When nearly empty it presents throughout a narrow, tubular form, excepting in the region of the fundus (fornix). This region, which contains the gas-bubble, remains somewhat distended even when the remainder of the stomach is empty and contracted. When food is introduced, it fills successively the various portions of the stomach as shown in fig. 985, the antrum (sinus) being filled first and the pyloric canal usually last.

The J-shape is typical for the upright posture; but in the dorsal (supine) position the lower curvature of the stomach becomes elevated and more constricted, the fundus (fornix) more distended and displaced to the left, so the organ tends to assume the 'cow-horn' form (fig. 987), with the axis of the cardiac portion more obliquely placed.

Dimensions.—The dimensions of the stomach are subject to great variation. The *length* of the lesser curvature averages about 10 cm. (7.5 to 15 cm.), and that of the greater curvature is three or four times as great. The *diameter* varies exceedingly according to the amount of contents. When nearly empty, it presents (excepting the fundus region) a narrow tubular form, with a diameter of about 4 or 5 cm. The diameter of the pylorus, which is the narrowest point in the alimentary canal below the esophagus, when constricted is only about 1.5 cm. It is distensible, however, as hard bodies with diameters of 2 cm. or more may readily pass through.

The average *capacity* of the stomach is about 1 liter, being subject to extreme individual variations. In the newborn, it averages about 30 cc. (see p. 48). The average *weight* of the adult stomach is about 135 gm.

Position and relations of the stomach.—The position and relations of the stomach, like its form and structure, are subject to many variations in different individuals, and in the same individual according to changes in physiological condition, distention, posture, etc. It is therefore difficult to give a concise and accurate description. The stomach is fixed and supported chiefly by (1) the attachment at the cardia; (2) the attachment at the pylorus; (3) the support of the adjacent viscera, especially (in the upright posture) by the transverse mesocolon and adjacent intestines, which in turn are supported by the musculature of the abdominal wall.

Topography.—In *surface relation* (figs. 975, 985, 1003), the stomach lies within the left hypochondriac and the epigastric regions. Often, however, especially when distended, it extends into the umbilical and even the right hypochondriac region. When empty, it usually lies almost entirely in the left half of the body, with the pylorus near the midsagittal plane. When distended, the stomach is

FIG. 986.—RADIOGRAPH OF STOMACH, PARTLY FILLED; BODY IN UPRIGHT POSTURE.

This form is most pronounced in individuals of hyposthenic type. Gas-bubble in fundus (fornix) region. Duodenal antrum visible just above the pylorus in the midline. (From plate by Dr. R. W. Mills, Washington University Medical School.)

lengthened and the pylorus may be displaced 5 cm. or more to the right and downward. In distention, the stomach expands in all directions (fig. 985); it changes in form, as above mentioned, but does not appear to rotate as is sometimes stated. The position of the stomach, especially when distended, also varies appreciably according to the *posture* of the body. It sags downward when the body is in the upright position, so the lowest part may normally reach considerably below the umbilicus (fig. 986). The stomach is also displaced to the right or left when the body is placed on the corresponding side. The *cardia*, which is the most fixed point, lies on the left side of the 10th or 11th thoracic vertebra, and corresponds to a surface point behind the left 7th costal cartilage about 2.5 cm. from its sternal end. The *pylorus* usually lies opposite the right side of the 1st lumbar vertebra, about midway between the xiphoid cartilage and umbilicus, (in Addison's 'transpyloric line,') when the body is recumbent; but descends to the 2nd or 3rd vertebra (or lower) in upright posture. The

fundus corresponds to the left dome of the diaphragm (which separates it from the lung and heart), opposite the sixth sternocostal junction. The fundus necessarily rises and falls with respiratory movements of the diaphragm, the excursion ordinarily being from 2 to 6 cm. The variations in the position of the stomach according to types of physique, and the changes during peristalsis, are mentioned later.

The relations of the stomach with *surrounding organs* are indicated diagrammatically in figs. 993, 1003, and are naturally variable according to the changes in form, size and position of the stomach. The *anterior surface* is in contact on the right with the left lobe of the liver, the pylorus reaching the quadrate lobe; on the left it is in contact with the diaphragm (separating it from the heart and left lung); and below with the anterior body-wall by a triangular area of variable size. The *posterior surface* is in relation (separated by the lesser sac) with the pancreas, above which are areas of contact with the diaphragm, spleen, left kidney and suprarenal body; below the pancreas, the stomach is in contact with the transverse mesocolon, and through this

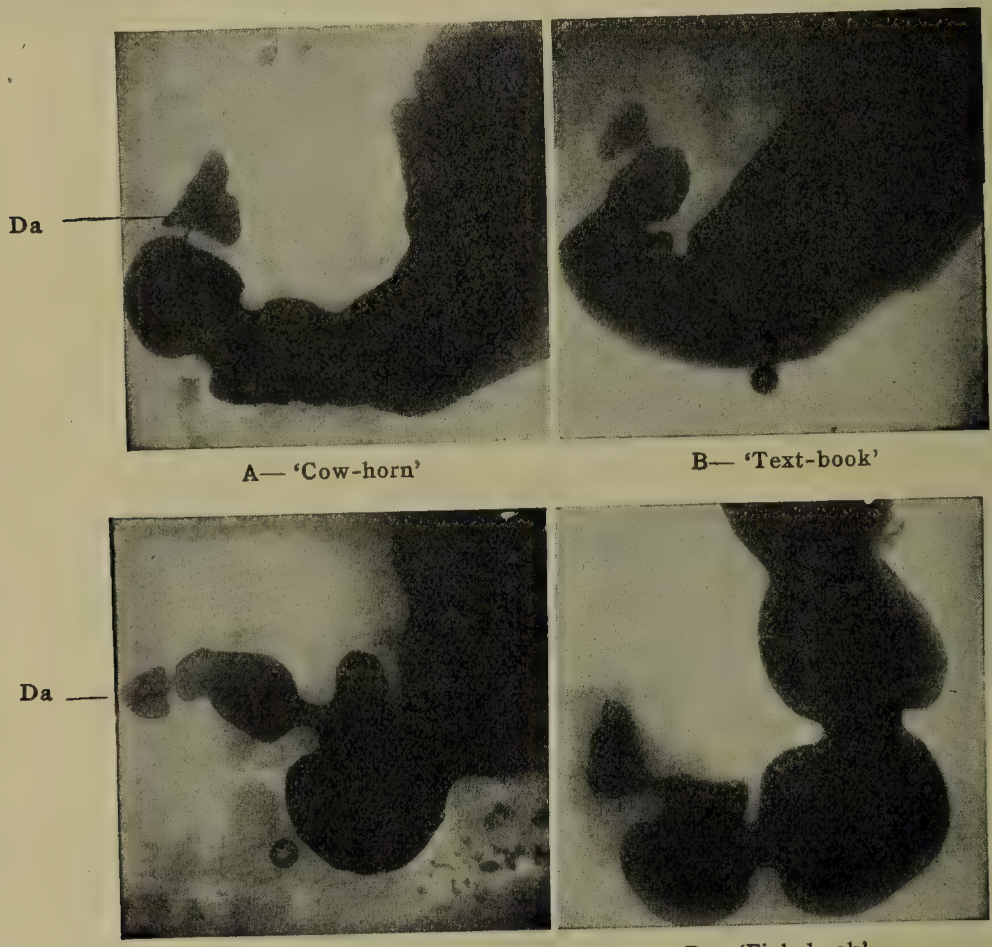


Fig. 987.—Different Forms of the Stomach as Shown by the Rœntgen Rays. (Cole.)

Fundus not represented. Da, duodenal antrum. Position of umbilicus shown in B and C.

with the transverse colon and coils of small intestine. The relation with the duodenojejunal flexure is indicated in fig. 971. The *fundus* invariably contains gas, even when the stomach contains no food. In extreme gastric distention the left dome of the diaphragm is so pushed up by the fundus that it lies at a level as high as or even higher than the right dome (Hertz). The pressure thus exerted on the heart accounts for the dyspnea and cardiac pain so often associated with flatulence.

Peritoneal relations.—The stomach is covered by peritoneum in its whole extent, except immediately along the curvatures and upon a small triangular space behind the cardiac orifice, where the viscus lies in direct contact with the diaphragm, and possibly with the upper part of the left suprarenal gland. It is enclosed between two layers of peritoneum. These two layers at its lesser curvature come together to form the gastrohepatic portion of the lesser omentum, and at the greater curvature extend downward to form the great omentum (figs. 979, 980). At the left of the esophagus the two layers pass to the diaphragm, forming the gastrophrenic ligament; and at the left of the stomach they pass on to the spleen, forming the gastrosplenic ligament.

The posterior surface of the stomach is in relation with the lesser sac (bursa omentalis), forming part of its anterior wall (fig. 982). The anterior surface of the stomach is in relation with the greater sac of the peritoneal cavity.

Perforations.—In connection with the extravasation of contents that results from perforating ulcers of the stomach, a knowledge of the subphrenic peritoneal fossæ is important (p. 1239). Perforation is rare on the posterior surface since it is less mobile than the anterior, and protective adhesions form readily. When it does occur, extravasation into the omental bursa results, and such a perforation is exposed by turning up transverse colon and stomach and incising the transverse mesocolon. Perforation on the anterior surface usually gives rise to general peritonitis, but in the less serious cases an abscess may form localized to (1) the right subphrenic space, (2) the subhepatic fossa, or (3) the left subphrenic space, according to the situation of the ulcer on the stomach.

Minute anatomy.—The stomach is composed of the four typical layers of the alimentary canal—mucosa, submucosa, muscularis and serosa. The *mucosa* (figs. 988, 989 and 990) is thrown into a series of coarse *folds* (plicæ mucosæ), chiefly longitudinal, which disappear when the stomach is distended. Along the lesser curvature, the ridges are more regular and form a longitudinal grooved channel (gastric canal), corresponding to Waldeyer's 'Magenstrasse.' Upon closer examination the inner surface of the mucosa presents a somewhat warty ('mammillated') appearance, due to numerous small elevated areas [areæ gastricæ], varying

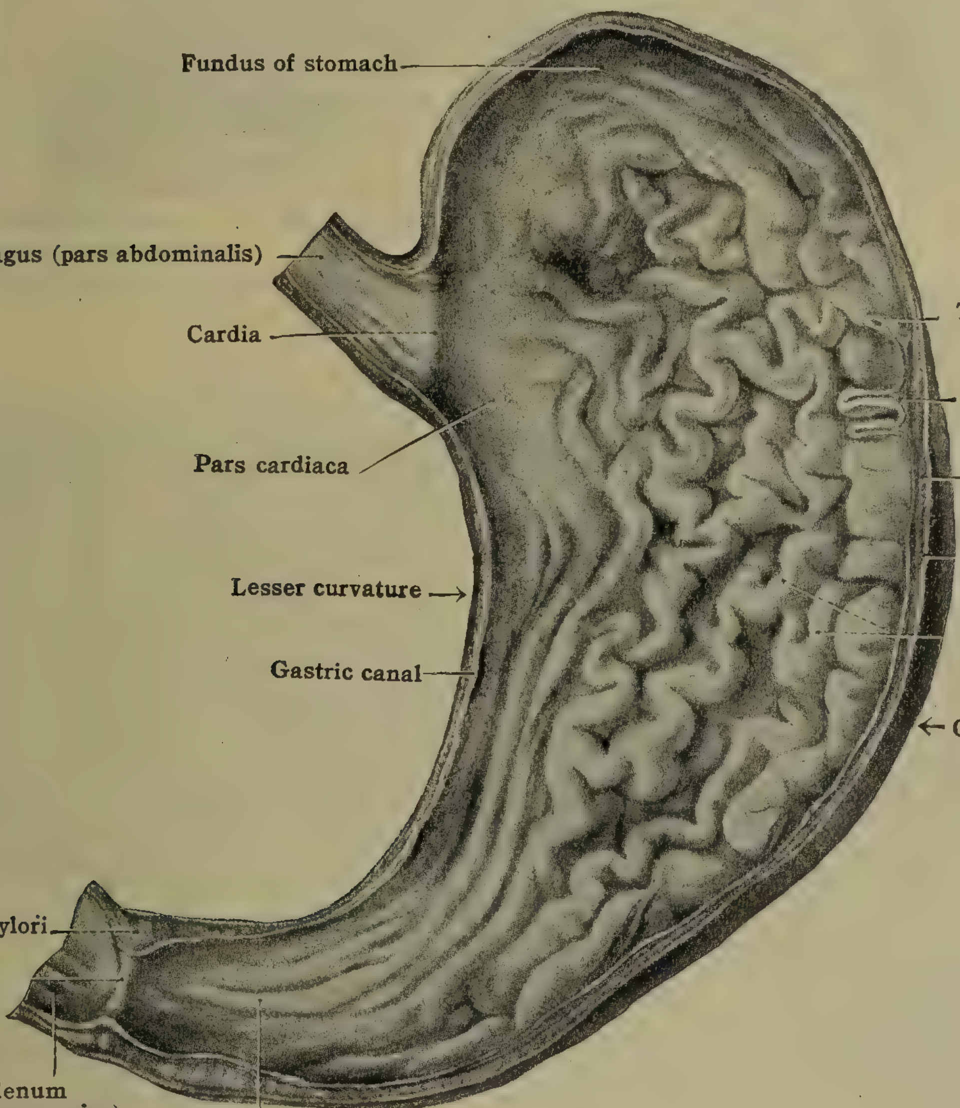


Fig. 988.—Longitudinal Section of Stomach, Showing the Interior of the Posterior Half. (Rauber-Kopsch.)

from 1 to 6 mm. in diameter. When examined with a lens (fig. 991) it is seen that each area is beset with numerous small *pits* [foveolæ gastricæ], separated by partitions which sometimes (especially in the pyloric region) bear villus-like prolongations [plicæ villosæ]. The average number of foveolæ in the adult is estimated at 62 per sq. mm., or about 3.4 millions for the entire stomach (Scott). Into each pit or foveola open 3 to 5 gastric glands.

The relations of the mucosa in section are shown in fig. 990. The thickness of the mucosa varies, being greatest (about 2 mm.) in the pyloric region, decreasing to less than .5 mm. in the cardiac region (Kölliker). The *lamina propria* is crowded with *glands*, of which three varieties are distinguished. The *cardiac* glands are tubuloracemose (chiefly mucous) glands occupying a narrow zone a few millimeters in width adjacent to the cardiac orifice. The *fundic* glands [gl. gastricæ propriæ] occupy the greater part of the stomach, and are simple (partly branched) tubular glands (fig. 990). The *pyloric* glands [gl. pyloricæ] are branched tubular glands occupying the pyloric region.

The interstitial tissue of the lamina propria contains diffuse lymphoid tissue and occasional small *lymph-nodules* (lymphonoduli gastrici NK), especially in the pyloric region. The *muscularis mucosæ* is a thin sheet of smooth muscle lying just below the fundus of the glands and is composed of an inner circular and an outer longitudinal layer.

The *tela submucosa* (fig. 990) is a very loose areolar, vascular layer which permits the wrinkling of the mucosa according to the degree of distention.

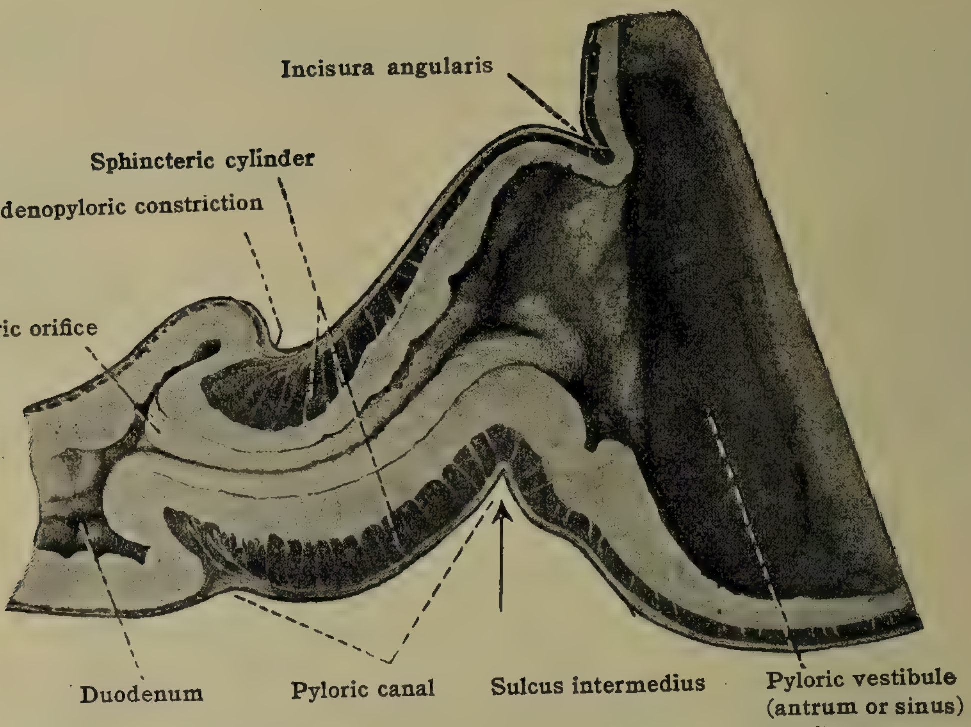


FIG. 989.—LONGITUDINAL SECTION OF THE PYLORIC PORTION OF THE STOMACH. (Cunningham, Trans. Royal Soc. Edinb., vol. 45.)

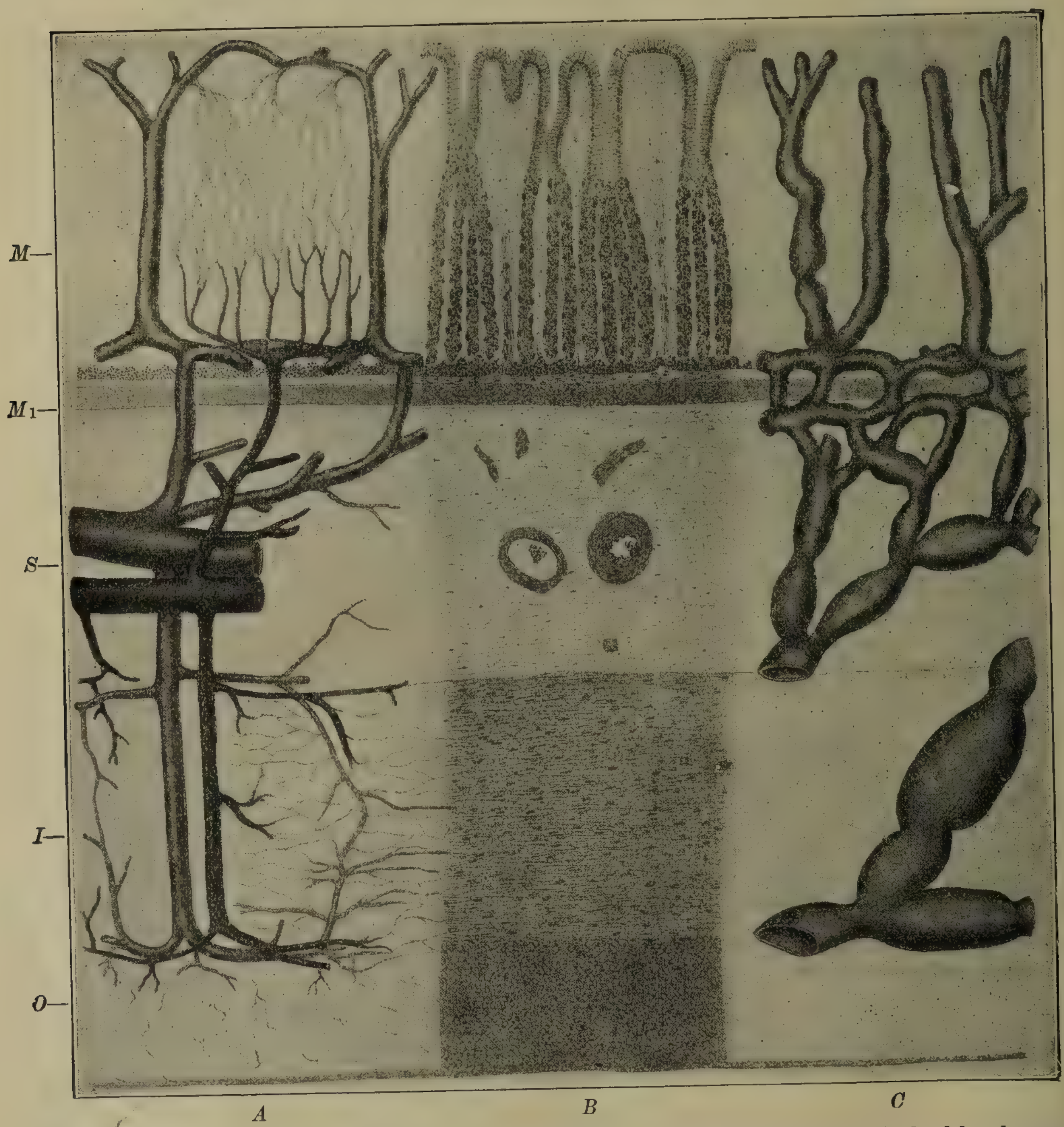


FIG. 990.—DIAGRAMMATIC SECTION OF THE STOMACH WALL SHOWING (*A*) the blood vessels, (*B*) the tunics, and (*C*) the lymphatics. *M*, mucosa. M_1, muscularis mucosæ. *S*, submucosa. *I*, circular, and *O*, longitudinal muscle-layer. (Szymonowicz, after Mall.)

The *tunica muscularis* contains three layers of smooth muscle (fig. 992). The outer or *longitudinal* layer [stratum longitudinale] is thickest along the lesser curvature, and is continuous with the longitudinal fibers of the esophagus and the duodenum. On the anterior and posterior walls of the antrum pylori, the longitudinal fibers form thickened bands, the *ligamenta pylori*. The middle or *circular* layer [stratum circulare] is continuous with the circular fibers of esophagus and duodenum and surrounds the entire stomach. It is especially thickened in the region of the pyloric canal, at the lower end of which it forms a thickened ring-like band, the *pyloric sphincter* [m. sphincter pylori]. The inner or *oblique* layer [fibræ obliquæ] is composed of fibers continuous with the deepest circular fibers of the esophagus. They form an incomplete layer which encircles the fundus and passes obliquely downward around the body of the stomach toward the greater curvature. Forssell has shown the fundamental importance of the arrangement of the musculature in determining the form of the stomach under various conditions.

The external *tunica serosa* is formed by the peritoneum, and has the smooth shiny appearance and the structure typical for a serous membrane. The position of the pyloric sphincter is shown on the outer surface by a very constant venous ring running toward both lesser and greater curvatures in the subserous layer at right angles to the long axis of the pyloric canal (Moynihan).

Blood-vessels.—The stomach receives its blood-supply from many branches. From the cœliac trunk there is the left gastric artery, which runs along the lesser curve from left to right anatomosing with the right gastric branch of the hepatic. Along the greater curvature run the right and left gastroepiploic arteries, anastomosing at the middle of the border, the left being a branch of the splenic, the right a branch of the hepatic, through the gastroduodenal artery. The stomach also receives branches from the splenic (vasa brevia) at the fundus. The vascular arches along the curvatures of the stomach are comparable to those in the intestinal mesentery

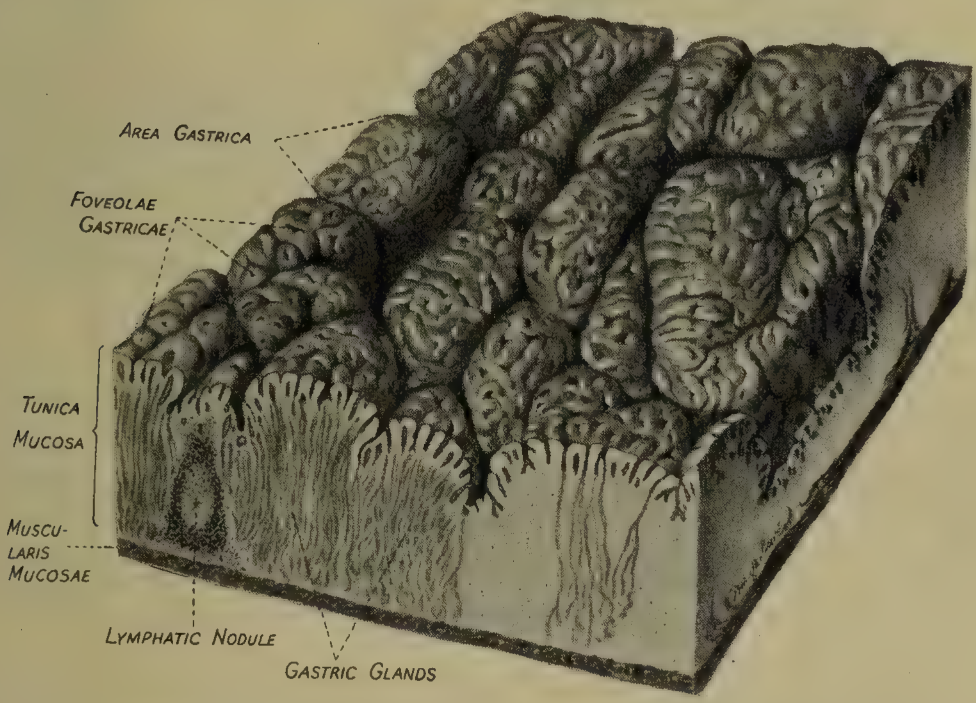


Fig. 991.—Surface View of Gastric Mucosa. (After Braus.)

(Mall). The blood of the stomach is returned into the portal vein. The coronary vein and pyloric vein open separately into the portal vein; the right gastroepiploic vein opens into the superior mesenteric, the left into the splenic. The arrangement and distribution of the blood-vessels within the stomach wall are illustrated in fig. 990. The rich capillary plexus in the mucosa supplies the glands and also serves for absorption.

Lymphatics.—There is a set of nodes lying along the lesser curvature and the pyloric portion of the greater curvature, and others at the pyloric and cardiac ends. These are entered by lymphatic vessels which, beginning in the mucous membrane (fig. 990), accompany all the gastric veins, but chiefly those of the lesser curvature. Vessels also accompany the left gastroepiploic veins to terminate in the splenic nodes (see fig. 652). On its way to the cisterna chyli, the gastric lymph passes through groups of nodes [lymphoglandulæ pancreaticolienales] situated above and behind the head and neck of the pancreas.

Nerves.—The nerves of the stomach are derived in part from the vagi (which form the motor fibers of the stomach), the right vagus descending on the posterior wall, and the left on the anterior wall. The stomach also receives sympathetic branches from the celiac plexus, following the arteries. Small ganglia occur along both vagus and sympathetic branches (Remak). The nerves join the gangliated plexuses, myenteric and submucous, in the wall of the stomach, from which branches are distributed to the muscularis and the mucosa as for the intestine in general.

Development.—For development of the stomach, see Developmental Anatomy, p. 46; also *general morphogenesis*, p. 1232. According to Johnson, in an embryo of 16 mm., the lining epithelium shows the primitive foveolæ as pit-like depressions which become elongated, forming irregular anastomosing grooves, separated by villus-like projections. The pits multiply and deepen, and from their bottoms the gastric glands bud off (at 120 mm.).

Variations.—The great variability of the stomach in form, position and relations has already been repeatedly emphasized. These variations, which depend chiefly upon the factors already

mentioned, have been observed both in properly fixed dead bodies and in the living body by means of the Rœntgen-rays, as shown especially by Moody and associates.

Physique.—As has been emphasized by Mills, visceral form and topography in general, while subject to marked individual variations, are often closely correlated with certain types of general physique. The extremes are the hypersthenic type, with broad thorax and capacious upper abdomen, and the asthenic slender type, with narrow thorax and small upper abdomen. In the hypersthenic type, the stomach ('cow-horn' type) and transverse colon are placed high, scarcely reaching the umbilical zone; while in the asthenic type, both sag low, toward

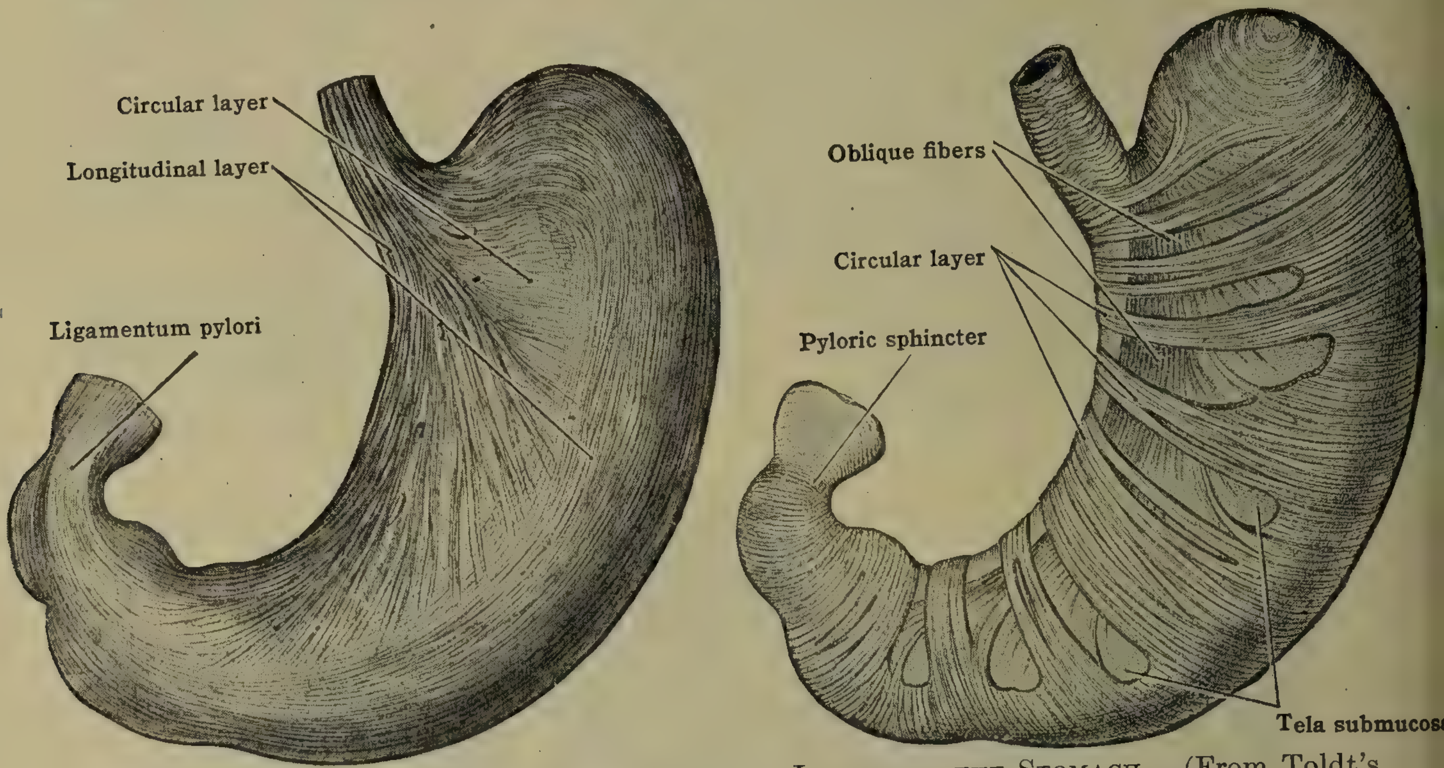


Fig. 992.—Dissections Showing the Muscular Layers of the Stomach. (From Toldt's Atlas.)

the pelvic region, approaching the condition known as *gastroptosis* (visceroptosis). Between these two extremes are the sthenic and hyposthenic types, in which the conditions are intermediate in character.

Peristalsis.—It would appear that many variations in the form of the stomach that have been described are merely various phases in the series of changes undergone by the stomach during the normal process of digestion. Observations by various investigators upon the living stomach of man and lower animals (especially the radiographic study of the cat by Cannon) have shown that the pyloric portion during digestion usually presents distinct peristaltic

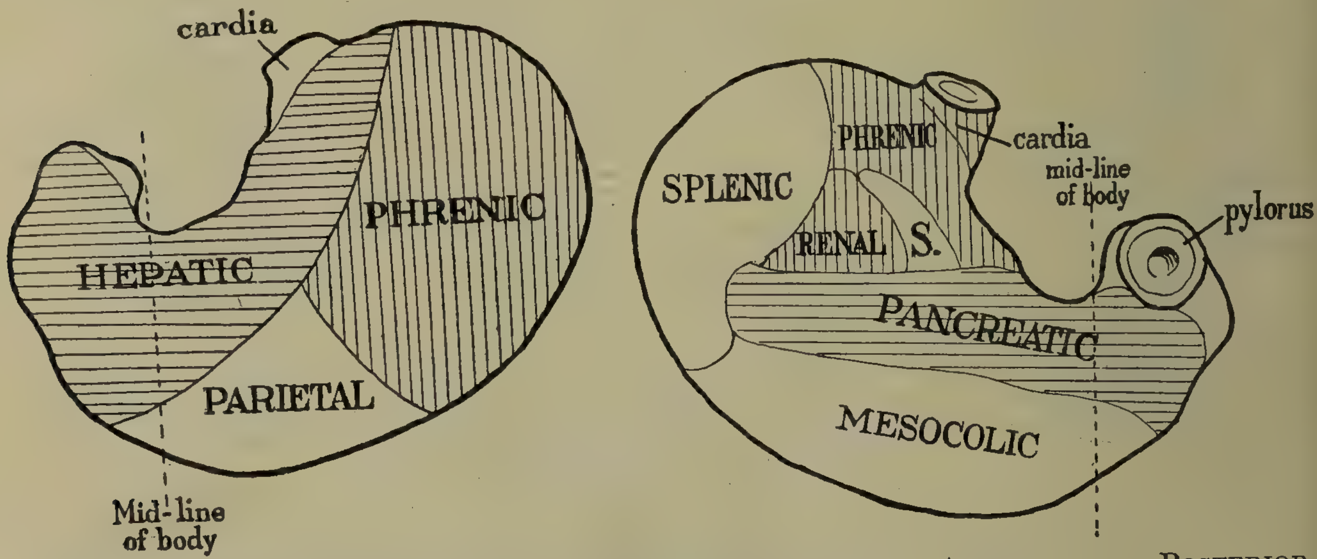


Fig. 993.—Diagram of the Contact Areas of the Stomach, Anterior and Posterior Views.

contractions passing pylorusward. Peristaltic contractions may also be observed to begin in the cardiac portion, although they are usually most distinct in the pyloric portion (fig. 987). In addition to the peristaltic waves, stationary constrictions may appear at various points, but all of these are transient in character (Forssell). The constrictions most frequently observed form the *incisura angularis* on the lesser curvature near the gastric angle and the *sulcus intermedius* on the greater curvature between the sinus (antrum) and the pyloric canal (figs. 984, 986, 987, 989).

In the earlier stages of gastric digestion the pylorus usually remains closed, but after a variable time it relaxes slightly (lumen about 3 mm. in diameter) at intervals, allowing the chyme to be spurted into the duodenum. This forms the 'duodenal antrum' seen with the *X*-rays (figs. 986, 987).

Thus the various constrictions often found in the formalin-hardened stomachs, and the pyloric antrum, appear to be merely transient phases of the digestive process. The 'hour-glass' stomach (fig. 986) is in most cases to be explained in this way; in others, however, the constriction is pathological and permanent. Various forms of abnormal lobulations and dilations also rarely occur. The tonus of the gastric musculature is of great importance in determining the form and position of the stomach, so that the pylorus may descend during a transient faintness or nausea (Barclay).

Comparative.—The primitive stomach is perhaps merely a receptacle for food, true digestive glands being absent in many of the fishes. The vertebrate stomach is a dilated sac of variable form, but is typically somewhat looped, with cardiac and pyloric segments. In *birds*, there is a peculiar arrangement, correlated with the absence of teeth. The stomach is divided into an anterior glandular *proventriculus*, and a posterior muscular *gizzard* with a horny lining serving to grind the food. The *mammalian* stomach is most variable in form and structure, which are correlated with the method and character of alimentation. The three kinds of glands, cardiac, fundic and pyloric, are typically present. In general, the stomach is larger and more complicated in herbivora than in carnivora. Instead of being a single sac, the stomach may be more or less divided into chambers. An incomplete division into cardiac and pyloric portions is so common that it may be considered as typical. The most extreme specialization is found in the ruminants. In these the stomach has four chambers, the first two of which, however, are expansions of the esophagus.

THE SMALL INTESTINE

The **small intestine** [intestinum tenue] extends from the pylorus to the ileocecal orifice, and occupies most of the abdominal cavity below the liver and stomach. It is a cylindrical tube whose diameter decreases from about 4 cm. above to about 2.5 cm. at the lower end. Its *length*, when removed from the body and measured fresh, averages about 7 meters (23 ft.); but when formalin-hardened *in situ*, the length (which is probably nearer that during life) is only about 4 meters. The length does not seem to vary according to sex, height or weight in the adult. The small intestine includes two main divisions, the *duodenum* and the *mesenteric small intestine*, the latter being further subdivided into *jejunum* and *ileum.*

Van der Reis and Schembra found that swallowed rubber tubes indicate an intestinal length of only about 2.5 meters during life, but this may be abnormal. Variations in muscular tone may greatly modify the length, form and position of the gastrointestinal canal in the living body (T. Wingate Todd).

THE DUODENUM

The **duodenum** is the first part of the small intestine, and is very definite in position and extent. It is firmly attached to the posterior abdominal wall, being almost entirely retroperitoneal. It is the widest part of the small intestine, the average width being 4 cm. or more, and is also the shortest segment, being only about 25 cm. in length. In general, it is somewhat **C**-shaped, the concavity enclosing the head of the pancreas (figs. 994, 995).

Parts.—For convenience of description, the duodenum is divided into the following parts: (1) the *superior* (or *cranial*) *portion* [pars superior] which is short (5 cm. or less), leading from the pylorus and forming the *superior flexure* [flexura duodenalis superior]; (2) the *descending portion* [pars descendens], about 7 or 8 cm. in length, which receives the bile and pancreatic ducts and joins the inferior portion at the *inferior flexure* [flexura duodenalis inferior]; (3) the *inferior* (*caudal*) *portion* [pars inferior], which is again subdivided into (a) *horizontal* portion [pars horizontalis], about 10 cm. long, which usually ascends slightly and passes gradually into (b) the *ascending portion* [pars ascendens], 2 or 3 cm. long, terminating in the *duodenojejunal flexure* [flexura duodenojejunalis].

Position and relations.—As shown in fig. 1032, the duodenum usually lies chiefly in the lower part of the epigastric region, only the inferior (horizontal) portion extending into the umbilical region. All but the terminal (ascending) portion of the duodenum usually lies to the right of the midline.

The *superior* portion usually lies at the level of the first lumbar vertebra (or slightly below). It is covered anteriorly, and to a variable extent posteriorly, by a prolongation of the peritoneum from the corresponding surfaces of the stomach. It is somewhat freely movable. When the stomach is empty, it extends from the pylorus almost horizontally to the right and backward. As

the stomach becomes distended, however, the pylorus is carried to the right and downward for a variable distance, and the position of the superior part of the duodenum is correspondingly altered.

Superiorly it is in contact with the liver (quadrate lobe) and the neck of the gall-bladder and forms the lower boundary of the epiploic foramen; *anteriorly*, with the liver and (often)

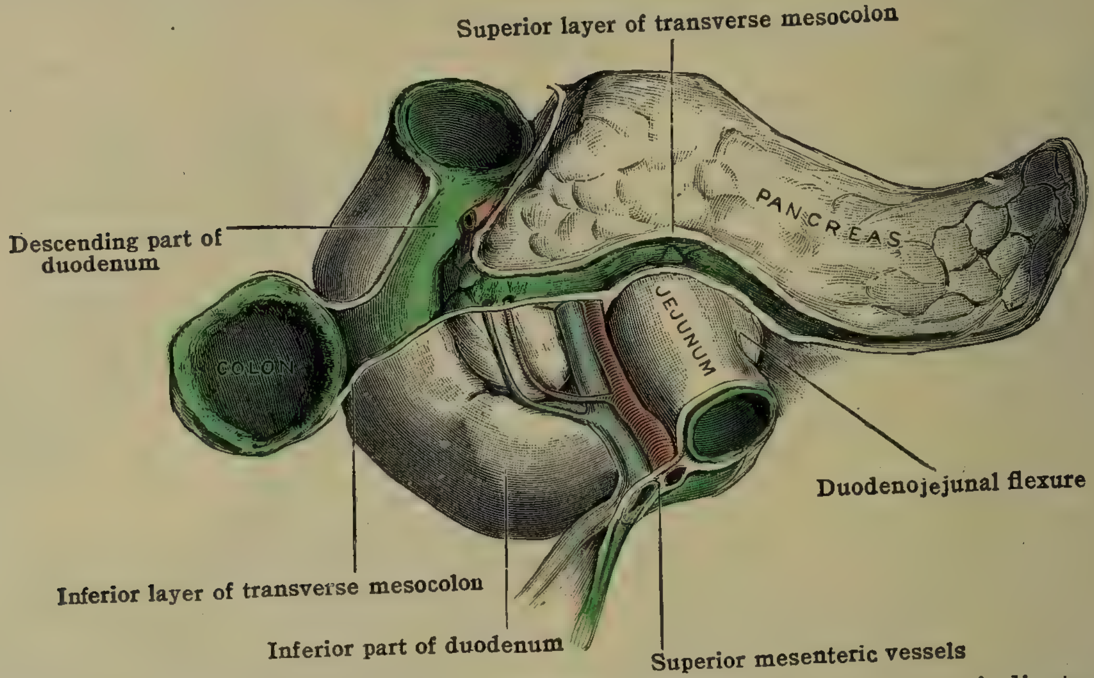


Fig. 994.—The Duodenum and Pancreas, Anterior View. Green indicates areas uncovered by peritoneum.

the transverse colon; *inferiorly* and *posteriorly*, with the head of the pancreas below, and with the common bile-duct, hepatic vessels and portal vein above.

The second or *descending* portion of the duodenum extends along the right side of the first to the third lumbar vertebra. It is covered anterolaterally by peritoneum, excepting (usually) the area of contact with the transverse colon (figs. 935, 981).

Posteriorly (fig. 1032) it is in contact with the right kidney, ureter and renal vessels, and below with the psoas muscle. *Anteriorly* (fig. 983) it is crossed by the transverse colon (the layers of

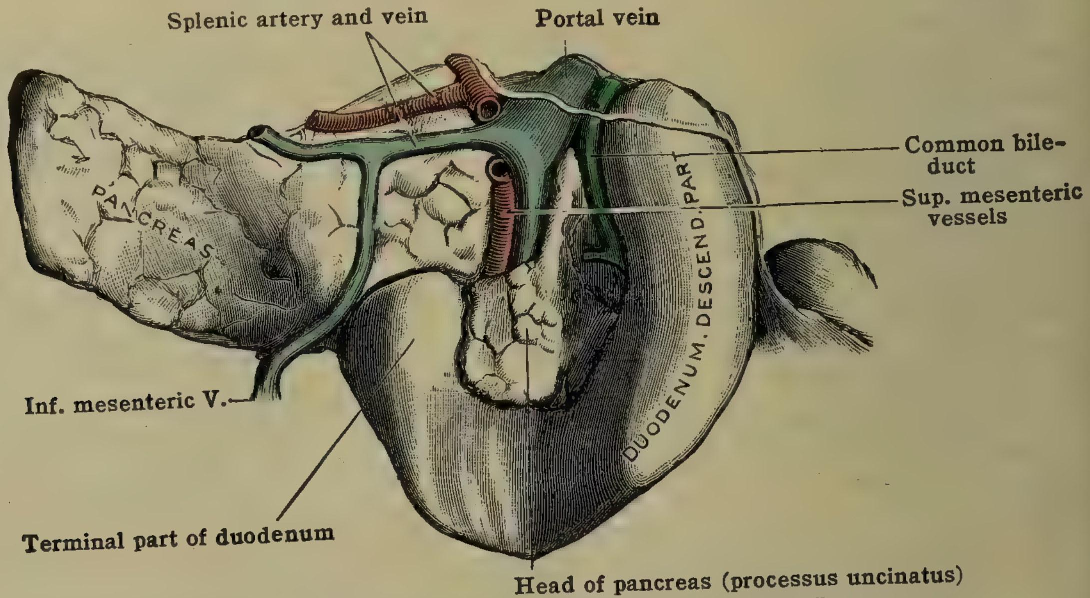


Fig. 995.—The Duodenum and Pancreas, Posterior View.

the transverse mesocolon usually separated by an area of direct contact); above the colon, it may be in contact with the gall-bladder, and below the colon with coils of small intestine. The *left or medial* aspect of the descending duodenum (figs. 994, 995) is in contact with the head of the pancreas, and some fibers from the muscular tunic are said to become intermingled with the pancreatic lobules. Somewhat posteriorly the common bile-duct descends between pancreas and duodenum, and enters the descending duodenum, in common with the pancreatic duct, about 10 cm. below the pylorus (fig. 1031). The loop formed by the pancreaticoduodenal arteries also runs along the descending duodenum.

The third or *horizontal* portion of the duodenum usually crosses the body of the third lumbar vertebra, ascending slightly from the right to the left side (figs. 994, 995). It is covered anteriorly with peritoneum, excepting a small space where the superior mesenteric vessels enter the root of the mesentery.

Anteriorly it is further in contact with coils of small intestine; *superiorly*, with the head of the pancreas, and the inferior pancreaticoduodenal vessels; *posteriorly*, with the vena cava. The constricting effect of the superior mesenteric vessels on the duodenum probably gives rise to the acute dilation of the stomach that sometimes follows abdominal operations.

The terminal or *ascending* portion is covered anteriorly and laterally by peritoneum, and is in contact with coils of the ileum. To the *right* it is in relation with the head of the pancreas (processus uncinatus) and the superior mesenteric vessels; and *posteriorly* with the psoas muscle, aorta and left renal vessels. The *duodenojejunal flexure* usually lies opposite the second lumbar vertebra, and is in contact above with the inferior surface of the body of the pancreas, and the root of the transverse mesocolon (figs. 981, 994).

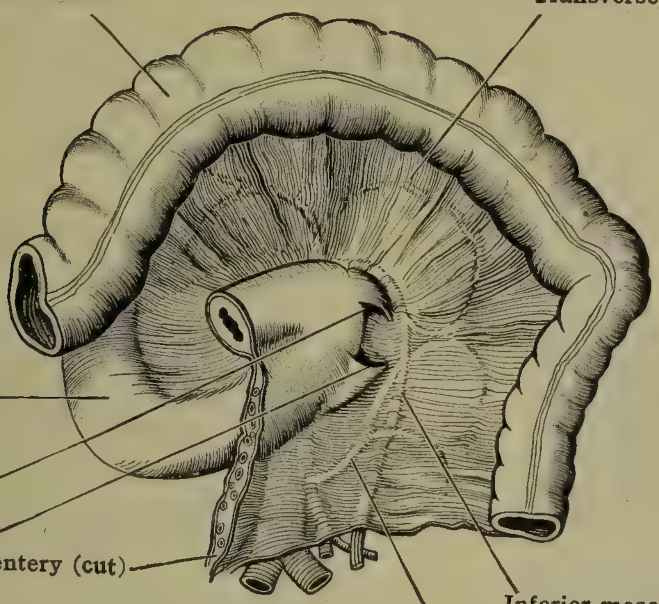


FIG. 996.—DUODENAL FOSSÆ AND FOLDS. Paraduodenal fossa is not shown. (After Cunningham.)

The duodenojejunal flexure is the commonest site of traumatic rupture of the small intestine, since it is the point of union of a fixed and a freely movable portion of the gut. In the operation of posterior gastroenterostomy, the duodenojejunal flexure is readily found by passing the hand along the under surface of the transverse mesocolon to the left side of the spine, the omentum and colon being turned upward. The first coil of the jejunum is anastomosed to the posterior wall of the stomach, which is exposed by making an opening in the transverse mesocolon.

The lower end of the duodenum is firmly fixed in its place by the *musculus suspensorius duodeni*, or *suspensory ligament of Treitz*. This name has been given to a fibromuscular band that contains, according to Treitz, smooth muscular fibers, and descends to the terminal part of the duodenum from the left crus of the diaphragm, passing to the left of the celiac artery and behind the pancreas. Lockwood points out that this band is continued on, after being inserted into the duodenum, between the layers of the mesentery. He suggests the name of the 'suspensory muscle of the duodenum and mesentery.' It may also contain cross-striated muscle from the diaphragm (van der Schaar).

In connection with this fourth portion of the duodenum, mention may be made of certain peritoneal folds and fossæ which are of some surgical interest by reason of their being associated with retroperitoneal hernia. Four such fossæ may be mentioned, namely, the superior and inferior duodenal fossæ, paraduodenal and the retroduodenal fossæ. On drawing the terminal portions of the duodenum to the right, two triangular folds of peritoneum, the superior and inferior duodenal folds, which extend from the wall of the duodenum to the posterior abdominal wall, may be observed (fig. 996). Beneath the free edge of each fold is found a pouch of peritoneum, constituting the **superior** and **inferior duodenal fossæ**. The former, the smaller, opens downward and is present in about 50 per cent., while the latter opens upward and is present in about 75 per cent. of the subjects examined (Jonnesco). The **paraduodenal fossa** (fossa of Landzert) is not often found in the adult; when present, it is situated to the left of the last part of the duodenum, and is formed by a fold of peritoneum enclosing the inferior mesenteric vein. The retroduodenal fossa is a rare form extending from below upward behind the transverse portion of the duodenum.

Interior of the duodenum.—The interior of the first part of the duodenum is smooth. The pylorus is often somewhat invaginated, much in the same way that the uterus projects into the vagina (fig. 989). On account of this arrange-

ment (which renders the complete emptying of the cavity somewhat difficult) and also on account of the distensibility of this portion, it is frequently seen very distinctly in radiographic pictures as a 'cap' (antrum) at the pyloric end of the stomach during digestion (fig. 987). In the lower portions of the duodenum, transverse ridges or folds of the mucosa appear which sometimes are also apparent in radiographs. On the medial wall of the descending portion, posteriorly, about half-way down, is a more or less distinct *longitudinal fold* [plica longitudinalis duodeni], toward the lower end of which is a small elevation, the bile papilla or *papilla major* [papilla duodeni], upon which open the common bile duct and the pancreatic duct, either separately or by a common aperture (fig. 1031).

Above the major papilla there is often a prominent *hood-like fold* (valvula connivens), and below it a variable fold or *frenum* which forms a continuation of the plica longitudinalis. About 2 cm. (0.9 to 3.5 cm., Baldwin) above and in front of the major papilla there is a second, smaller, rounded *papilla minor*, upon which the accessory pancreatic duct (of Santorini) ends.

The minute structure, vascular relations, development, variations, etc., of the duodenum will be considered later, with those of the small intestine as a whole.

THE JEJUNUM AND ILEUM

The mesentric portion of the small intestine [intestinum tenue mesenteriale] is divided into an upper portion, the *jejunum*, and a lower portion, the *ileum*. Although the character of the gut changes considerably from the upper end of the jejunum to the lower end of the ileum, the transition is gradual, with no

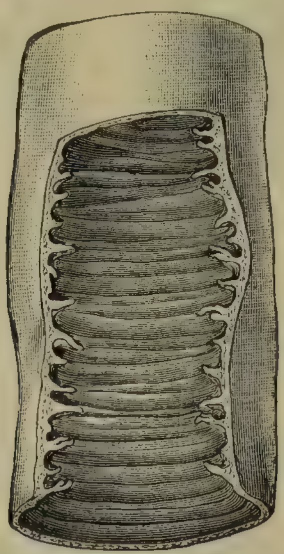


Fig. 997.—Portion of the Small Intestine, Laid Open to Show the Plicæ Circulares. (Brinton.)

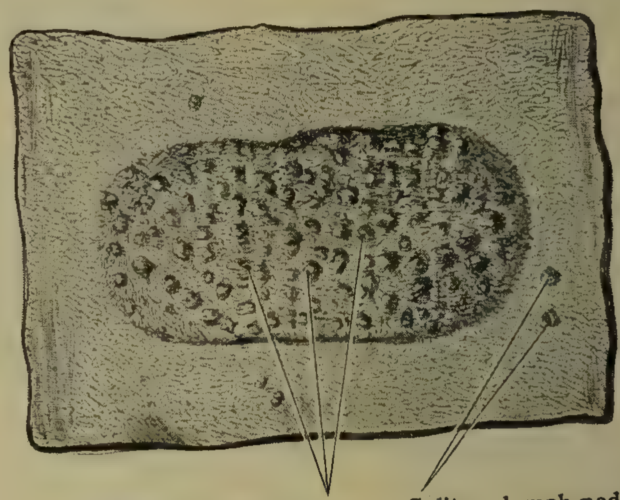


Fig. 998.—Surface View of the Mucosa of the Ileum, Showing Aggregated Lymph-nodes (Peyer's Patch). (From Toldt's Atlas.)

definite line of demarcation. In general, the jejunum is somewhat wider, has thicker walls, is more vascular and has a more complicated mucosa. The lymphoid organs (Peyer's patches) are, however, characteristic of the ileum.

The **jejunum** begins at the duodenojejunal flexure. The first coil is variable in direction, being found (in order of frequency) as follows: (1) downward, forward and to the left; (2) directly forward and downward; (3) to the left, then downward; (4) forward and to the right (Harman). Some further details as to the position of the various succeeding coils are given later under the development of the intestine (figs. 1001, 1002). While there is considerable individual variation it is true in general that the coils of *jejunum* occupy the upper and left portion of the body cavity, while those of the *ileum* occupy the lower and right side, the lower portion lying in the pelvic cavity. The ileum finally passes upward over the pelvic brim to the right iliac fossa where it terminates in the ileocecal orifice.

The **mesentery** [mesenterium] is a fan-shaped fold extending from the duodenojejunal flexure to the ileocecal junction. It is composed of a double layer of peritoneum which encloses and supports the jejunum and ileum and their vessels, connecting them with the abdominal wall. The *root* of the mesentery [radix mesenterii], or parietal attachment, is only about 15 cm. long, corresponding to a line extending from the duodenojejunal flexure obliquely downward and to the right, across the transverse duodenum, the great vessels and the vertebral column to the ileocecal junction (fig. 981).

The *visceral* attachment of the mesentery to the intestine, corresponding to the length of the jejunoileum, is nearly 7 meters long (postmortem), and is thinner than at the root. The *width* of the mesentery, measured from parietal to visceral attachment, varies somewhat in different parts of the canal, the average being 18 or 20 cm. (ranging from 15 to 25 cm.). It is narrow above (also at the lower end), and reaches its greatest width from 2 to 4 m. (6 to 11 feet) below the duodenum (Treves). Between the two peritoneal layers of the mesentery is a third layer [lamina mesenterii propria] containing the superior mesenteric vessels (arteries, veins and lymphatics) with their branches and accompanying nerves, the small mesenteric lymph-

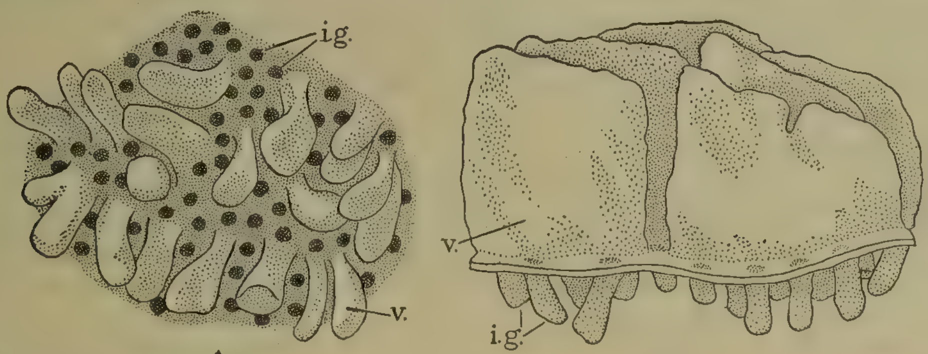


Fig. 999.—*A*, Surface View of the Mucosa of the Small Intestine. (After Kölliker.) *B*, Side View of a Wax Reconstruction of the Epithelium in the Human Duodenum. (Huber.) *i.g.*, intestinal glands. *v.*, villus.

nodes (50 to 100 in number), and a variable amount of fibroadipose connective tissue. The lymph-nodes become notably enlarged during intestinal infections, such as tabes mesenterica.

Minute anatomy.—The small intestine has the four typical layers—mucosa, submucosa, muscularis and serosa (fig. 1000). They are, in general, somewhat similar in structure to those of the stomach (fig. 990), excepting the mucosa.

The **mucosa** is lined with a simple cylindrical epithelium, underneath which is a fibrous *lamina propria*, limited externally by a *muscularis mucosæ*, as in the stomach. The inner surface of the mucosa (fig. 997) presents numerous coarse, closely set, transverse folds [*plicæ circulares*]. These are permanent, crescentic folds, involving both mucosa and submucosa,

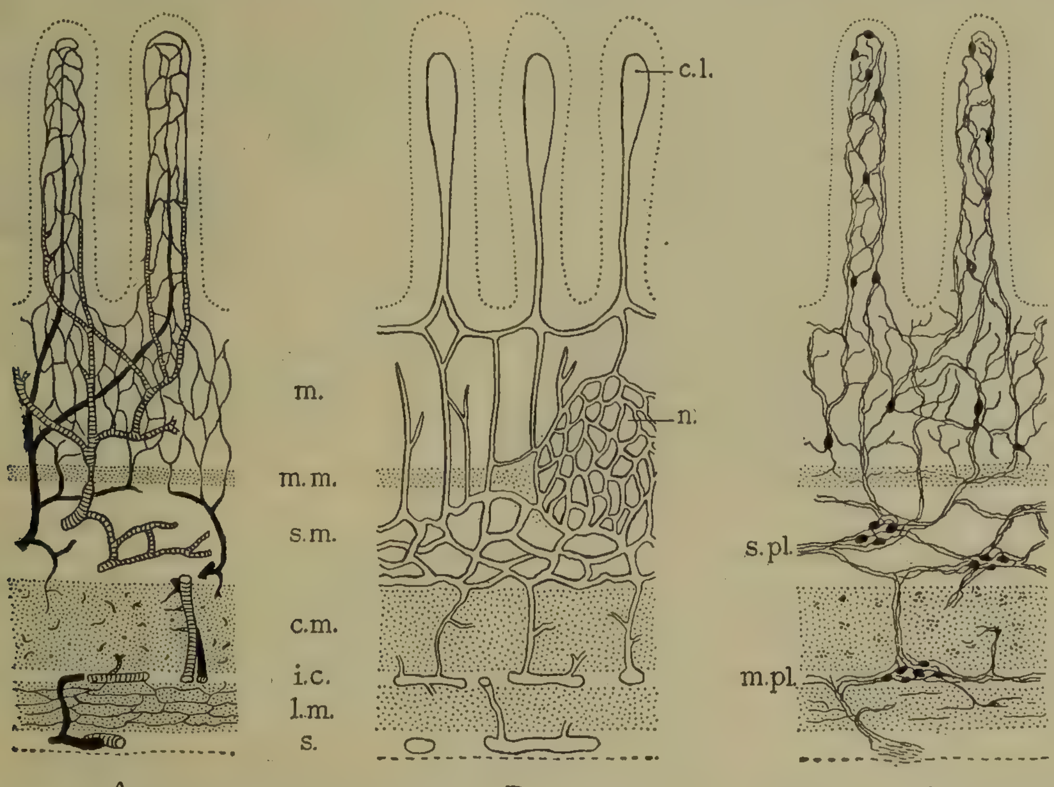


Fig. 1000.—Diagrams of the Vessels and Nerves of the Small Intestine *A*, Blood vessels; arteries as coarse black lines, capillaries as fine lines, veins shaded (after Mall). *B*, Lymphatics (after Mall). *C*, Nerves, based on Golgi preparations (after Cajal). *m*, mucosa. *mm.*, muscularis mucosæ. *s.m.*, submucosa. *c.m.*, circular muscle. *i.c.*, intermuscular connective tissue. *l.m.*, longitudinal muscle. *s*, serosa. *c.l.*, central lymphatic. *n.*, lymph nodule. *s.pl.*, submucous plexus. *m.pl.*, myenteric plexus. (Lewis and Stöhr.)

and usually extending one-half to two-thirds of the way around the lumen. They often branch and anastomose, sometimes forming circles or spirals. The largest exceed 5 cm. in length and 3 mm. in width. The plicæ circulares are absent from the first part of the duodenum, but become well marked in the descending portion. They are largest and best developed in the lower duodenum and upper half of the jejunum, below which they gradually become smaller and disappear at the lower end of the ileum. The total number of plicæ in the adult is about 800 (Gundobin).

The digestive and absorptive surface of the small intestine is further greatly increased by multitudes of small processes, the *villi* (fig. 999), which give the mucosa a velvety appearance.

They are largest (0.5 to 0.7 mm. in height) and most numerous in the duodenum and jejunum, where they are typically leaf-shaped, and gradually become smaller, scattered and conical in the ileum. The villi are much reduced in distention of the intestine, and may even be temporarily obliterated. Between the bases of the villi there open short, simple tubular glands—the crypts of Lieberkuehn [gl. intestinales]. In the duodenum there are found, in addition, the larger tubuloracemose glands of Brunner [gl. duodenales], which occupy the submucosa, and are especially numerous in the upper portion of the duodenum.

Scattered over the whole of the mucous membrane of the small intestine are numerous small lymph-nodules, the larger of which extend into the submucosa; these are the so-called *solitary glands* [noduli lymphatici solitarii]. Aggregations of lymph-nodules, known as *Peyer's patches* [noduli lymphatici aggregati], situated in the mucosa and submucosa, are found in the ileum especially toward the lower end (fig. 998). They are oval, from 1.2 to 7.5 cm. in length and about 1 to 2.5 cm. in breadth, and are placed in the long axis of the bowel along a line most remote from the mesentery. They are variable in number, the average being about 20 to 30. They are the chief sites of ulceration in typhoid fever and intestinal tuberculosis.

The **submucosa** is in general a loose areolar layer containing vascular and sympathetic plexuses (fig. 1000). The **muscularis** is composed of smooth muscle arranged in the two typical layers—a thinner, outer longitudinal and a thicker, inner circular—both of which become thinner toward the lower end of the ileum. The **serosa** is typical in structure, the mesothelial covering being absent in the retroperitoneal areas of the duodenum.

Intestinal localization.—The surgeon often wishes to ascertain roughly to what part of the small intestine a given coil presenting in a wound belongs. The variations in length of the small intestine and the considerable range of movement of the coils during peristalsis render the problem difficult, but it may be stated as a general rule that the upper third of the intestine lies in the left hypochondrium and is not usually encountered in a wound; the middle third occupies the middle part of the abdomen, and the lower third lies in the pelvis and right iliac fossa (Monks). (See further details later under development of the small intestine). The jejunum is thicker walled and more vascular than the ileum. The lumen steadily diminishes as we pass downward, hence foreign bodies such as gall-stones that pass through the jejunum are apt to become impacted in the lower ileum.

The most reliable indications of the level of a given coil are found, however, on inspection of the mesentery and its blood-vessels (see next paragraph). The mesenteric fat in the upper third never reaches quite to the free edge of the mesentery, so that clear transparents space are left near the bowel. In the lower third the fat usually occupies the whole of the mesentery right up to the intestine, and makes it thicker and more opaque. (Monks: Trans. Amer. Surg. Assoc., 1913.)

Blood-supply of the small intestine.—The small intestine receives its blood from the superior mesenteric artery and a branch coming indirectly from the hepatic, the superior pancreatico-duodenal. The superior mesenteric artery runs between the layers of the mesentery and gives off six or seven relatively large branches and a variable number of smaller branches. The first two or three of the larger branches each divide into an ascending and a descending branch, which join above and below with the corresponding branches of the contiguous arteries, forming thus a single row of arches. From about the beginning of the second quarter of the small intestine a second tier of arches, formed in a similar manner, is often noted, and below the middle of the jejunoileum more than two tiers of arches may be present, the complexity of the arches increasing, while the size of the vessels diminishes (see fig. 559). From the convex border of the most distally placed arches there pass to the intestine straight branches, so-called vasa recta. Near the beginning of the jejunum these are numerous and large, about 4 cm., long, and are quite regular. After the first third of the intestine is passed the vasa recta become smaller and shorter, and toward the lower end of the ileum they become short and irregular and are often less than 1 cm. in length (Dwight). The blood is returned by means of the superior mesenteric vein, which, with the splenic vein, forms the portal. The vascular arrangement in the intestinal wall is shown in figs. 1000 and 1008.

The **lymphatic** vessels form a continuous series, which is divided into two sets—viz., that of the mucous membrane and that of the muscular coat. The lymph-vessels of both sets form a copious plexus (fig. 1000). The efferent lymphatic vessels form the so-called lacteals, which pass through the mesenteric lymph-nodes, finally reaching the cisterna (receptaculum) chyli.

The nerves.—The small intestine is supplied by means of the superior mesenteric plexus which is continuous with the lower part of the celiac (solar) plexus. The branches follow the blood-vessels, and finally form two plexuses: one (Auerbach's or myenteric) which lies between the muscular coats; and another (Meissner's) in the submucous coat. The nerve-fibers are chiefly from the sympathetic, partly from the vagus.

Development of the small intestine.—The early stages in the formation of the intestines have been described in Section I (p. 48), and also in connection with the *general morphogenesis* (p. 1232). Even in an embryo of 19 mm., while the intestine is still in the umbilical celom, Mall described six primary coils of the small intestine which could still be recognized after the return of the intestines to the general body cavity, and could usually be identified even in the adult (fig. 1001). *In the adult*, as also through the various stages of development, loop 1 forms the duodenum. From the primary groups of coils marked 2 and 3 are developed the greater part of the jejunum, arranged in two distinct groups of loops, situated in the left hypochondriac region. The part of the intestine developed from group 4 of the primary coils passes across the umbilical region to the right upper part of the abdomen. That part developed from group 5 of the primary coils recrosses the median line to the left iliac fossa, while that part derived from group 6 of the primary coils is found in the false pelvis and the lower part of the abdominal cavity between the psoas muscles. They present what may be regarded as the normal arrangement of the small intestine, having been found 21 times in 41 cadavers examined. Variations from this arrangement occur, however.

According to Johnson (upon whose descriptions the following account is based), there is in embryos of 13 mm. to 23 mm. a formation of vacuoles in the duodenal epithelium, which

leads to complete temporary occlusion of the lumen. A persistence of this condition may cause permanent atresia. In the epithelium of the small intestine numerous pockets or cysts occur, which usually disappear, but may persist and form permanent diverticula or accessory pancreas. The *villi* begin to appear at 19 mm., first in the mucosa of the upper portion of the intestine, as localized outgrowths which become arranged in longitudinal rows. The crypts of Lieberkuehn bud off from the epithelium at 55 mm., and from those in the duodenum, the duodenal (Brunner's) glands begin to bud off at 78 mm. The plicæ circulares begin to appear at the mid-region of the small intestine at 73 mm. The circular muscle-layer begins to appear at about 12 mm., the longitudinal at 75 mm.

Variations in the small intestine.—Although relatively fixed in position, the *duodenum* is quite variable in form. The C-shape previously described is the most common. When the pylorus and the duodenojejunal flexure are approximated, the form is nearly circular. When the two ends are more widely divergent, it approaches a U-form. Not infrequently, the inferior portion ascends abruptly from the inferior angle, giving a V-form. Finally, the terminal ascending portion may be very small or absent, in which case the duodenum approaches an L-form. Variations in the position of the various coils of the jejunum and ileum have already been discussed. Occasionally there is a partial fusion of the left half of the mesentery with the parietal peritoneum so as to immobilize the ileum for a few inches above the ileocecal valve.

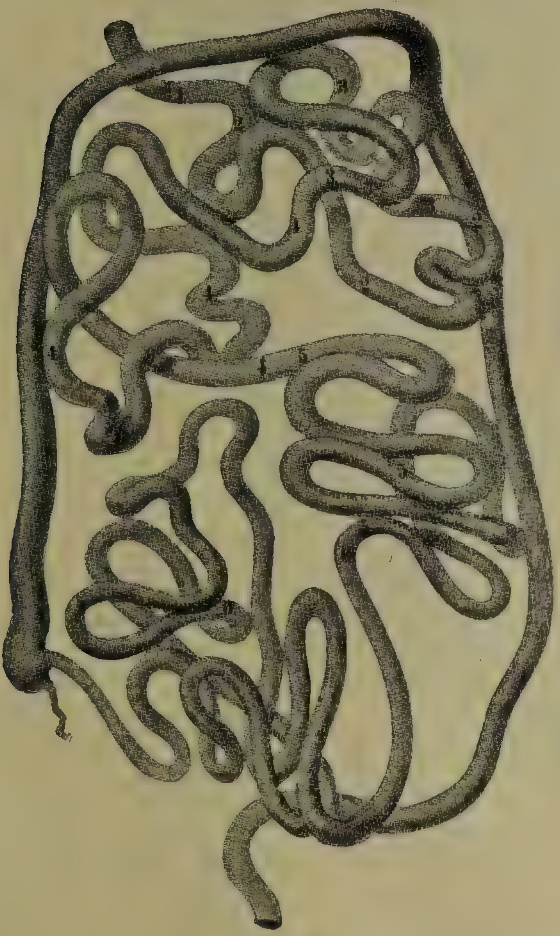


Fig. 1001.—Model Showing Course of Intestine, Made from Same Cadaver from which Fig. 1002 was Drawn. (Mall.)

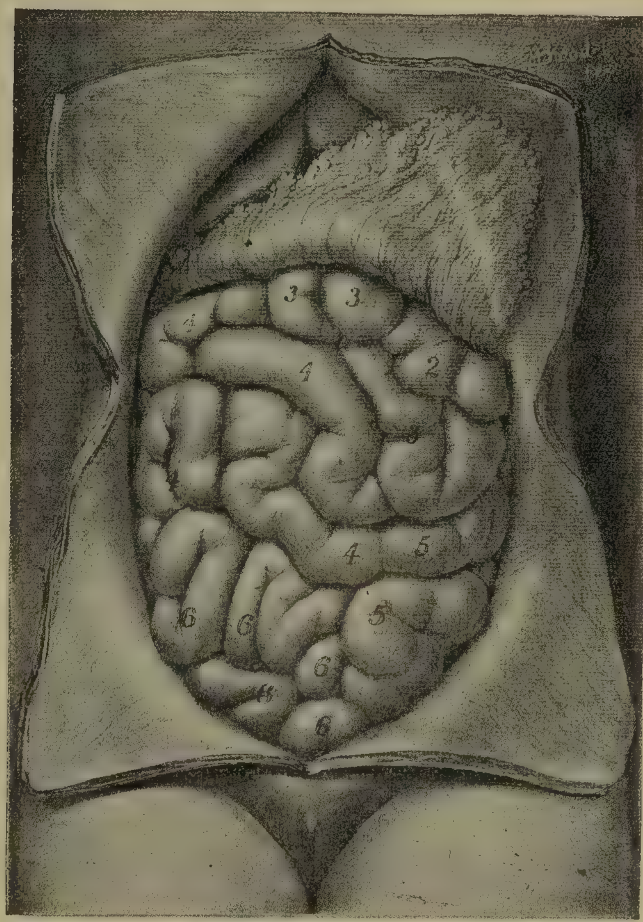


Fig. 1002.—The Usual Position of the Intestine in the Abdominal Cavity. The numbers in the figure mark the parts which are homologous with the primary bends and groups of coils numbered from 1 to 6. (Mall.)

The lymph-nodules, including Peyer's patches, like all lymphoid structures, are prominent during youth, but become atrophied in old age.

Meckel's diverticulum, which represents a derivation from the embryonic yolk-stalk and sac, is found in 1.5 per cent. of all adults, but much oftener in males (Brites). It is a blind tube or diverticulum of variable size, usually approaching the intestine in width and averaging 5 cm. in length (ranging from 1 cm. to 13 cm.). Its attachment to the intestine varies from 15 cm. to 360 cm. (average 80 cm.) above the cecum. It may end freely, but is occasionally adherent to adjacent intestinal coils or connected with the anterior abdominal wall in the umbilical region by a cord or band-like process. This cord may cause acute intestinal obstruction by strangulating a coil of gut, or the diverticulum may become invaginated and form the starting-point of an intussusception.

Other diverticula of variable size and number may occur, usually along the mesenteric border of the intestine. They may be either congenital (probably from the embryonic pockets previously mentioned) or acquired. They occur most frequently in the duodenum (found by Moynihan in 1 per cent. of all cases, using the Roentgen rays) where they are usually associated with the openings of the bile and pancreatic ducts.

Comparative.—The comparative anatomy of the small intestine will be discussed later together with that of the large intestine.

THE LARGE INTESTINE

The **large intestine** [intestinum crassum] is that part of the alimentary canal between the ileum and the anus. It is divided into the following parts: Cecum, ascending, transverse, descending, and sigmoid colons, and rectum. It is so arranged as to surround the small intestine, making a circuit around the abdominal cavity from right to left (figs. 932, 1009). The *cecum* lies in the right iliac fossa; thence the colon passes vertically upward on the right side (*ascending colon*) until the liver is reached. Here it forms a more or less rec-

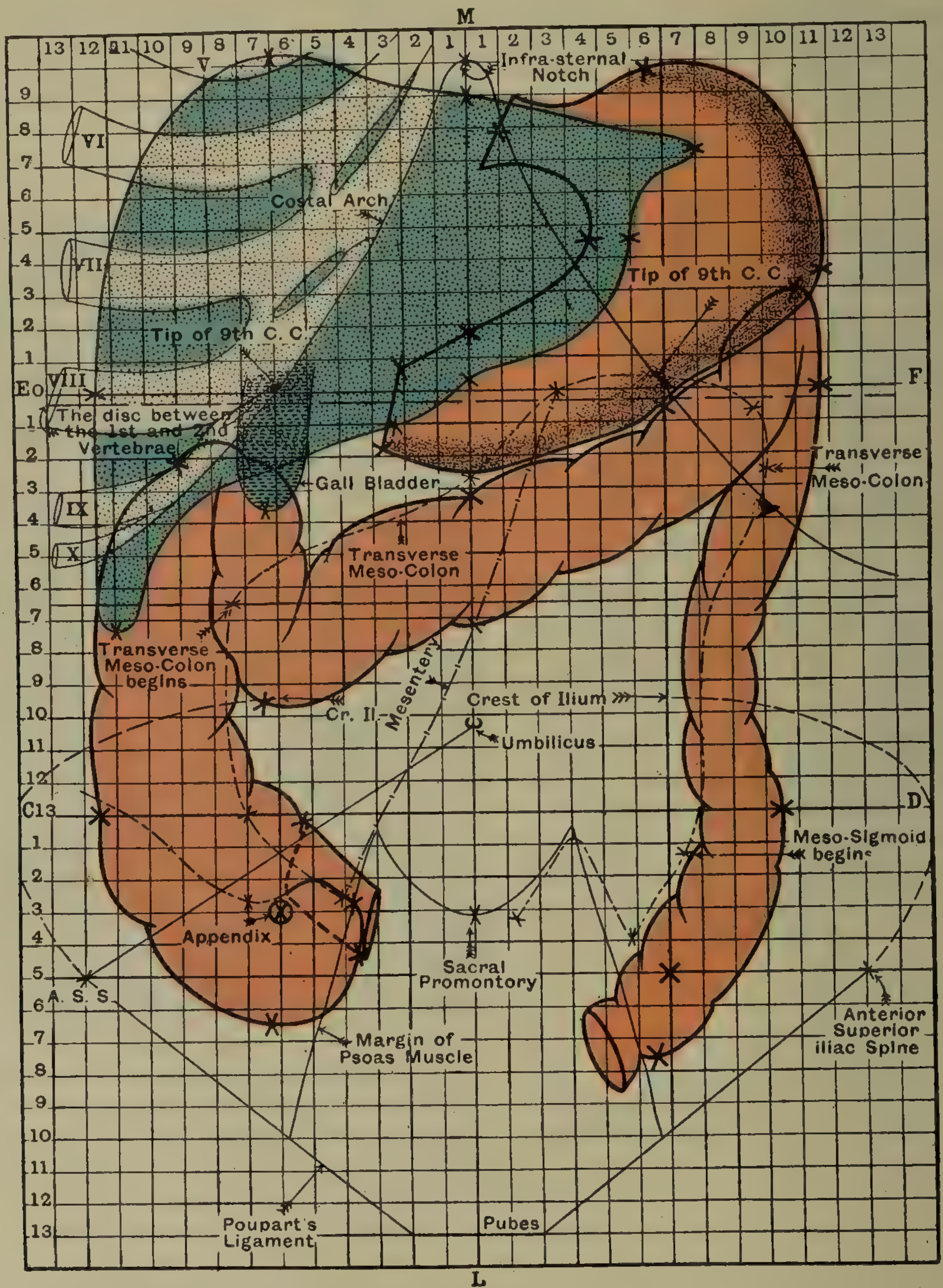


FIG. 1003.—OUTLINE SHOWING THE AVERAGE POSITION OF THE ABDOMINAL VISCERA. (Addison.)

tangular bend (the right colic or hepatic flexure), and then passes transversely across the belly (*transverse colon*) below the stomach. It then reaches the spleen, where it makes a second sharp bend (the left colic or splenic flexure), and, passing vertically downward on the left side (*descending colon*), reaches the left iliac fossa. At this point it forms the loop of the sigmoid colon, and finally passes through the pelvis as the rectum (fig. 983).

Dimensions.—The large intestine is much larger in diameter than the small intestine, and is not so much convoluted. Excepting the dilated portion of the rectum, it is wider at the beginning than at the end. It varies in width at different parts from 3 to 8 cm. The length from the tip of the cecum to the point where the pelvic mesocolon ends is, in the male, about

140 cm., and in the female about 130 cm. The average total length, including the rectum, is about 150 cm. (5 ft.). The extremes found are 100 to 200 cm.

The large intestine, in all parts except the rectum, has a peculiar arrangement of its walls, which makes it in appearance very different from the small intestine. It is *sacculated*, and the sacculations [*haustra*] are produced by the gut having to adapt its length to three shorter muscular bands [*tæniæ coli*] which run the course of the intestine. These bands, which are about 12 mm. wide and 1 mm. thick, are really the longitudinal fibers of the muscular wall, which are chiefly collected along three lines (fig. 1007).

One band [*tænia mesocolica*], corresponding to the attachment of the mesocolon, is posterior on the transverse colon, and posteromedial on the ascending and descending colons. A second band [*tænia omentalis*] is anterosuperior on the transverse colon, elsewhere posterolateral. The third band [*tænia libera*] is free; it is inferior on the transverse colon, anterior elsewhere. All

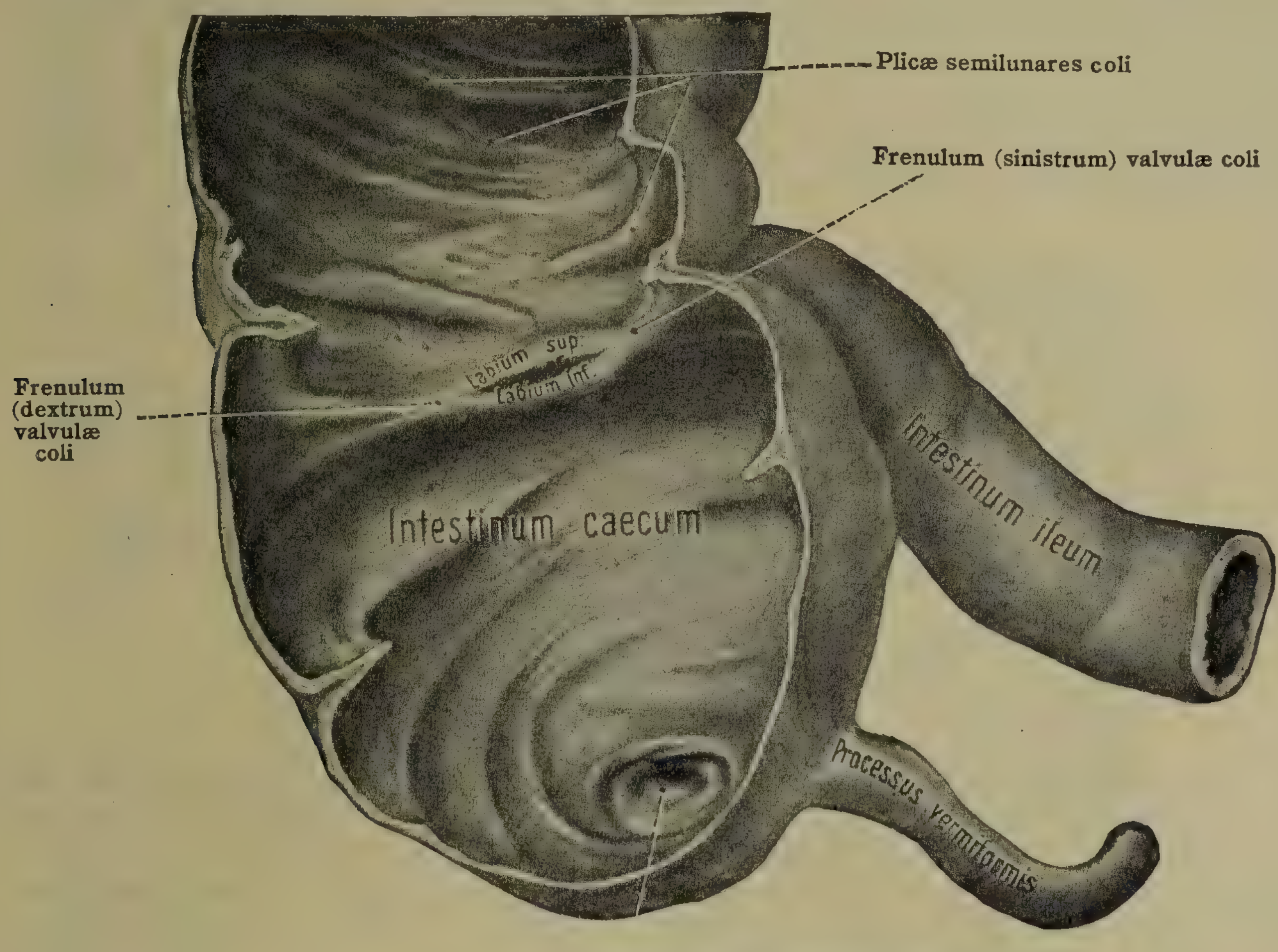


Fig. 1004.—Interior of the Cecum, Anterior View. (Rauber-Kopsch.)

these bands start on the cecum at the vermiform process, and spread out to form a uniform layer on the rectum. Between the sacculations are *semilunar folds* [plicæ semilunares coli], which involve the entire thickness of the intestinal wall, forming crescentic ridges of the mucosa which project into the lumen (figs. 1004, 1007).

Along the free surface of the colon, especially near the teniæ, are numerous small appendages [*appendices epiploicæ*], which are pouches of peritoneum containing fat (figs. 983, 1007).

The cecum.—The cecum [intestinum cæcum] is a *cul-de-sac* forming the first part of the large intestine. It is defined as that part of the tube situated below the entrance of the ileum. Its breadth is about 7.5 cm., and its length about 6 cm. (fig. 1004). There is usually a more or less well marked constriction of the colon opposite the ileocecal orifice marking the boundary between cecum and colon. The cecum itself also sometimes presents a constriction dividing it into two sacculations.

It usually lies in the right iliac fossa, just behind the abdominal wall, upon the iliopsoas muscle, and so placed that its apex or lowest point is just projecting beyond the medial border of that muscle (figs. 975, 983). It is usually entirely enveloped in peritoneum, and projects free in the peritoneal cavity, but is more or less adherent posteriorly in about 10 per cent. of all cases. The apex of the cecum usually corresponds to a point a little to the medial side of the middle of the inguinal ligament (fig. 1003). Less frequently the cecum will be found to be in rela-

tion with the iliacus muscle only; or the bulk of it will lie upon that muscle, while the apex rests upon the psoas. In many cases (especially in the upright posture) the cecum hangs over the pelvic brim, or is lodged entirely within the pelvic cavity. The cecum is also markedly variable in form.

The *variations* in the form of the cecum may be described under four types:

1. The fetal type is conical in shape, the appendix arising from the apex, and forming a continuation of the long axis of the colon. The three muscular bands which meet at the appendix are nearly at equal distances apart (fig. 1005, A). When the cecum is empty and contracted it tends to approach this type.

2. The second form is more quadrilateral in shape than the last; the three bands retain their relative positions; the appendix appears between two bulging sacculi, instead of at the summit of a cone (fig. 1005, B).

3. In the third type, that part of the cecum lying to the right side of the anterior band grows out of proportion to that part to the left of the band. The anterior wall becomes more developed than the posterior, so that the apex is turned so much to the left and posteriorly that it nearly meets the ileocecal junction. A false apex is formed by the highly developed part to the right of the anterior band. This is the usual cecum found (fig. 1005, C).

4. In the fourth type, the development of the part to the right of the anterior band is excessive, while the segment to the left of the band has atrophied. In this form the anterior band runs to the inferior angle of junction of the ileum with the cecum. The root of the appendix is posterior to that angle. There is no trace of the original apex, and the appendix appears to spring almost from the ileocecal junction (fig. 1005, D).

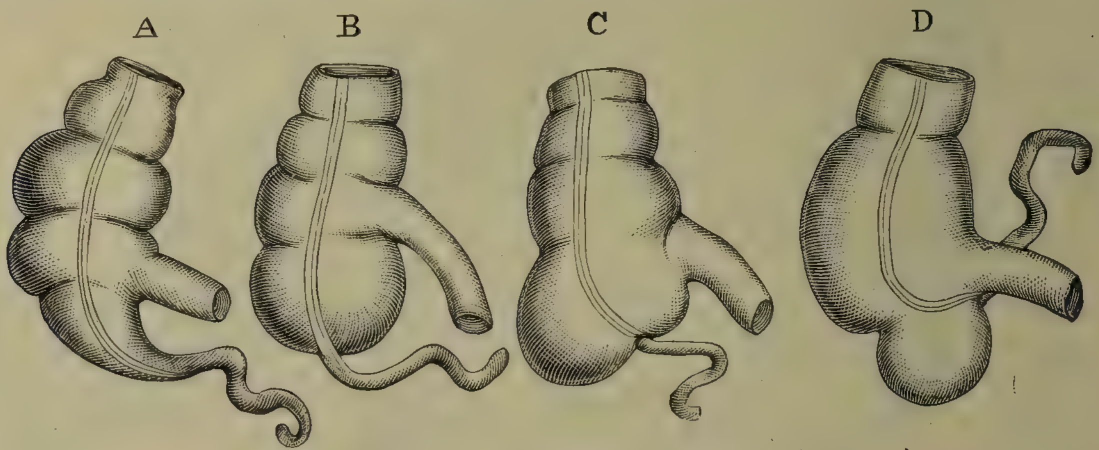


FIG. 1005.—THE FOUR TYPES OF CECUM. (Treves.)

The ileocecal valve.—The ileocecal valve [valvula coli] is situated at the entrance of the ileum into the large intestine at the upper border of the cecum, on the posterior aspect and toward the medial side (fig. 1004). The valve usually lies nearly opposite the middle of a line from the right anterior superior iliac spine to the umbilicus (fig. 1003), but often lower. The ileum passes from below upward and toward the right, and terminates obliquely. The valve is formed by two lip-like folds projecting into the large intestine, the upper [labium superius], and the lower [labium inferius]. They are nearly horizontal in direction (fig. 1004). The opening between them takes the form of a narrow transverse slit about 1.2 cm. in length. At the ends of the slit the valves unite and are prolonged at either end as a ridge [frenulum valvulæ coli] partially surrounding the intestine.

Villi cover that surface of the folds looking toward the ileum; the surface toward the large intestine is free from villi. In the formation of this valve the longitudinal muscular fibers pass across from the ileum to the large intestine without dipping down between the two layers of each fold. The circular muscular fibers, on the other hand, are contained between the mucous and submucous layers which form these folds.

The efficiency of the valve in preventing the return of feces is due largely to its oblique projection into the lumen of the large intestine. (Symington.) In the commonest form of intussusception, the ileocecal valve and lower ileum are prolapsed into the colon and carried down by the force of peristalsis toward the anus. The valve in these cases forms the apex of the intussusceptum, however far it travels.

Ileocecal fossæ.—About the cecum, and especially in the vicinity of the ileocecal junction, are certain fossæ collectively known as the ileocecal fossæ. Two only appear to be fairly constant, although a third is now and then present.

The first, the *superior ileocecal* or *ileocolic fossa,* is formed by the passage across the junction of the cecum and ileum of the anterior cecal artery, a branch of the ileocolic artery, which produces a fold of peritoneum [plica ileocolica] limiting a pouch. It is on the anterior aspect of the ileocolic junction, and the pouch opens downward (fig. 983). It is present in about one-third of all cases.

The second fossa is not quite so simple. If the cecum be turned upward so as to expose its posterior surface as it lies *in situ*, and if the appendix be drawn down so as to put its mesentery on the stretch, a peculiar fold will be found to join that mesentery (shown in fig. 1008). This fold arises from the border of the ileum opposite the insertion of its mesentery. It then passes over the ileocecal junction on its inferior aspect, is adherent to the cecum, and finally joins the surface of the mesentery of the appendix. This fold is peculiar in the absence of any visible vessels, and is often known as the 'bloodless fold of Treves.' Between it and the appendix there is an almost constant fossa, the *inferior ileocecal fossa.* It is usually large, admitting two fingers, and occurs in nearly 85 per cent. of all cases. It is bounded on one side by the small intestine and on the other by the cecum. The appendix is occasionally found in the fossa.

The *subcecal* or *retrocolic* fossa is behind the cecum and is found in about 10 per cent. of all cases. It may extend for some distance behind the ascending colon. The appendix may be lodged in this fossa. *Paracecal* fossæ rarely occur, at the side of the cecum.

Variations.—In addition to variations already mentioned the cecum may vary in its general development. It is sometimes small and insignificant; in other cases it reaches a large size. It may be so rotated that the ileum passes behind the colon and opens on the right side. The posterior part may be much more developed than the anterior, so that the ileum enters from the front, and the appendix comes off from the anterior wall. The cecum may remain undescended, and be found just under the liver or in the vicinity of the umbilicus. In case the rotation of the embryonic intestinal loop fails to occur (or is incomplete) the cecum may remain near the midline, or on the left side. If the normal process of adhesion fails to occur, the cecum and colon, along with the small intestine, may remain suspended from the middorsal line by the primitive *mesenterium commune.* Or any of the intermediate stages of partial adhesion may persist.

FIG. 1006.—RADIOGRAPH SHOWING CECUM AND UNUSUALLY LONG VERMIFORM PROCESS, EXTENDING INTO THE PELVIC CAVITY. (Dr. R. D. Carman, Mayo Clinic.)

The vermiform process (appendix).—Attached to what was originally the apex of the cecum is a narrow, blind tube, the *vermiform process* [processus vermiformis] or *appendix.* It comes off at a variable distance (usually about 2.5 cm.) below the ileocecal valve on the posteromedial aspect of the cecum, though sometimes from the lower end of the cecum, or elsewhere. On the interior, at the point where it joins the cecum (fig. 1004), there is a slight, inconstant valve [valvula processus vermiformis]. The appendix joins the cecum at the point where the three teniæ meet, and the anterior tenia forms the best guide to this point. In the adult, the average length of the appendix is between 8 cm. and 10 cm., the extremes being 2 cm. to 25 cm. It is usually much twisted and coiled upon itself. Its direction is frequently downward toward the pelvic cavity.

In 5000 cases, Wakeley and Gladstone found the appendix postcecal or retrocolic in position in about 64 per cent., pelvic or descending in 32 per cent. More rarely the position was subcecal, preilial, postileal or ectopic. Only the position of the base of the appendix is at all constant. It lies about an inch (2.5 cm.) below McBurney's point, which is midway between the umbilicus and the anterior superior iliac spine. This point is often the seat of greatest tenderness in appendicitis. The course and gravity of abscesses originating in the appendix will depend somewhat upon the position of the inflamed organ at the time of perforation.

The vermiform process does not have a true mesentery, but usually (in about 90 per cent. of cases) is provided with a falciform fold [mesenteriolum] or *mesoappendix* of peritoneum, continuous with the left (lower) layer of the mesentery of the ileum (figs. 983, 1008).

In general outline this mesoappendix is triangular. In the adult it does not extend along the whole length of the tube. It is, in fact, too short for the appendix, and it is this that accounts for the twisted condition of this process. Along the free margin of the fold runs the artery of the appendix, a branch of the ileocolic artery (fig. 1008). Rarely the artery comes from the anterior branch of the ileocolic.

The ascending colon.—The ascending colon [colon ascendens] (figs. 982, 983) extends in the right lumbar (lateral abdominal) region from the cecum to the inferior surface of the liver, lateral to the gall-bladder, forming there the right colic [flexura coli dextra] or hepatic flexure. Its average length is about 20 cm. (or somewhat less when measured *in situ*).

Peritoneal relations.—The ascending colon is covered by peritoneum in front and on the side (fig. 978), but in certain proportion of cases (26 per cent. according to Treves) this part of the large intestine is connected with the posterior wall of the abdomen by a mesocolon (usually very short) and is therefore surrounded by peritoneum. For an explanation of this and other peritoneal variations on a developmental basis, see p. 1240. Connected with the ascending colon is sometimes found a fold of peritoneum, extending from the right side of the gut to the abdominal wall at a little above the level of the highest part of the iliac crest. It forms a shelf upon

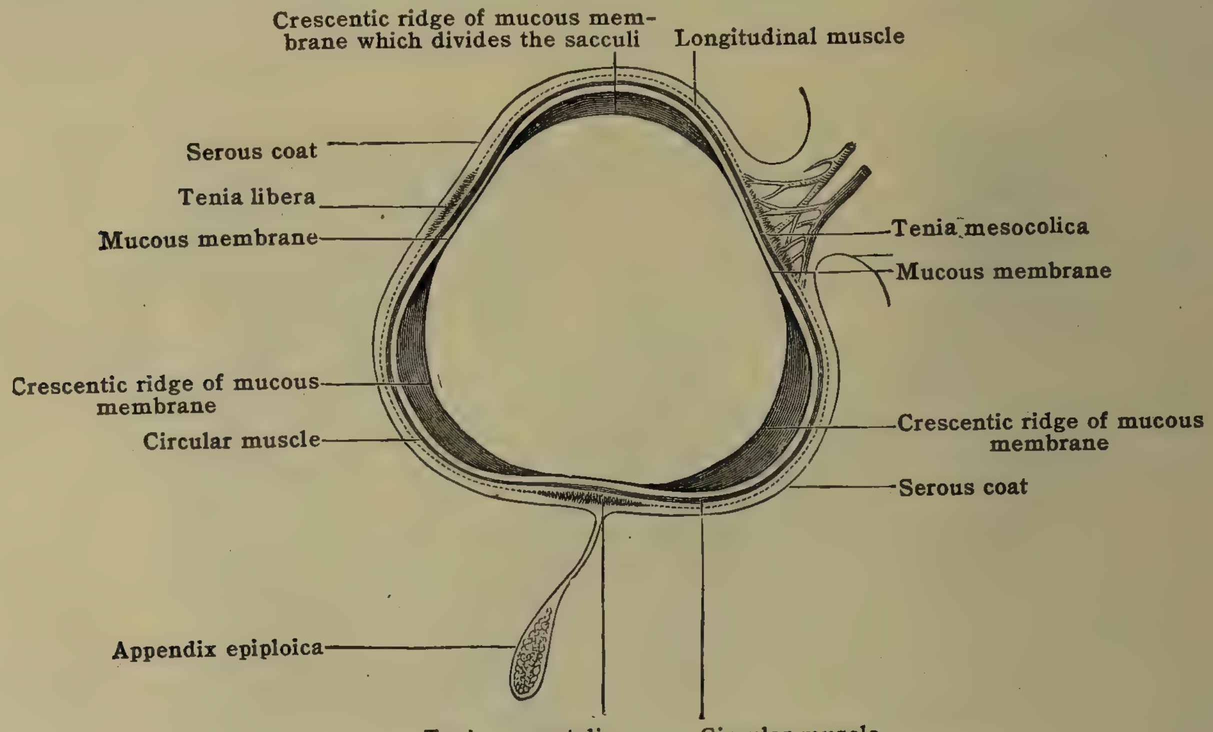


Fig. 1007.—Cross-section of the Ascending Colon. (Allen Thomson.)

which rests the extreme right margin of the liver. It might be called the *sustentaculum hepatis*. In the region of the hepatic flexure are three inconstant peritoneal folds: (1) the *phrenocolic;* (2) the *hepatocolic;* and (3) the *cystocolic* (Testut).

In the common types of incomplete fusion of its peritoneal attachments the colon is inadequately adapted to the upright position and is predisposed to ptosis. A layer of peritoneum sometimes found passing downard and medially from the parietes in the right flank onto the front of the ascending colon, known as Jackson's pericolic membrane, is possibly due to persistence of an early stage in the development of the great omentum, which passes to the right across the ascending colon to join with the parietal peritoneum before the descent of the cæcum is complete, and so is the most primitive agent in fixing the proximal colon back in the right loin. This membrane is usually associated with a congenitally mobile ascending colon (Morley, Lancet, Dec. 1913).

The ascending colon is in relation *behind* with the right kidney, and the iliacus and quadratus lumborum. *In front* are some of the coils of the ileum (fig. 975), separating it from the anterior abdominal wall. The colon ascends in the angle between the quadratus and psoas, also passing slightly backward at an angle with the horizontal. The hepatic flexure lies in the right hypochondriac region, under the 9th costal cartilage, at the level of the 2nd lumbar vertebra when recumbent. It may sink to the infracostal plane (3d lumbar vertebra) or lower in the upright posture. The cecum and ascending colon are usually distended with feces and gas.

The transverse colon.—The transverse colon [colon transversum], smaller in diameter than the ascending, extends from the lower surface of the liver to the spleen. Its average length is from 40 cm. to 50 cm. It describes an arch with its convexity forward and downward. It crosses through the umbilical region from the right hypochondrium to the left hypochondrium (figs. 975, 982, 983).

In the majority of cases the superficial part of the colic arch—as seen in horizontal posture before the viscera are disturbed—is either in whole or in greater part above a straight line drawn

transversely across the body between the highest points of the iliac crest (fig. 1009). In vertical posture, however, as shown by X-ray observations, the transverse colon sags markedly downward. It may lie anywhere between the infracostal plane and the pubes.

Certain remarkable bends are sometimes formed by the transverse colon. The bending is always in the same direction, namely, downward, and is usually abrupt and angular. The apex of the **V** or **U**-shaped bend thus formed may reach the pubes. This bend appears to be due to various causes, including long-continued distention, congenital malformation, and movements of the stomach (to which it is attached by the gastrocolic ligament).

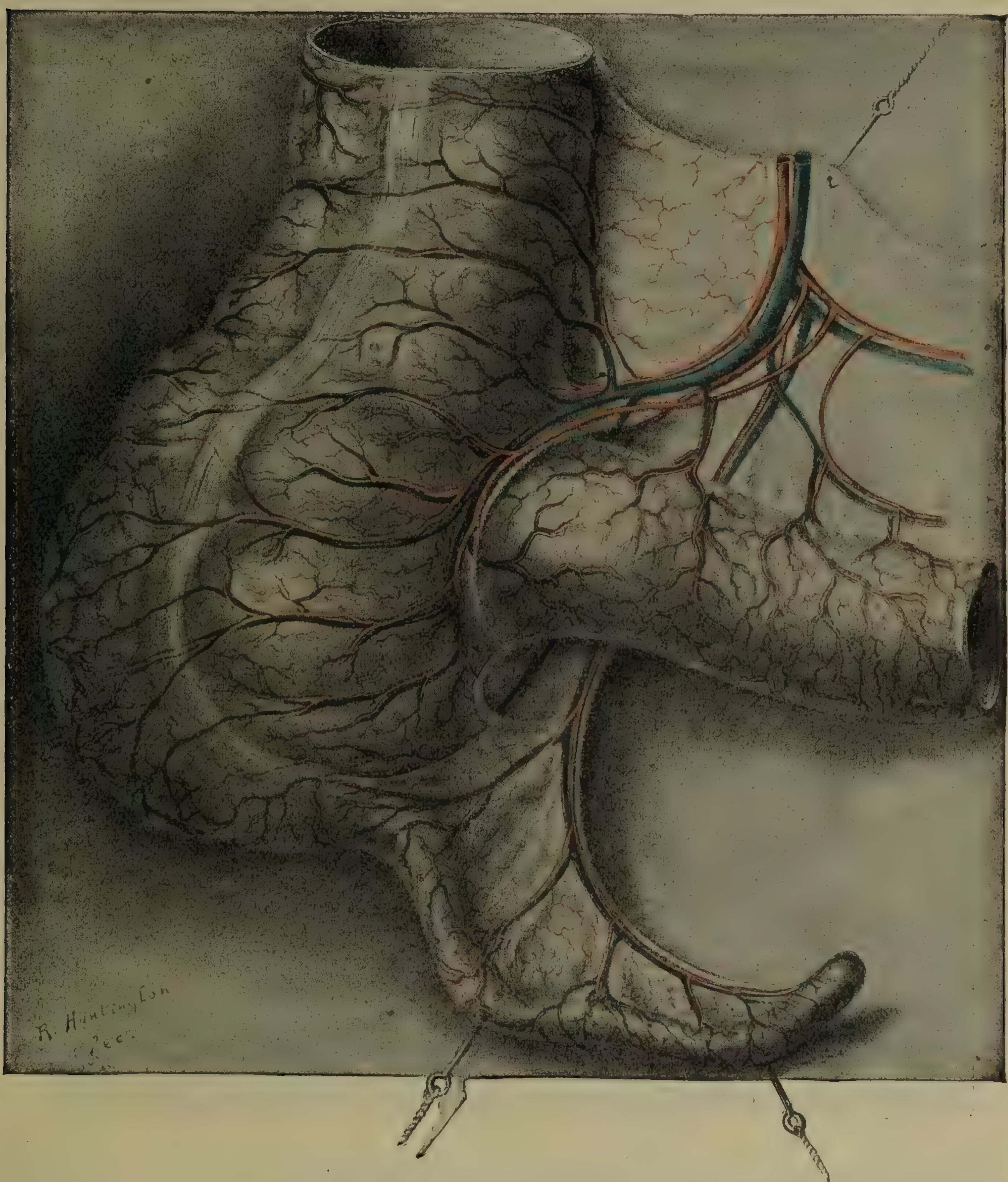


FIG. 1008.—BLOOD-VESSELS OF THE ILEOCECAL REGION AND APPENDIX. (Kelly). (See explanation of fig. 560.)

The transverse colon is in relation *above* with the liver and gall-bladder, the stomach, and at its left extremity with the spleen. The second portion of the duodenum passes *behind* it. *Below* are the coils of the small intestine. It is almost completely surrounded by peritoneum, being connected with the posterior abdominal wall (chiefly the anterior border of the pancreas) by the transverse mesocolon. This is usually lacking on the right of the midline, however, where the colon crosses the descending duodenum and the head of the pancreas (fig. 981).

The main artery to the colon, the middle colic branch of the superior mesenteric, must be carefully avoided in the operations of gastroenterostomy and gastrectomy, since the ligature of this vessel may cause gangrene of the transverse colon.

The **descending colon** [colon descendens] is 25 cm. to 30 cm. in length (less when *in situ*) and extends from the spleen nearly to the pelvic brim (figs. 983,

1009). It is more movable than the ascending colon and is also narrower. At its beginning it is usually connected with the diaphragm, on a level with the tenth and eleventh ribs, by a fold of peritoneum, the *phrenocolic ligament* [lig. phrenicocolicum] (or *sustentaculum lienis*, from the fact that it supports the spleen). The bend between the transverse colon and descending colon is called the left colic or splenic flexure [flexura coli sinistra].

Fig. 1009.—Radiograph of the Large Intestine. Sthenic habitus; recumbent posture. Vermiform process faintly visible. (Dr. R. W. Mills, Washington University Medical School.)

The descending colon is situated in the left hypochondriac, lumbar and iliac regions (fig. 983). Its relations to the peritoneum are the same as obtain with the ascending colon, that is, it is covered in front and on the sides. A mesocolon is met with oftener on this side than on the right, occurring in 36 per cent. of all cases (Treves) (see figs. 978, 981). It is found especially in the lower part of the descending colon, in the iliac fossa. This portion, extending from the iliac crest to the brim (superior aperture) of the pelvis, is sometimes described as a separate segment, the **iliac colon** (Jonnesco).

The descending colon is covered *anteriorly* by coils of small intestine; *posteriorly* it is in contact with the lower part of the left kidney, the quadratus lumborum, iliacus and psoas muscles. It terminates by crossing medialward over the psoas muscle and the external iliac vessels to join the sigmoid colon.

The **sigmoid colon** [colon sigmoideum] or pelvic colon, extends from the descending colon to the rectum (figs. 983, 1009). It includes the parts formerly

described as the 'sigmoid flexure' and the 'first portion' of the rectum. These together form a single loop which cannot conveniently be divided into parts.

The average length of this sigmoid colon is about 40 cm. It usually begins on the psoas muscle about midway between the lumbosacral promontory and the inguinal (Poupart's) ligament. It descends at first along the left pelvic wall, and may at once reach the pelvic floor. It then passes more or less horizontally and transversely across the pelvis from left to right, and commonly comes into contact with the right pelvic wall. At this point it is bent upon itself, and, passing once more toward the left, reaches the midline and joins the rectum opposite the second or third sacral vertebra (fig. 1011).

The sigmoid colon is in more or less direct contact with the bladder (and uterus in the female), and may touch the cecum. It is very closely related with the coils of small intestine that occupy the pelvis, and by these coils the loop is usually hidden. In about 90 per cent. of cases, the sigmoid colon lies almost entirely within the minor pelvic cavity. In the remainder, it loops upward for a variable distance toward the umbilicus, a position normally found in infancy.

The sigmoid colon is attached to the abdominal and pelvic wall by the sigmoid mesocolon, so that it is quite surrounded by peritoneum. The line of attachment of this mesocolon is as follows: It usually crosses the psoas in a slight curve upward so as to pass over the left common iliac vessels at or about their bifurcation. The curve ends at the medial side of the psoas muscle, most frequently just over the bifurcation of the left iliac vessels. From this point the line of attachment proceeds vertically down, taking at first a slight curve to the right. Its course is to the left of the midline, ending in the midline about the second or third sacral vertebra. The sigmoid mesocolon measures from 3 to 8.7 cm. in width—i. e., from the parietes to the bowel—at the widest point. Since the two ends of the sigmoid colon are somewhat close together, the loop is anatomically predisposed to axial rotation, and volvulus is frequent at this region.

When a descending mesocolon exists, it joins that of the sigmoid colon. There is often no mesocolon over the psoas, the gut being adherent to that muscle. In connection with the sigmoid mesocolon is often found a fossa or pouch of peritoneum, known as the *intersigmoid fossa* [recessus intersigmoideus]. This pouch is formed by the incomplete adhesion of the primitive mesocolon to the posterior abdominal wall. It is generally found over the bifurcation of the left iliac vessels. The pouch is funnel-shaped, and the opening looks downward and to the left. It varies in depth from 2.5 to 3.7 cm., and is rarely the seat of the sigmoid hernia, which may become strangulated.

The upper part of the pelvic colon is frequently brought out and opened through an incision in the left iliac region to form an artificial anus in cases of inoperable growth of the rectum.

In advanced life, and in the chronically constipated, certain diverticula of mucous membrane are occasionally met with which project through the vascular gasps of the muscular coat into the bases of the appendices epiploicæ in this region, and also between the layers of the pelvic mesocolon (usually at the points where the vessels enter). They often contain fecal concretions and may become inflamed or even perforate, forming an abscess in the left iliac fossa. (McGrath: Surg., Gyn. and Obst., 1912, 15: 429.)

The junction of pelvic colon and rectum opposite the second (or third) sacral vertebra forms a more or less acute angle and constitutes the narrowest part of the colon. It is a frequent site of stricture.

The rectum.—The rectum, according to the BNA nomenclature, is recognized as a division separate from the large intestine. The term rectum is now limited to that portion of the bowel below the midsacral region, where the mesocolon ceases. It is divided into two portions: the first extends downward and forward, in front of sacrum and coccyx, to the level of the pelvic floor; the second portion (the anal canal) extends from this point downward and backward to the anus (figs. 1011, 1012).

The *upper* or *first portion* of the rectum is 10 cm. to 12 cm.long, and is concave forward [flexura sacralis] except at the lower end where it curves backward and downward [flexura perinealis] to join the second portion. Internally the mucosa presents three shelf-like folds [plicæ transversæ rectales], the so-called valves of Houston, which are described later. The lower part of the first portion often presents a dilation, [ampulla recti] (pars ampullaris NK), due to accumulation of feces. This part is sometimes described as the *infraperitoneal portion* of the rectum proper.

Usually, however, the rectum does not form a fecal reservoir. The feces are normally retained in the lower part of the pelvic colon, above the upper transverse fold, leaving the rectum empty except in defecation.

Relations.—*Anteriorly*, the rectum is in contact with coils of ileum and, in the male, with the trigone of the bladder, the vesiculæ seminales, ductus deferentes, and posterior aspect of the prostate (fig. 1011). In the female, it is in contact anteriorly with the vagina and the cervix uteri (fig. 1012). *Posteriorly*, it is in contact with the sacrum, coccyx and anococcygeal body.

In the male, a small band of muscle fibers, the *rectourethral* muscle, extends from the perineal flexure of the rectum to the membranous urethra.

The *peritoneum* is reflected anteriorly from the rectum to the bladder in the male (rectovesical pouch) and to the fornix of the vagina in the female (rectouterine pouch). In the newborn, the peritoneum reaches to the base of the prostate (Symington). On the posterior surface of the gut, there is no peritoneum below a point about 12.5 cm. from the anus. Thus the peri-

FIG. 1010.—INTERIOR OF THE RECTUM. (×3/5). (From Toldt's Atlas.)

toneum at the upper end of the rectum entirely surrounds the gut. Lower down it covers only the sides and anterior wall, and lower still the anterior wall only, where it is reflected upon the bladder or vagina.

The *second portion* of the rectum, or **anal canal** [pars analis recti], is from 2.5 cm. to 3.5 cm. in length. From the lower end of the first portion, it turns at right

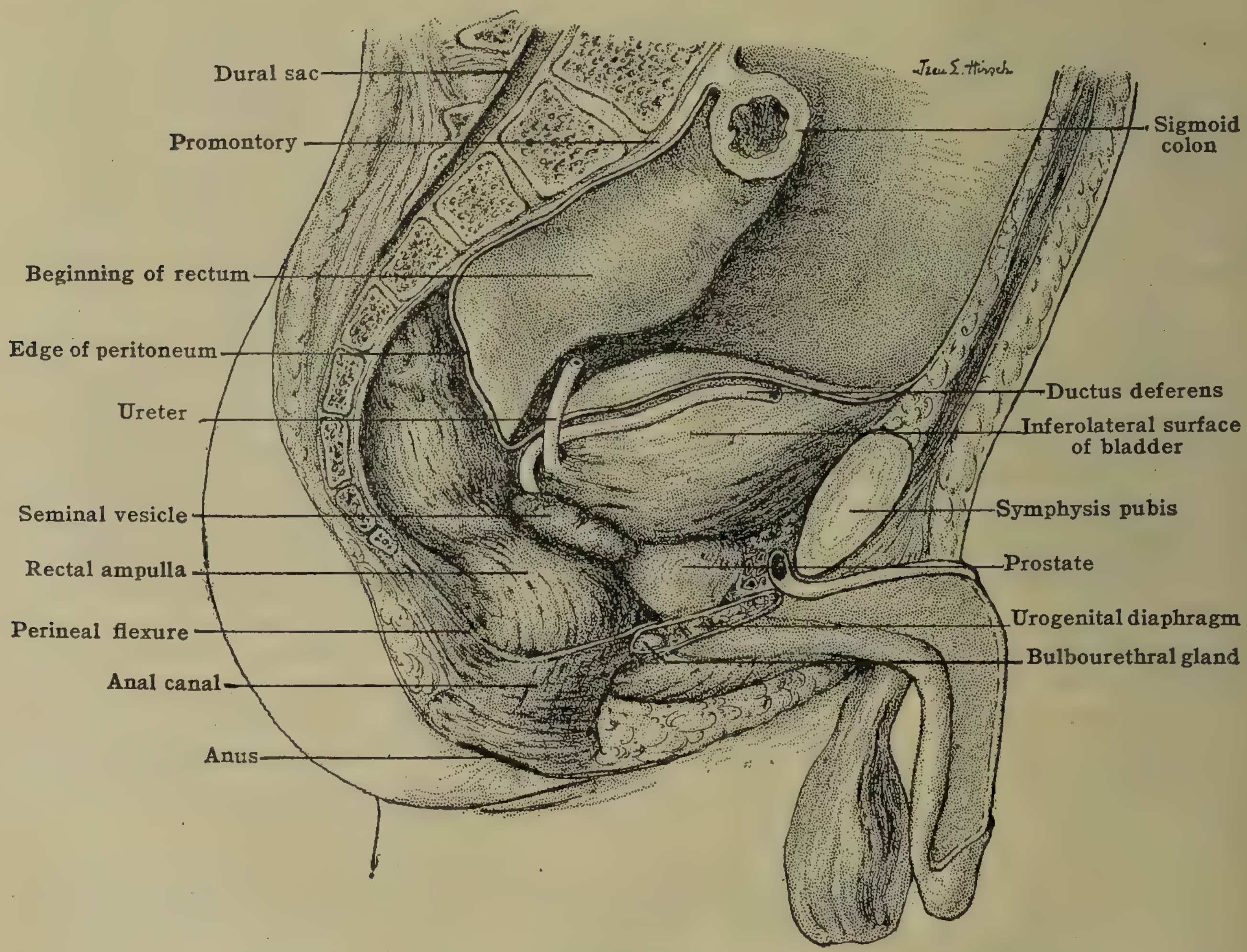


FIG. 1011.—LATERAL VIEW OF THE MALE PELVIC VISCERA. (After His models.)

angles downward and backward, passing through the pelvic floor, and ending at the anus. It is entirely below the peritoneum, and is surrounded by the two sphincter muscles (figs. 1010, 1011).

Anteriorly is the bulb of the urethra and the posterior margin of the urogenital trigone in the male (fig. 1011), while in the female it is separated from the vestibule and the lower part of the vagina by the 'perineal body' (fig. 1012). *Posteriorly* it is connected with the tip of the coccyx by the anococcygeal body. *Laterally* it is in contact with the margins of the levatores ani, which act as an accessory sphincter, and help to support the ampulla recti.

The anus.—The anus is the aperture by which the intestine opens externally. During life it is contracted by the sphincters, so as to give the surrounding skin a wrinkled appearance. Around the lower part of the rectum and anus certain muscles that are connected with its proper function are situated. They are the internal sphincter, the levator ani, and the external sphincter. The levator ani and external sphincter will be found described in the section on MUSCULATURE. The *internal sphincter* is a thickening of the circular fibers of the rectum, situated around the second portion or anal canal. It forms a complete muscular ring, 2 mm. to 3 mm. thick, and is composed of smooth muscle.

Structure.—The rectum differs from the colon in having smoother walls and no appendices epiploicæ. At the upper end of the rectum, the tenia libera and tenia omentalis join to form a broad band which spreads out, covering the entire anterior aspect of the rectum. Similarly the tenia mesocolica spreads out upon the posterior aspect. Thus the rectum has a complete longitudinal muscle-layer, which, however, is thicker anteriorly and posteriorly than laterally. It sends a bundle of fibers to the coccyx [m. rectococcygeus]. Below, the longitudinal layer passes between the two sphincters and breaks up into numerous bundles which are interwoven with the external sphincter and levator ani, some of them terminating in the circumanal skin.

The rectal mucous membrane is thicker than that of the rest of the large intestine. As seen by the sigmoidoscope during life, it is of a bright pink color. Certain folds, chiefly longitudinal in direction, are seen in the lax state of the tube, which disappear when distended. Houston described three permanent oblique **transverse folds** [plicæ transversales recti] (fig. 1010), containing smooth muscle, which project into the lumen of the tube: one is on the right at the level of the reflection of the peritoneum from the rectum; and two are on the left, one above and one below the right fold. The upper fold is near the junction of the rectum with the pelvic colon, where the gut is often constricted. That upon the right side is the largest and most constant, and its muscular bundle is sometimes called the *sphincter tertius*. It is located about 7.5 cm. above the anus. These folds, like the corresponding semilunar folds of the colon, when well marked may involve the entire wall. These folds may obstruct the introduction of rectal tubes or instruments (sigmoidoscope).

The mucous membrane of the upper portion of the anal canal presents a series of vertical folds known as **rectal columns** [columnæ rectales] (columns of Morgagni), containing bundles of smooth muscle longitudinally arranged. These columns become more prominent as they extend downward. Just above the anus each two adjacent columns are united by an arch-like fold of mucous membrane, these folds forming what are known as the **anal valves**, while the small fossæ formed by them are known as the **rectal sinuses**. The anal valves probably represent the original cloacal membrane, dividing the proctodeum (formed from the ectoderm) from the entodermal hindgut, and persistence of this membrane gives one form of imperforate anus. (Wood Jones, Brit. Med. J., Dec. 14, 1904.) The tearing down of a valve by hard feces may be a cause of anal fissure, etc. (Ball). The mucous membrane of the anal canal is more firmly adherent to the underlying muscular coat than that of the rectum, hence in prolapse the mucosa of the rectal ampulla is the first to be extruded. The area below the valves and extending to the anus is termed the *annulus hemorrhoidalis* (fig. 1010). This is lined by a modified skin, while the area above the valves forms a transition to the typical mucosa of the rectum.

Supports of the rectum.—The anal canal is fixed by its attachment to the levator ani and perineal body. After division of the perineal body and rectourethral muscle in front, the rectum is readily separable from the back of the prostate and rectovesical septum. When the levator ani has been divided on each side and the peritoneum opened, as in the perineal operation for excision of the rectum, the gut cannot be pulled down freely. The hand passed up behind it in the hollow of the sacrum meets on each side with a dense fibrous layer running from the sacrum opposite the third foramen onto the side of the rectum. This is the *rectal stalk* (Elliot Smith) and consists of dense fibrous tissue round the nervi erigentes from second, third and fourth sacral foramina and the middle hemorrhoidal vessels. It lies about 2.5 cm. above the levator ani, and after division of it the bowel is easily freed, so that the whole of the rectum and part of the pelvic colon may be drawn out at the perineum without tension.

Rectal examination.—The following points can be made out by the finger introduced into the male rectum (cf. fig. 1103):—(1) The thickened, roll-like feel of a contracted external sphincter; (2) the thinner, more expanded, internal sphincter extending upward for 2.5 cm. (1 in.) from this; (3) the rectal insertion of the levatores ani, which here narrows somewhat the lumen of the gut; (4) above the anal canal is the more or less dilated ampulla of the rectum proper; (5) the condition of the ischiorectal fossæ on either side; (6) the membranous urethra in front, especially if a staff has been introduced; the instrument now occupies the middle line, and has the normal amount of tissue between it and the finger, thus differing from one in a false passage (in a child an instrument is especially distinct); (7) just beyond the sphincters anteriorly, or 3.7 cm. (1½ in.) from the anus, lies the prostate; (8) converging above the base of the prostate, and forming the sides of the triangular space, are the vesiculæ seminales and ejaculatory ducts. These can rarely be felt unless diseased and enlarged; any enlargement of the sacculated ends of the deferential ducts is much more perceptible; (9) it is within this triangular space that the elasticity of a distended bladder can be felt. (10) Usually the lowest of the transverse folds (valves of Houston), semilunar in form and about 1.2 cm. (½ in.) in width, can be made

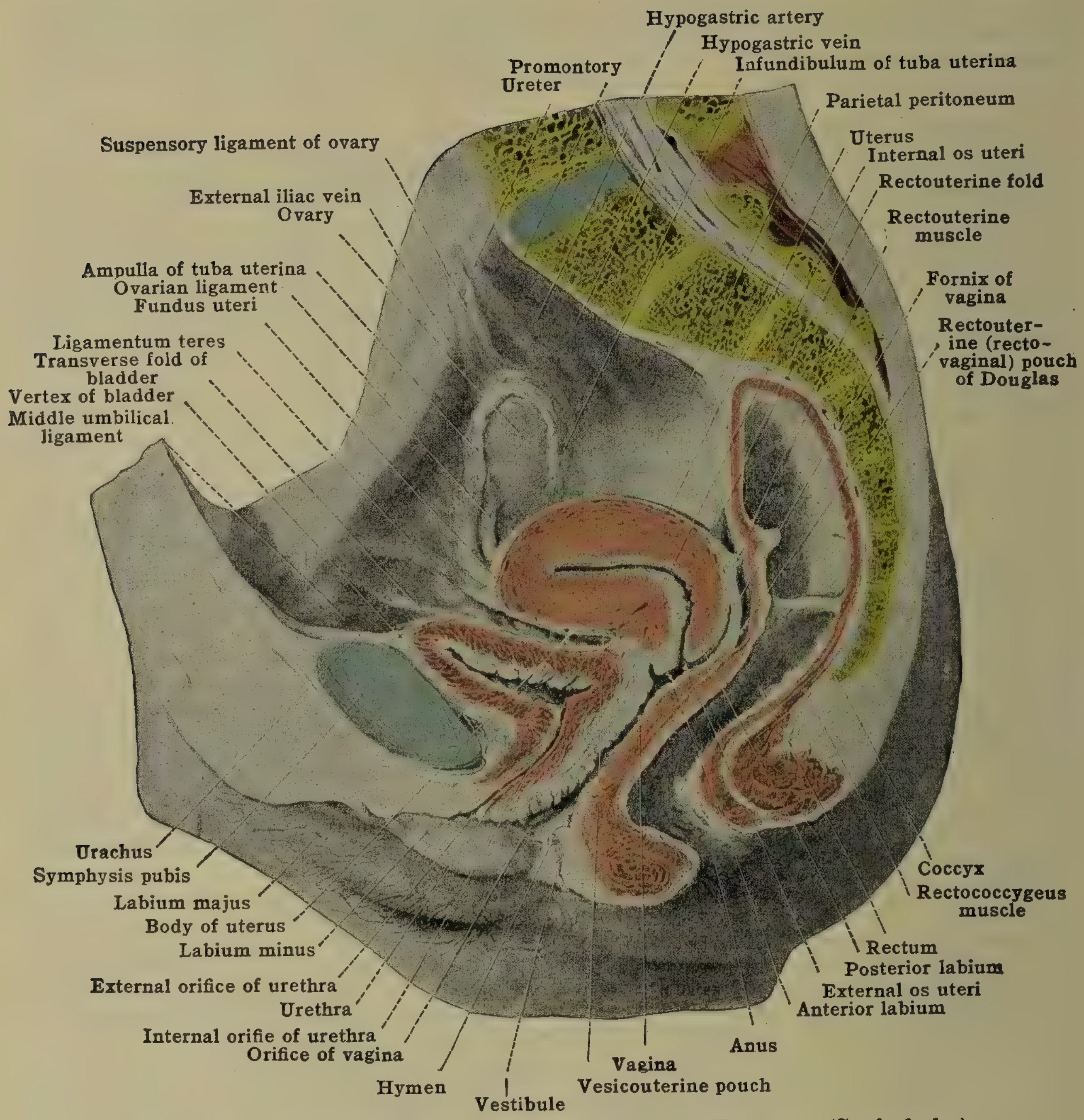


FIG. 1012.—MIDSAGITTAL SECTION OF THE FEMALE PELVIS. (Spalteholz.)

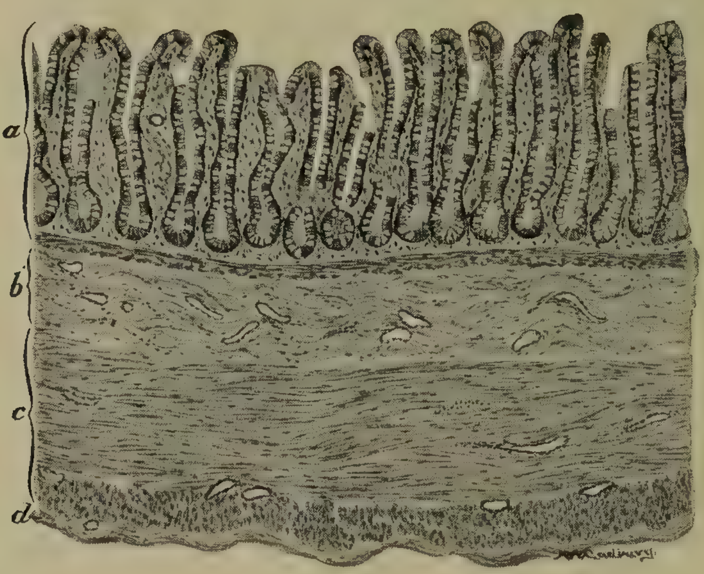


FIG 1013.—CROSS-SECTION OF THE LARGE INTESTINE. *a*, mucosa. *b*, submucosa. *c*, muscularis. *d*, serosa. (Radasch.)

out (fig. 1012). (11) Behind, the coccyx and its degree of pliability and the lower part of the sacrum. It may also be possible to feel enlarged sacral nodes or a growth from the other pelvic bones.

The following relations are found by **rectal examination in the female** (cf. figs. 1012, 1132): Anteriorly, the soft perineal body and rectovaginal septum will be met with, and, through the latter, the cervix and external orifice (os uteri), and, higher up, the lower part of the cervix uteri. More laterally the ovaries may be felt, but the uterine or Fallopian tubes, unless enlarged and thickened, are not to be made out. The student should be familiar with the feel of a healthy rectouterine or rectovesical pouch, according to the sex, and the coils of intestine which it may contain, so as to be able to contrast this with any collection of inflammatory or other fluid or mischief descending from the upper pelvis, e. g., from the vermiform appendix. Posteriorly, certain structures are met with in either sex. After a very short interval (sphincter and anococcygeal body) the finger reaches the tip of the coccyx and explores the hollow of the sacrum. On each side are the ischial tuberosity and wall of the true pelvis. The finger hooked lateralward and upward, comes on the border of the falciform process of the sacrotuberous (great sacrosciatic) ligament, passing between the above-mentioned bones.

FIG. 1014.—TRANSVERSE SECTION OF THE HUMAN VERMIFORM PROCESS. (× 20.) (Stöhr and Lewis, from Sobotta.) Note absence of villi and abundance of lymph-nodules. *F*, Clusters of fat cells in submucosa. Only the inner part of the circular muscle is shown.

Minute structure of the large intestine.—In general, the large intestine has the four coats (fig. 1013)—mucosa, submucosa, muscularis, and serosa—characteristic of the alimentary canal. The *mucosa* lacks the villi and plicæ circulares characteristic of the small intestine. It contains many solitary lymphatic nodules, but no Peyer's patches. It differs from the stomach in the absence of foveolæ, and in the presence of large numbers of mucous 'goblet cells' found both on the surface and along the numerous crypts of Lieberkuehn. The surface is dotted over by numerous *rectal pits*, visible to the naked eye. The *submucosa* is much as in the small intestine. The *muscularis* has a continuous inner circular layer, the outer longitudinal fibers being chiefly gathered into the three bands, the teniæ coli, as above mentioned. The serosa is typical, excepting extraperitoneal areas where the epithelium is lacking. The appendices epiploicæ were also mentioned above. The cecum and colon present no special features worthy of mention, beyond the typical structure above outlined.

The *vermiform process* (appendix), however, differs in several important respects (fig. 1014). The walls are relatively thick and the lumen small. The solitary lymph-nodules are closely packed or confluent (especially in young people). They occupy the greater part of the submucosa, and somewhat resemble the Peyer's patches of the ileum. They have even been compared to an 'abdominal tonsil.' They, like all the lymphoid structures in general, tend to become atrophied in old age. Fat cells are usually abundant in the submucosa. The *muscularis* presents an inner circular layer and also a thin but complete outer longitudinal layer. The serosa is typical. The lumen shows a progressive tendency to obliteration as age advances (Ribbert). This condition is never found in infancy but occurs usually (only partial) in over 25 per cent. of adults and in 50 per cent. of all cases over 50 years of age. It is, however,

somewhat uncertain whether this represents a normal process. In obliteration, the glands and lymphoid nodules disappear, and the entire mucosa is transformed into an axial mass of fibrous connective tissue.

The *rectum* also presents several peculiarities of structure. Attention has already been called to the transverse folds (of Houston) and the rectal columns, sinuses and valves. Just above the valves, the mucosa is transitional, the epithelium being partly stratified, and the crypts of Lieberkuehn few and scattering. Below the valves, the annulus hemorrhoidalis is lined by a modified skin. Hairs and sebaceous and sweat-glands do not appear until just outside the anal orifice. The thickening of the circular muscle to form the internal sphincter, and the somewhat uniform disposition of the longitudinal muscle have already been mentioned, as well as the absence of a serous coat in the lower portions.

Blood-vessels.—The *large intestine* is supplied with blood by the branches of the superior mesenteric and inferior mesenteric arteries, while it also receives a blood-supply from the internal iliac hypogastric at the rectum. The vessels form a continuous series of arches from the cecum, where the vasa intestini tenuis anastomose with the ileocolic, the first branch of the superior mesenteric given to the large intestine. The vermiform process (appendix) is supplied by a special branch of the ileocolic artery (figs. 560,. 1008). This branch, the appendicular artery, crosses behind the terminal portion of the ileum (where pressure may obstruct the circulation) to enter the mesenteriolum. An accessory artery of small size also may descend along the medial margin of the colon and cecum, entering the base of the appendix.

The blood-supply of the *rectum* is from three arteries. (1) The *superior hemorrhoidal artery*, a continuation of the inferior mesenteric, reaches the rectum behind, via the pelvic mesocolon and bifurcates at once. The two branches run around on either side below the peritoneal reflection; giving off secondary branches that pierce the muscular coat about the level of the inferior transverse fold, or anterior peritoneal reflection. Joining the submucous layer, these arteries run down in the rectal columns to the anal canal, where they anastomose with (2) the *middle hemorrhoidal arteries*, branches of the hypogastric (internal iliac) and (3) the *inferior hemorrhoidal* branches of the internal pudendal. The veins correspond. Their free anastomosis in the *hemorrhoidal plexus* under the rectal columns, the union afforded here between the portal and systemic veins, the absence of valves in the superior hemorrhoidal veins, and the constriction they are subject to in passing through the muscular coat, are some of the anatomical causes of the frequency of hemorrhoids.

The branches of the superior hemorrhoidal artery to the rectum anastomose but little with one another, as compared with the sigmoid arteries to the pelvic colon. The main trunk of the superior hemorrhoidal usually receives a large anastomotic branch from the lowest sigmoid artery 1–2 cm. below the sacral promontory, upon which the upper part of the rectum is dependent for its blood-supply after ligature of the superior hemorrhoidal. Hence in high excision of the rectum it is important to place the ligature on the superior hemorrhoidal above the sacral promontory if sloughing of the gut is to be avoided. (Hartmann, Ann. Surg., Dec., 1909.)

The **nerves** and **lymphatics** of the large intestine differ in no important particular from those of the small intestine, so far as their relations within the intestinal wall are concerned.

The efferent lymphatic vessels in general follow the blood-vessels and pass through corresponding lymph nodes in the various regions (see p. 806). Those of the cecum and vermiform process pass through the appendicular and ileocecal nodes; those of the colon through mesocolic and mesenteric nodes. Those of the descending and sigmoid colons connect with the inferior mesenteric and lumbar nodes. The superior zone of the rectum is drained by lymphatics passing to the anorectal and inferior mesenteric nodes; the middle zone (region of rectal columns) to nodes along the three hemorrhoidal arteries; the inferior zone (anal integument) chiefly to the superficial inguinal nodes.

Development of the large intestine.—For the earlier stages, see Section I, p. 48, also *general morphogenesis*, p. 1232. The ascending and descending colons, the sigmoid mesocolon (in part), and the rectum with corresponding portions of the mesorectum, become adherent to the posterior body wall during the fourth and fifth fetal months. At the same time, the posterior layer of the great omentum becomes fused with the upper (anterior) surface of the transverse mesocolon. The layer of retroperitoneal fascia corresponding to the obliterated mesocolon is shown in figs. 977, 978, 980. Variations in the process of fusion give rise to numerous peritoneal variations in the adult.

In fetuses of four to six months (length 100 mm. to 240 mm.) transitory villi appear in the mucosa throughout the large intestine, including the vermiform process. Their early obliteration is possibly due to distention of the gut by the meconium. The glands bud off like those of the small intestine. Lymphoid nodules are present abundantly in the vermiform process at birth (Johnson). The circular muscular-layer begins to appear in the lower part of the large intestine in embryos at 23 mm.; the teniæ at 75 to 99 mm. (F. T. Lewis.)

Development of the rectum and anus.—Earlier stages are described in Section I, p. 49. Folds of the mucosa representing the rectal columns, valves and sinuses appear in embryos during the third month, and are well developed during the latter half of the fetal period (Johnson).

Variations.—The large intestine is exceedingly variable in its structure and relations, especially with reference to the peritoneum—so much so that it has been found more convenient to include a consideration of the variations along with the preceding description of the individual parts. The contents of feces (and gas) is as a rule relatively greatest in the cecum, decreasing in ascending and transverse colons. The descending colon is usually empty, or nearly so, the sigmoid colon and rectum somewhat variable. The rectal ampulla is usually more dilated in women.

Comparative.—The morphology of both small and large intestines will be briefly considered here. As previously mentioned, the primitive form of intestine is a comparatively straight tube extending from stomach to anus, and connected by a primitive mesentery to the mid-dorsal line of the body cavity. There is in many of the lower forms no clear division into small

and large intestine, though the rectal region is usually more dilated, and opens into a cloaca. *Diverticula* often occur in the region between large and small intestine. In many fishes, numerous 'cæca' occur just below the pylorus, and in others an extensive *spiral valve* projects into the lumen of the intestine. The absorptive and digestive surface of the mucosa is further increased by the formation of various kinds of *folds*, and (beginning in amphibia) of *villi*. *Lymphoid tissue* is typically present in the mucosa, often localized in definite masses. Solitary nodules appear in amphibia, and Peyer's patches in birds. Tubular mucous glands occur in the lower forms, but Brunner's glands and crypts of Lieberkuehn apparently only in mammals. A *cecum* is usually present from the reptiles upward (double in birds), and often forms an important organ of digestion. The bile and pancreatic ducts open constantly a short distance below the pylorus. The small intestine is always longer than the large, but there is extreme variation in length among the various species. The four tunics—mucosa, submucosa, muscularis and serosa—are typical for vertebrates, the muscularis consisting of inner circular and outer longitudinal smooth muscle-fibers.

Among *mammals*, the divisions of the intestine correspond in general to those found in the human species, but there is exceedingly great variation in the relative development of the various parts. In general, the length, size and complexity of structure is relatively greatest in the *herbivora* (whose food is more difficult of digestion), least in the *carnivora*, and intermediate in the *omnivora*. Even in the same species, the structure of the intestine may be appreciably modified according to habitual diet. The large intestine varies, but is always shorter and wider than the small intestine. In mammals the rectum only is said to be homologous with the large intestine of lower vertebrates. The *cecum* is rarely absent and is enormously developed in herbivora. It often contains large amounts of lymphoid tissue, which, in pig and ox, forms a so-called 'intestinal tonsil.' The *vermiform process* (found typically developed in man and higher anthropoids) apparently represents a retrogressive evolutionary change in the cecal apex, although this interpretation is denied by some (Berry), who interpret the appendix as a progressive, functional lymphoid organ.

HERNIA

Hernia (or 'rupture') denotes the protrusion of any viscus from its normal enclosure. Thus cerebral, cardiac or pulmonary hernias may occur, but abdominal hernias are much more frequent. They may involve any of the abdominal viscera, and especially the jejunum, ileum and great omentum. The causes of hernia include the factors of increased pressure on the one hand, and of decreased resistance by the abdominal wall on the other.

Causes of hernia.—Increased intra-abdominal pressure may result from strenuous exercise, lifting heavy weights, tenesmus, or increased expiratory efforts (coughing, etc.). The abdominal walls may be weakened by debilitating illness or old age, prolonged distention (ascites, tumors, pregnancies), corpulence, emaciation or injuries (including postoperative hernias). There are also differences according to age and sex, as will appear later.

Sites of hernia.—Hernias are likely to occur in regions where the abdominal walls are structurally weakened by the passage of large vessels, nerves, and the like; and especially by certain developmental peculiarities. The assumption of the upright posture probably contributes to the greater frequency of human hernias in the pelvic region, while the quadrupeds are predisposed to umbilical hernia.

Classification.—Hernias are classified in various ways according to their location and character. The abdominal hernias are internal or external. The **internal** are formed by protrusion (chiefly of the gut) into certain preformed peritoneal fossæ, within the abdominal wall. Thus there may be a *bursal* hernia through the epiploic foramen into the omental bursa; a *retroperitoneal* hernia, through the inferior duodenal fossa; or similarly, an *intersigmoid* hernia or a *retrocecal* (*retrocolic*) hernia. The **external** hernias push through gaps or weak places in the muscular wall, usually covered by the 'sac' derived from the parietal peritoneum. These include *diaphragmatic* hernia (usually congenital, through developmental defects); *lumbar* hernia through Petit's trigonum lumbale; *sciatic* hernia through the great sciatic foramen; *perineal* hernia through the pelvic diaphragm; *obturator* hernia through the obturator foramen; *ventral* hernia usually through the linea semilunaris or linea alba, above the umbilicus; *umbilical* hernia at the umbilicus; *inguinal* hernia through the inguinal canal; and *femoral* hernia through the femoral canal. Most of these varieties are comparatively rare. Inguinal, femoral and umbilical hernias are more frequent and will be described separately.

Inguinal hernia is by far the most frequent variety of hernia (95 per cent in males and 55–60 per cent in females). In inguinal hernia there is a weak spot in the abdominal wall, associated with the passage of the testis from within to outside the abdomen (p. 56). The parts immediately concerned are the two inguinal rings, subcutaneous (external) and abdominal (internal), and the canal (figs. 1015–1017). It must be remembered at the outset that the rings and canal are only potential—they do not exist as rings or canal save when opened up by a hernia, or when so made by the scalpel. The canal is merely an oblique slit or flat-sided pasage. The subcutaneous and abdominal rings are intimately blended with the structures that pass through them.

The subcutaneous inguinal (external abdominal) ring (fig. 453). This is usually described as a ring: it is really only a separation or gap in the aponeurosis

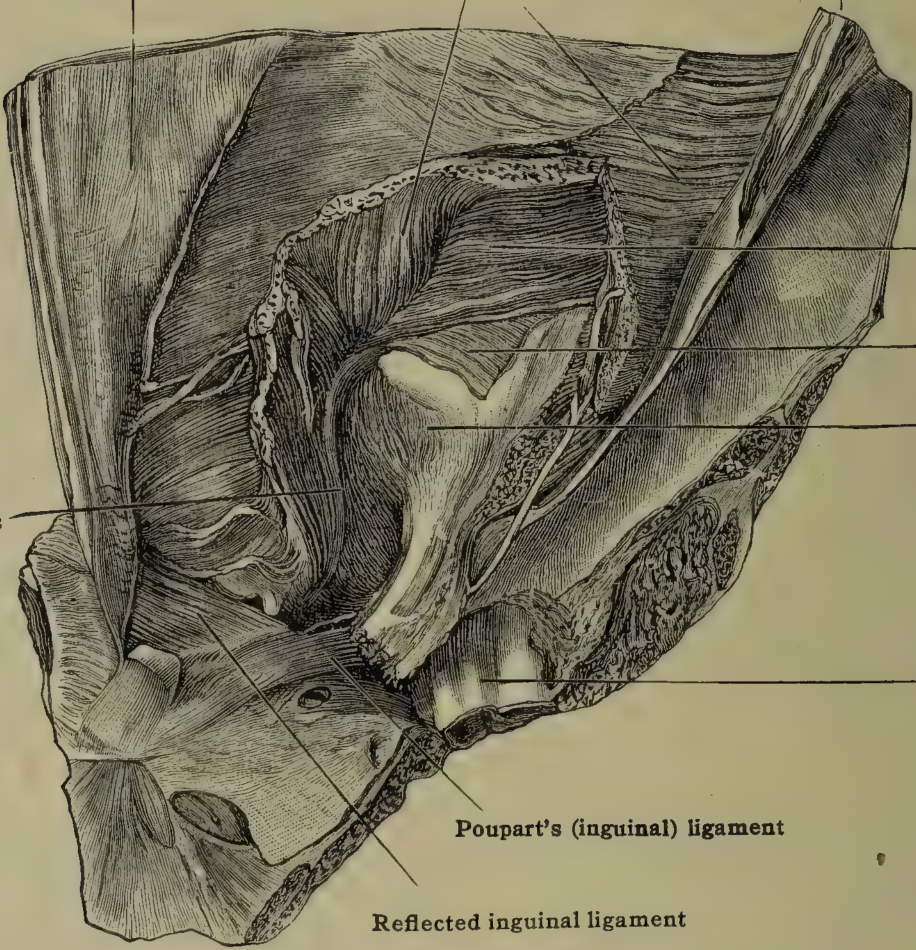


Fig. 1015.—The Parts Concerned in Inguinal Hernia.
(From a dissection in the Hunterian Museum.)

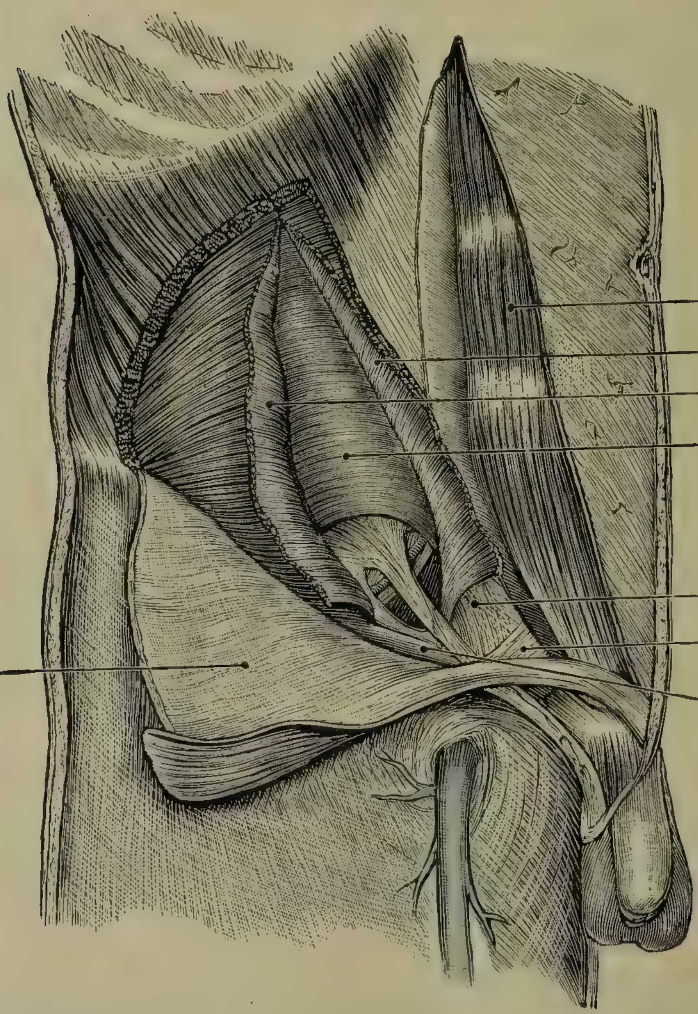


Fig. 1016.—Dissection of Inguinal Canal. (Wood.)

of the external oblique, by which in the male the spermatic cord, and in the female the round ligament, pass out from the abdomen. The size of this opening, the development and strength of its crura (pillars), the fascia closing the ring—all vary extremely. **Formation:** by divergence of two fasciculi of the external oblique aponeurosis. **Boundaries:** two crura—(1) *Superior*, the smaller, attached to the symphysis and blending with the suspensory ligament of the penis; (2) *inferior*, stronger, attached to the pubic tubercle and blending with the inguinal ligament, and so with the fascia lata. On this inferior, stronger crus rests the cord (and so the weight of the testis) or round ligament. **Shape:** triangular or elliptical, with the base downward and medially toward the pubic crest.

Intercrural, intercolumnar or external spermatic fascia.—This fascia, derived from the lower part of the aponeurosis of the external oblique, ties the two crura together, and is continued over the cord without forming any ring here. This is the rule in the body: when any structure passes through an opening in a fibrous or muscular layer, it carries with it a coating of tissue from that layer; e. g., the inferior cava passing through its foramen in the diaphragm, and the membranous urethra through the urogenital diaphragm.

Effect of position of the thigh on the ring.—As the lower crus is blended with Poupart's ligament, and as the fascia lata is connected with this, movements of the thigh will affect the ring much, making it tighter or looser. Thus extension and abduction of the thigh stretch the crura and close the ring. In flexion and adduction of the thigh the crura are relaxed; and this is the position in which reduction of a hernia is attempted.

Helping to protect this most important ring, are not only the two crura and the intercrural fascia, but also a variable structure which has been called a third or posterior 'pillar,' namely, the **reflected inguinal ligament** (figs. 1015, 1016). This has its base above at the lower part of the linea alba, where it joins its fellow and the aponeurosis of the external oblique, and its apex downward and laterally, where, having passed behind the medial crus it blends with the lacunar (Gimbernat's) ligament. Again, the **falx inguinalis** (the conjoined tendon of the internal oblique and transversalis), curving medially and downward to be attached to the iliopectineal line and spine, is a most powerful protection, behind, to what is otherwise a weak spot.

Inguinal canal (fig. 1016).—This is not a canal in the usual sense, but a chink or flatsided passage in the thickness of the abdominal wall. The descriptions of the canal usually given apply rather to the abnormal than to the healthy state. It was a canal once, and for a time only, i.e., in the later months of fetal life (p. 56). It remains weak for a long time after, but only a vestige of it remains in the well-made adult.

Length.—In fetal life there is no canal; one ring lies directly behind the other, so as to facilitate the easy passage of the testis. In the adult it measures about 37 mm. (1½ in.) in length, this lengthening being associated with by the growth and separation of the pelvis. The increased obliquity gives additional safety. On the other hand, a large hernia has not only opened widely the canal and rings, but it has pulled them close together, and one behind the other, thus not only rendering repair much more difficult, but also the path to the peritoneal sac shorter and more direct. **Direction.**—From the abdominal to the subcutaneous ring, downward, forward, and medially.

Boundaries.—For convenience sake, certain limits (largely artificial) have been named:—(1) *Floor.*—This is best marked near the outlet, where the cord rests on the grooved upper margin of the inguinal (Poupart's) and the lacunar (Gimbernat's) ligament. The meeting of the transversalis fascia with this ligament forms the floor. (2) *Roof.*—The apposition of the muscles and the arched border of the internal oblique and transversus. (3) *Anterior wall.*—Skin, superficial fascia, external oblique for all the way. Internal oblique, i.e., that part arising from Poupart's ligament, for the lateral third or so. To a slight extent, the transversus and the cremaster. (4) *Posterior wall.*—For the whole extent, transversalis fascia, extraperitoneal tissue, and peritoneum. For the medial two-thirds, conjoined tendon of internal oblique and transversus, and the lateral edge of the reflected inguinal ligament, when developed.

The **transversalis fascia** is thicker and better marked at its attachments below; these are—(*a*) laterally, to medial lip of iliac crest; (*b*) to the inguinal ligament between the anterior-superior spine and the femoral vessels, where it joins the fascia iliaca; (*c*) opposite the femoral vessels it also joins the fascia iliaca, and forms with it a funnel-shaped sheath; (*d*) medial to the femoral vessels the fascia transversalis is attached to the terminal (iliopectineal) line, behind the conjoined tendon, with which it blends.

The **falx inguinalis** (*conjoined tendon*) needs special reference (figs. 1015, 1017). It is formed by the lower fibers of the internal oblique and transversus (arciform fibers) arching downward over the cord to be inserted into the crest and spine and the terminal (iliopectineal) line. The fibers of the internal oblique become increasingly tendinous as they descend, and this, with the fact that below they give off the cremaster, may make them difficult to identify when it is desired to unite them to the upper surface of Poupart's ligament in the operation of radical cure.

The abdominal inguinal (internal abdominal) ring (figs. 1015, 1017).—It has already been said that the term 'ring' is here misapplied except in an artificial sense, as when an opening is made by a scalpel; or in abnormal conditions when a

hernial sac is present. The abdominal ring is not a ring in the least, but merely a funnel-shaped expansion of the transversalis fascia (anulus inguinalis praeperitonealis NK), which envelops the cord as it escapes from the abdomen.

Site.—Midway between the anterior superior iliac spine and pubic tubercle; center of inguinal (Poupart's) ligament, about 12 mm. (½ in.) below. **Shape**: oval, with the long diameter vertical. **Boundaries**: Medially, the inferior epigastric artery (fig. 1017); the position of this vessel, by its pulsation, is an important guide to the insertion of the highest sutures between the arciform fibers and the inguinal ligament. Owing to the artery lying to the medial side, the incision, in cutting to relieve the deep constriction of an inguinal hernia, should always be made directly upward, so as to avoid the above vessel. A large oblique hernia may so have altered the relations of the parts, including the artery, that it is difficult to decide whether the hernia is oblique or direct. The above incision will be safe, because, in either case, parallel to the vessel.

Forms of inguinal hernia.—There are two chief forms of inguinal hernia:—

A. **Lateral, or oblique.**—*Lateral,* because it appears (at the abdominal ring) lateral to the inferior epigastric artery. *Oblique,* because it traverses the whole

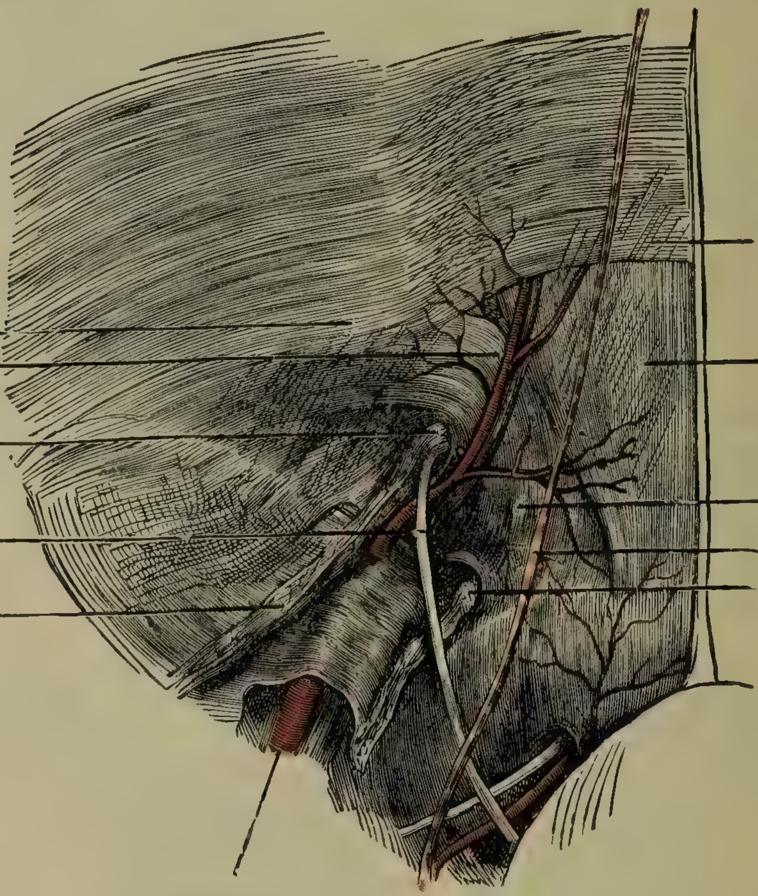


FIG. 1017.—DISSECTION OF THE LOWER PART OF THE ABDOMINAL WALL FROM WITHIN, THE PERITONEUM HAVING BEEN REMOVED. (Wood.)

of the inguinal canal, entering it at its inlet and leaving it at its outlet. This is the common form (in 95 per cent) of inguinal hernia. In the oblique inguinal hernia, the hernial sac passes downward on the lateral and upper side of the spermatic cord, to which it is closely attached. If the fibers of the cremaster muscle are incised longitudinally the sac is exposed and can be easily isolated.

B. **Medial, or direct.**—*Medial,* because it appears medial to the inferior epigastric artery. *Direct,* because, instead of making its way down the whole oblique canal, it comes by a short cut, as it were, only into the lower part of the canal, and then emerges by the same opening as the other. This is the rarer form of inguinal hernia (occurring in less than 5 per cent).

The sac in medial or direct hernia lies on the medial side of the spermatic cord, to which it is not closely related. In the direct form considerable fat is always found in front of the peritoneum. The bladder is often closely related to the sac in the direct form and care should be taken not to injure it in freeing the sac. It may be necessary to divide the remains of the obliterated hypogastric artery in order to free the sac.

A. **Oblique inguinal hernia.**—This form (which may be either congenital or acquired) possesses coverings as follows:—(1) **At the abdominal ring**, or **inlet**, it obtains three:—(*a*) Peritoneum; (*b*) extraperitoneal fat; (*c*) infundibuliform fascia, or the vaginal process of transversalis fascia prolonged along the cord. (2) **In the canal**, as it emerges beneath the lower

border of the internal oblique it gets some fibers from the cremaster. (3) **At the subcutaneous ring,** or **outlet,** the hernia obtains three, viz.: (*a*) Intercrural (intercolumnar) fascia; (*b*) superficial fascia; and (*c*) skin.

B. **Direct inguinal hernia.**—This does not come through the abdominal ring, but, making its way through the posterior wall of the lower third of the canal, either through the medial or intermediate inguinal fossa. Its coverings, therefore, vary slightly with its mode of exit (*evid infra*).

Hitherto the two forms of inguinal hernia have been considered from the **superficial aspect,** that in which they are met with in practice. The inguinal region should also be studied as to the **posterior aspect** of its so-called rings and canal, as these have to bear the early stress of a commencing hernia. It is against this aspect that a piece of omentum or intestine is constantly and insiduously pressing and endeavoring to make its way out. On the posterior wall are certain peritoneal folds (cf. fig. 981) and depressions, marking off regions. Thus, there are three more or less prominent peritoneal *folds* (one median unpaired and two lateral paired) and three paired *fossæ.* The three folds are: (1) **median umbilical,** due to the *urachus,* a fibrous cord derived from the embryonic allantois, extending from the apex of the bladder to the umbilicus; (2) the **lateral umbilical fold,** enclosing the *obliterated hypogastric* artery, extending up to the umbilicus; and (3) the **epigastric fold,** enclosing the inferior epigastric vessels (figs. 981, 1017).

In relation to these folds are the following pouches or **fossæ**:—(*a*) A medial or **supravesical fossa,** between the median and lateral umbilical folds. Direct inguinal hernia may occur in the lateral part of this fossa, lateral to the margin of the rectus (fig. 1017). (*b*) Between the lateral umbilical and the epigastric fold is the **medial inguinal fossa,** an intermediate fossa, through which direct inguinal hernia may pass. (*c*) Most laterally is the **lateral inguinal fossa,** corresponding to the abdominal ring, through which oblique inguinal hernia passes.

The **coverings** of a direct hernia may now be considered, together with **the two-fold manner of exit** of this hernia. It traverses only the lower part of the canal, making its way through either the medial or the intermediate pouch. (i) The commonest form, coming through the medial (supravesical) pouch, either pushes its way through or stretches before it the falx inguinalis. Its *coverings* are:—(1) Peritoneum; (2) extraperitoneal fat; (3) transversalis fascia; (4) falx inguinalis (unless this is suddenly burst through); (5) (6) (7). At the subcutaneous ring the three coverings are the same as in the oblique variety. (ii) This rarer form of direct hernia comes through the intermediate pouch. As a rule, the falx inguinalis does not reach over this fossa. The coverings will be the same as in the last, with two exceptions—there is no falx inguinalis, and the cremasteric fascia, if well developed, will be present.

Varieties of inguinal hernia according to the condition of the vaginal process of peritoneum. Inguinal herniæ have above been classified according to their relation to the deep epigastric artery. It remains to allude to the arrangement of these same herniæ according to the varying condition of the **processus vaginalis.** This pouch of peritoneum, which paves the way for the passage of the testis before this organ makes its start, eventually becomes the parietal layer (p. 56) of the tunica vaginalis below, in this fashion: During the first few weeks after birth the process becomes obliterated at two points—one near the abdominal ring, and one just above the testis. The obliteration, commencing first above and descending, and then, ascending from below, continues until nothing is left save the tunica vaginalis below. The following are possible hernial results of an imperfect obliteration of the process:—

(1) If the process does not close at all, a descending **hernia** is called **congenital.** This may make its way into the scrotum. The testis is now enveloped and concealed by the hernia.

(2) If the process is closed only above, i. e., near the abdominal ring, two varieties may be met with, *the infantile* and the *infantile encysted.* In the *infantile* owing to pressure above, the weak septum gradually yields and forms a sac behind the unobliterated lower part of the processus funiculovaginalis. Thus three layers of peritoneum may now be met with in an operation, the two of the incompletely obliterated tunica vaginalis, and the proper sac of the hernia. In the **encysted infantile** variety the hernial pressure causes the septum to yield and form a sac projecting into, not behind, the incompletely obliterated tunica vaginalis. Here, theoretically, two layers of peritoneum will be met with. Another variety of such an encysted hernia may be produced by rupture, not stretching, of the above-mentioned septum. The discussion of these forms which have been handed down by the older anatomists is of theoretical interest. Surgically the classification is of little importance for the sac is removed usually without any attempt at determining the number of layers of peritoneum in front of the contents.

(3) If the processus vaginalis be closed below and not above, a patent tubular process of peritoneum will lead down as far as the top of the testis. Any hernia into this process is called a **hernia into the funicular process.** All these varieties save the congenital and hernia into the funicular process are rare in practice. Other practical points are that all herniæ in children and young adults are probably of congenital origin, and therefore, the weakness is often bilateral, though it may not be so palpably. This applies to both sexes. Again in hernia of sudden origin into the funicular process with narrow surroundings, strangulation may be very acute.

Inguinal hernia in the female.—The inguinal canal in women is smaller and narrower than in men. Inguinal hernia is, therefore, less common in the female sex, and occurs in patients who happen to be the subjects of an unobliterated processus vaginalis, which extends for a varying distance along the round ligament, and is called the *canal of Nuck.* Inguinal hernia in the female is, therefore, always congenital. It is practically always of the oblique variety, and travels along the round ligament toward the labium majus. Its coverings will be the same as those of the oblique variety in the male, save that the cremaster, as a distinct muscle, is absent, and any fibers of the internal oblique which may be present are but little developed.

In *repairing a hernia,* removal of the sac is one of the essentials. The sac should be removed high enough to obliterate any funnel-shaped process. In closing the canal, the Bassini operation in which the falx inguinalis (conjoined tendon) and the transversalis and internal oblique muscles are sutured to the shelf of Poupart's ligament is still extensively employed. For operative details, the surgical text-books should be consulted.

FEMORAL HERNIA

Parts concerned in fermoral hernia.—These include (1) superficial fascia, (2) inguinal (Poupart's) ligament, (3) lacunar (Gimbernat's) ligament, (4) fascia lata, (5) fossa ovalis, (6) femoral sheath, (7) femoral canal, (8) femoral ring. (Figs. 1019, 1020.)

(1) **Skin and superficial fascia of groin.**—The latter consists of two layers: (*a*) *Superficial layer of superficial fascia* (Camper's fascia).—Fatty, met with over the whole groin, and continuous with the superficial fascia of the rest of the body. (*b*) *Deep layer of superficial fascia* (Scarpa's fascia).—Thin and membranous, only met with over the lower third of the abdominal wall and to the medial side of the groin, joining the fascia lata just below the inguinal ligament.

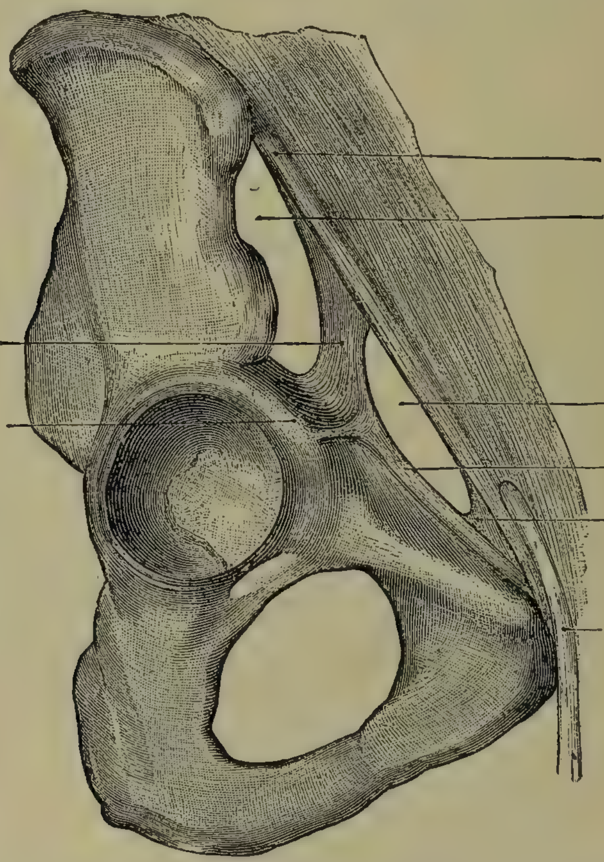


Fig. 1018.—The Lacunæ beneath the Inguinal Ligament. (Lockwood.)

Between the two layers of superficial fascia lie the superficial lymph nodes of the groin, the superficial branches of the common femoral artery, cutaneous nerves, and some veins descending to the fossa ovalis to join the great saphenous vein.

(2) **Inguinal (Poupart's) ligament** (fig. 1018).—This is also known as the crural arch, a misnomer, as 'crus' means leg. A description of its shape and attachments is given on p. 497. Owing to the connection of the fascia lata to its lower border, the fossa ovalis (saphenous opening), which is situated in the fascia lata, and has its upper cornu blending with the inguinal ligament, will be affected by movements of the thigh, much as is the subcutaneous inguinal (external abdominal) ring, being tightened and stretched when the limb is extended and abducted, relaxed when it is adducted and flexed.

The **parts beneath the ligament** which block up the gap between it and the hip bone are of the utmost importance in preventing the escape of a femoral hernia. The different structures are arranged in three compartments, (fig. 1018), named lateromedially:—(A) **lateral iliac** or **muscular**; (B) **central** or **vascular**; and (C) **medial** or **pectineal**. Of these, the first is the largest; the second or intermediate one lies slightly nearer to the inguinal ligament than the other two; while the medial compartment differs from the other two by not communicating with the pelvis, being closed above (*vide infra*).

(A) The **lateral** or **iliac compartment** [lacuna musculorum] is bounded in front by the inguinal ligament and the attached iliac fascia, behind by the ilium, laterally by this bone and the sartorius, and medially by the iliopectineal septum. The septum, descending from the inguinal ligament above, passes down to the iliopectineal eminence, and thence to the medial aspect of the front of the capsule of the hip-joint. This compartment transmits the

iliopsoas muscle and femoral (anterior crural) and lateral cutaneous nerves. (B) The **vascular compartment** [lacuna vasorum] is bounded in front by the inguinal ligament and the transversalis fascia, which here blends with it, forming the so-called *deep crural arch,* and at the same time descends on to the front of the femoral sheath. The posterior boundary, *Cooper's ligament* (figs. 1018, 1020), is formed by the meeting of the iliopectineal septum laterally and the pectineal fascia or sheath. Medially is the lacunar (Gimbernat's) ligament, and laterally the iliopectineal septum. This intermediate compartment transmits the external iliac vessels and the lumboinguinal nerve. The nerve lies to the lateral side of the artery, the vein medially. Between the vein and the base of the lacunar ligament is the femoral ring (*vide infra*). (C) The **medial or pectineal compartment** is bounded by the pectineal fascia, continuous with the pubic part of the fascia lata, and behind by the pubic ramus. It lodges the upper end of the pectineus muscle, so that the handle of a scalpel passed upward along the muscle would be prevented from passing into the pelvis by the lacunar ligament and the blending of the pectineal fascia with the upper border of the pubic ramus. The pectineal fascia is employed in some operations for the cure of femoral hernia.

(3) **Lacunar (Gimbernat's) ligament.**—This is merely the triangular medial attachment of Poupart's ligament. Its apex is attached to the pubic tubercle; of its three borders, the base is free toward the vein and the femoral ring. Its upper border is continuous with Poupart's ligament; its lower is attached to the terminal (iliopectineal) line (fig. 1018).

(4) **Fascia lata.**—Two portions are described over the upper part of the thigh:—(*a*) An **iliac,** lateral and stronger, attached to the inguinal ligament in its whole extent and lying over the sartorius, iliopsoas, and rectus. (*b*) A **pubic,** medial, weaker, and much less well defined, is attached above to the terminal line and the tubercle of the pubis. The upper cornu of the fossa ovalis is at the lacunar ligament, and at the lower cornu the two portions of the fascia blend.

Relation of fascia lata to the femoral vessels.—The iliac portion, being attached along Poupart's ligament, passes over these. The pubic portion, fastened down over the pectineus, which slopes down on to a deeper plane than the adjacent muscles, passes behind the femoral vessels to end on the capsule of the hip-joint.

(5) **Fossa ovalis (saphenous opening).**—This is not an opening, but an oval depression, situated at the spot where the two parts of the fascia lata diverge on different levels. Though the fascia lata is wanting here, there is no real opening, as the deficiency is made up by the deep layer of superficial fascia, or cribriform fascia, which fills up the opening (fig. 453).

Though a weak spot, the fossa ovalis serves to transmit the saphenous to the femoral vein and the superficial to the deep lymphatics. The depression is present in order to allow the saphenous vein to be protected from pressure in flexion of the thigh. It is located at the medial and upper part of the thigh, with its center 3.7 cm. (1½ in.) below and lateral to the tubercle of the pubis. It is 2.5 cm. (1 in.) in height by 1.2 or 1.8 (½ or ¾ in.) in width. *Shape:* oval, with its long axis downward and laterally. *Two extremities* or *cornua:* upper blending with the lacunar ligament; lower, where the two parts of the fascia lata meet. *Two borders:* lateral or falciform, also known as the *ligament of Hey,* or femoral ligament. Semilunar in shape, arching downward and laterally from the lacunar ligament to the inferior cornu. This lies over the femoral vessels, and is adherent to them; to it is fixed superficially the cribriform fascia (*vide infra*). The medial border is much less prominent, owing to the recession of the pubic part of the fascia lata which forms it.

(6) **Femoral sheath.**—This is a funnel-shaped sheath, carried out by the femoral vessels under Poupart's ligament, and continuous above (in front) with the transversalis fascia as it descends to the ligament, lining the inner surface of the abdominal wall, and (behind) with the iliac fascia, and below continuous with the proper sheath of the femoral vessels.

It is not only funnel-shaped, but large and loose, for two reasons:—(*a*)That there be plenty of room for the femoral vein and the slowly moving venous current in it to ascend without compression; (*b*) to allow all the movements of the thigh—flexion and extension—without undue stretching of the vessels. By two connective-tissue septa the sheath is divided into three compartments—the lateral for the artery, the intermediate for the vein, and the medial one for the femoral canal (*vide infra*). Thus one septum lies between the artery and vein, and another between the vein and the femoral canal.

(7) **Femoral canal.**—This occupies the medial division of the femoral sheath. The fascia transversalis and fascia iliaca meet directly on the lateral side of the femoral artery, but not so closely on the medial side of the femoral vein. Hence a space exists here, perhaps to prevent the thin-walled vein, with its sluggish current, from being pressed upon; but it is merely a slight gap, not a canal, unless so made by a knife or by the dilating influence of a hernia.

Length: about 1.9 cm. (¾ in.). *Limits:* below, fossa ovalis; above, femoral ring. *Boundaries.*—Laterally, a septum between it and the vein; medially, base of the lacunar ligament (above) and meeting of fasciæ iliaca and transversalis; behind, fascia iliaca; in front, fascia transversalis. *Contents.*—Cellular tissue and fat, continuous with extra-peritoneal fatty layer and a lymphatic node, which is inconstant. Lymphatic vessels pass from inguinal nodes to those in the pelvis through the femoral canal, which is therefore sometimes called the 'lymphatic canal' (fig. 1017).

(8) **Femoral ring.**—This is mainly an artificial product. It is the upper or abdominal opening of the femoral canal (figs. 572, 1017, 1018). *Shape:* oval, with its long axis transverse. It is larger in women. *Boundaries:* medially, the lacunar ligament; laterally, the femoral vein; in front, the inguinal ligament and the thickening of the transversalis fascia attached to it (called 'the deep

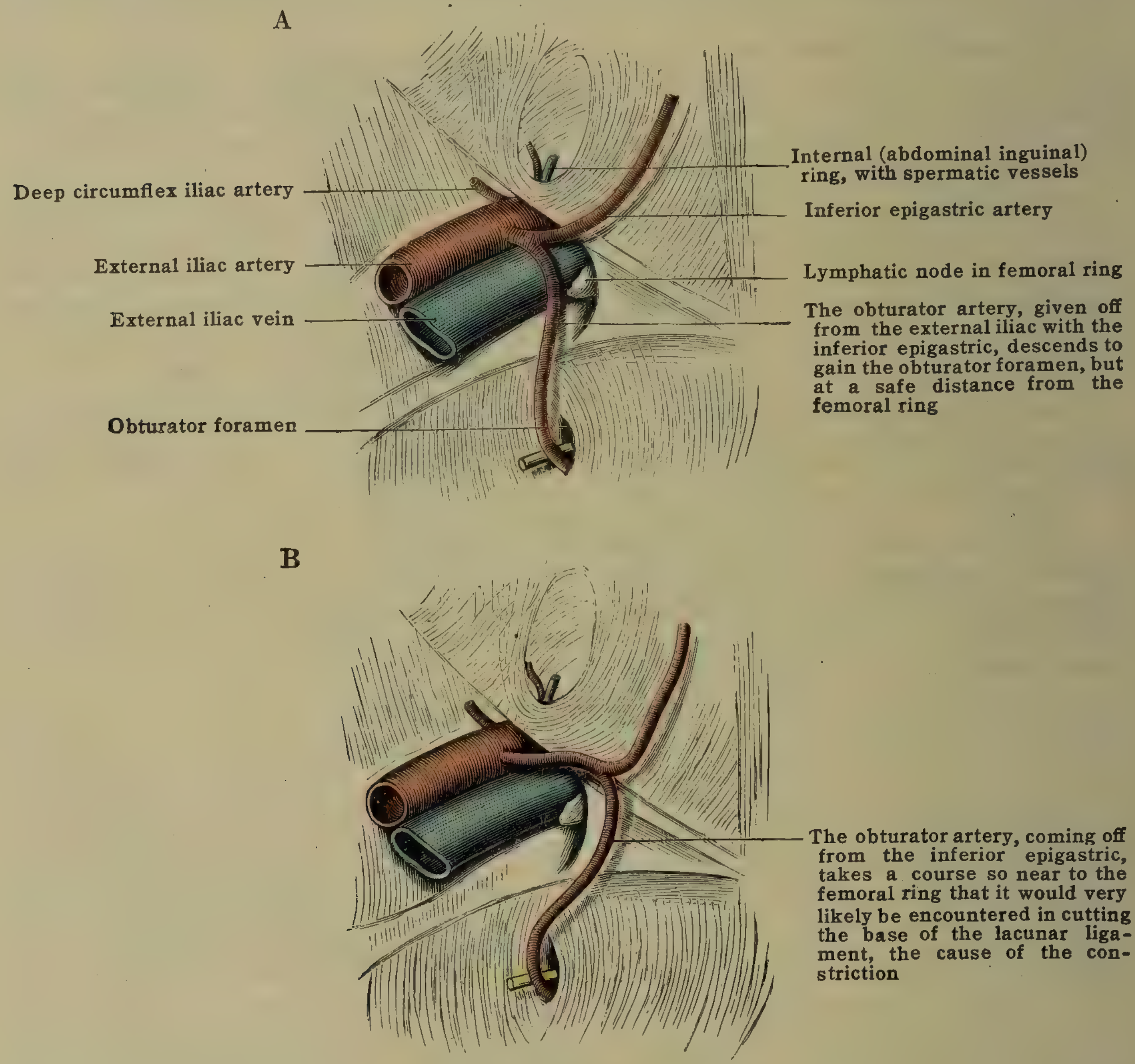


Fig. 1019.—Femoral Ring and Irregularities of the Obturator Artery. (After Gray.)

crural arch'); behind, the pectineus and Cooper's ligament. It is closed by the *septum crurale,* which is a mass of fatty connective tissue, continuous with the extraperitoneal fatty layer, perforated by lymphatics passing upward to the pelvic nodes (figs. 1017, 1019).

Position of vessels around the ring.—Laterally the femoral vein; above, the epigastric vessels as they ascend from the external iliac vessels, pass close to the upper and lateral aspect of the ring; immediately in front are the cord and spermatic vessels always to be remembered in this hernia in the male; toward the medial side there may be an unimportant anastomosis between the epigastric artery above and the obturator below (fig. 1017).

If from dilation of this anastomosis the obturator artery comes off abnormally from the inferior epigastric, it will usually descend close to the junction of the external iliac and common femoral vein, and thus to the lateral, and so the safe, side of the ring (fig. 1019, A). In a very few cases it curves more medially, close to the lacunar ligament, and thus to the medial side of the ring, and is then in great danger (fig. 1019, B) if the constricting femoral ring is incised. In two out of every five cases the obturator arises from the inferior epigastric. In about thirty-seven per cent. of the cases with such an origin the artery either crosses or courses along the side of the ring. (Cunningham.)

Course of femoral hernia.—At first this is downward in the femoral canal. A pouch of peritoneum having been gradually, after repeated straining, coughing, etc., pushed through the weak spot, the femoral ring, further weakened perhaps, together with all the parts in the femoral arch, by child-bearing, some extra effort will force intestine or omentum into this pouch and thus form a hernia. It has been recently claimed that some femoral hernias are congenital; the peritoneal pouch which forms the sac being carried out with the limb-bud as it develops. When formed, femoral hernia passes at first downward in the femoral canal as far as the fossa ovalis, but, as a rule, does not go father downward on the thigh, but mounts forward and upward, and somewhat laterally, even reaching the level of the inguinal ligament. The reasons for this change of position are:—(1) The narrowing of the femoral sheath, funnel-like, i. e., wide above, but narrowed below; (2) the unyielding nature of the lower margin of the fossa ovalis; (3) the fact that this margin and the lateral border are united to the femoral sheath; (4) the constant flexion of the thigh; (5) the fact that vessels (chiefly veins) and lymphatics descend to the fossa ovalis, the veins to join the saphenous vein and the lymphatics to join the deeper group; these descending vessels serve to loop upward or suspend a femoral hernia, and thus prevent its further course downward. (For relations of femoral hernia, see fig. 1020).

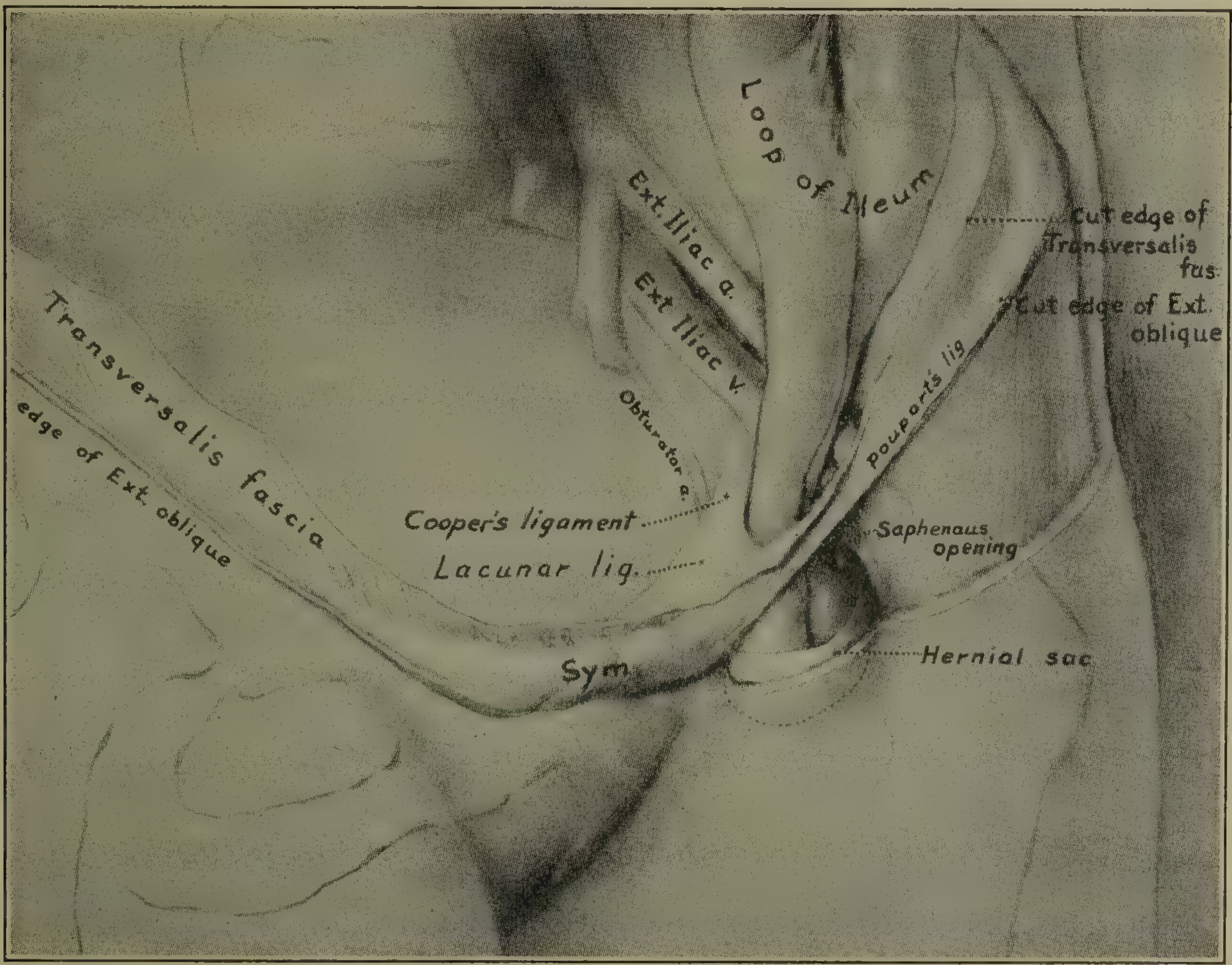


FIG. 1020.—RELATIONS OF FEMORAL HERNIA. (From Seelig and Tuholski; in Binnie's Regional Surgery.)

Coverings of a femoral hernia.—(A) *At the upper* or *femoral ring* it includes peritoneum, extraperitoneal fat, and septum femorale (crurale). (B) *In the canal,* a coating of the femoral sheath. (C) *At the external opening,* further coverings of cribriform fascia, skin, and superficial fascia are added.

Some of these coverings may be deficient by the hernia bursting through them, or they may be matted together. Sir A. Cooper thought this matting likely to occur with the layer of femoral sheath and septum crurale, to which he gave the name of *fascia propria.* The sac of a femoral hernia is usually covered by a relatively large amount of fat. At times there may be so much fat that the sac is found with difficulty.

The relations of an inguinal and a femoral hernia respectively to the pubic tubercle are of importance in distinguishing between them clinically. If a finger is placed on the pubic tubercle a hernia that lies above and medial to it will be inguinal, one below and lateral to it will be femoral.

Frequency.—Femoral hernia is more frequent in the female, but even in this sex is less frequent than inguinal hernia. Of 100 hernias of both types, the distribution is 83.5 male inguinal; 8.5 female inguinal; 5.9 female femoral; 2.1 male femoral (Macready).

Radical cure of femoral hernia.—The close proximity of the femoral vein always introduces difficulty in the introduction of the deep sutures for closure of the femoral ring. Any closure below this point is certain to be inefficient. The safest and simplest method is to feel for the pulsation of the femoral artery, and make allowance for the vein on its medial side. The latter vessel is then protected by the finger-tip passed up the femoral canal, so that its dorsum rests against the vein and its tip upon the linea terminalis. The sutures are then passed so as to pick up the iliopectineal fascia and its thickened part, Cooper's ligament, below, and the deep crural arch and Poupart's ligament above (fig. 1018). Thus, when tightened, they draw

the anterior and posterior boundaries of the ring together. (Lockwood, Bassini.) There is a growing tendency to operate upon femoral hernia from above, that is through the inguinal canal. The hernial sac can thereby be completely removed, and the opening completely closed.

UMBILICAL HERNIA

A hernial protrusion at the umbilicus may occur at three distinct periods of life. This region, originally a distinct opening, is gradually closed and changed into a knotty mass of scar, the strongest point in the abdominal wall.

During early fetal life, in addition to the urachus and umbilical vessels, some of the mesentery and a loop of the intestine pass through the opening to occupy a portion of the body cavity (the umbilical celom) situated in the umbilical cord, later on returning to the abdominal cavity (cf. p. 48). Occasionally this condition persists, owing to failure of development, and the child is born with a hernial swelling in this region, covered with skin and peritoneum. This condition is termed **congenital umbilical hernia.**

A Meckel's diverticulum may extend into the hernia. In some cases the hernia is small, and the enclosed loop of intestine may be endangered if the cord is ligated close to the abdominal wall.

In later fetal life the umbilical vessels alone pass through this opening. At birth the umbilicus is surrounded by a distinct ring [*annulus umbilicalis*], which can be felt for some time afterward in the flaccid wall. If this condition persists, a portion of intestine or omentum may find its way through, forming the condition commonly known as **infantile umbilical hernia.** Why it is not more frequently met with is explained by the way in which this ring of infancy is closed and gradually converted into the dense mass of scar tissue so familiar in adult life. This is brought about—(1) by changes in the ring itself; (2) by changes in the vessels.

(1) **Changes in the ring.**—The umbilical ring is surrounded by a sphincter-like arrangement of elastic fibers, best seen during the first few days of extrauterine life, on the posterior aspect of the belly wall. In older infants these fibers lose their elasticity, become more tendinous, and then shrink more and more. As they contract they divide, as by a ligature, the vessels passing through the ring, thus accounting for the fact that the cord, wherever divided, drops off at the same spot and without bleeding.

(2) **Changes in the vessels.**—When blood ceases to traverse these vessels, their lumen contains clots, and their muscular tissue atrophies, while the connective tissue of their outer coat hypertrophies. Thus, the umbilical vessels and the umbilical ring are alike converted into scar tissue, which blends together. This remains weak for some time, and may be distended by a hernia (infantile).

Adult umbilical hernia is more common in females. The very dense, unyielding, fibrous knot shows two sets of fibers:—(1) Those decussating in the middle line; and (2) two sets of circular fibrous bundles which interlace at the lateral boundaries of the ring. The lower part of the ring is stronger than the upper. In other words, umbilical hernia of adult life, when it comes through the ring itself and not at the side, always comes through the upper part. In the lower three-fourths of the umbilicus the umbilical arteries and urachus are firmly closed by matting in a firm knot of scar tissue; in the upper there is only the umbilical vein and weaker scar. Owing to the rapid growth of the abdominal wall and pelvis before puberty, and the fact that the urachus and the umbilical arteries, being of scar tissue, elongate with difficulty, the latter parts depress the umbilicus by reason of their attachment below.

Owing to the usual exit of an umbilical hernia of adult life being through the upper part of the ring, the constricting edge in strangulation should be sought below and divided downward. As pointed out by Mr. Wood, it is here that the dragging weight of the hernial contents and the weight of the dress tend to produce the chief results of strangulation. An incision here also gives better drainage if required.

Coverings of an umbilical hernia.—These, more or less matted together, are:—(1) Skin; (2) superficial fascia, which loses its fat over the hernia; (3) prolongation of scar tissue of the umbilicus gradually stretched out; (4) transversalis fascia; (5) extraperitoneal fatty tissue; (6) peritoneum. If the hernia come through above the umbilicus, or just to one side, the coverings will be much the same; but, instead of the layer from the umbilical scar, there will be one from the linea alba.

Strangulated umbilical hernia of adult life.—In this, the most fatal of the strangulated hernias ordinarily met, the following are practical points in the surgical anatomy:—1. The coverings, including the sac, are always thin, at times so markedly that the intraperitoneal contents are practically subcutaneous. 2. The sac is multilocular, and one or more of its chambers may lie very deep. 3. The contents are numerous, viz., omentum, often voluminous and adherent, transverse colon, and later in the history, small intestine. 4. The contents are often

adherent to the sac and each other, thus explaining the irreducibility. 5. The long duration of the presence of the transverse colon with its stouter walls accounts for the period, often prolonged, in which warning evidence of incarceration precedes that of strangulation. 6. The communication with the peritoneal sac is direct, short, and during a prolonged operation, free. Infection is thus readily brought about.

Ventral hernia.—In its broad supraumbilical portion, small hernial protrusions of subperitoneal fat sometimes force their way through interstices in the linea alba, and true peritoneal sacs may be drawn through after them. Subperitoneal fat usually forms the greater part of such a protrusion. The linea alba is not very vascular, and hence was at one time the favorite site of incisions in opening the abdominal cavity. Since the resulting scar is weak and yielding, however, it is now more customary to make vertical incisions through the rectus sheath, to one side of the middle line, where the abdominal wall can be sutured in layers, and an incisional hernia prevented.

THE LIVER

The **liver** [hepar] is the largest gland in the body. Its secretion, the bile [bilis; fel], is poured into the duodenum through the common bile-duct. In addition it has important functions as a 'ductless gland' in connection with the nitrogenous

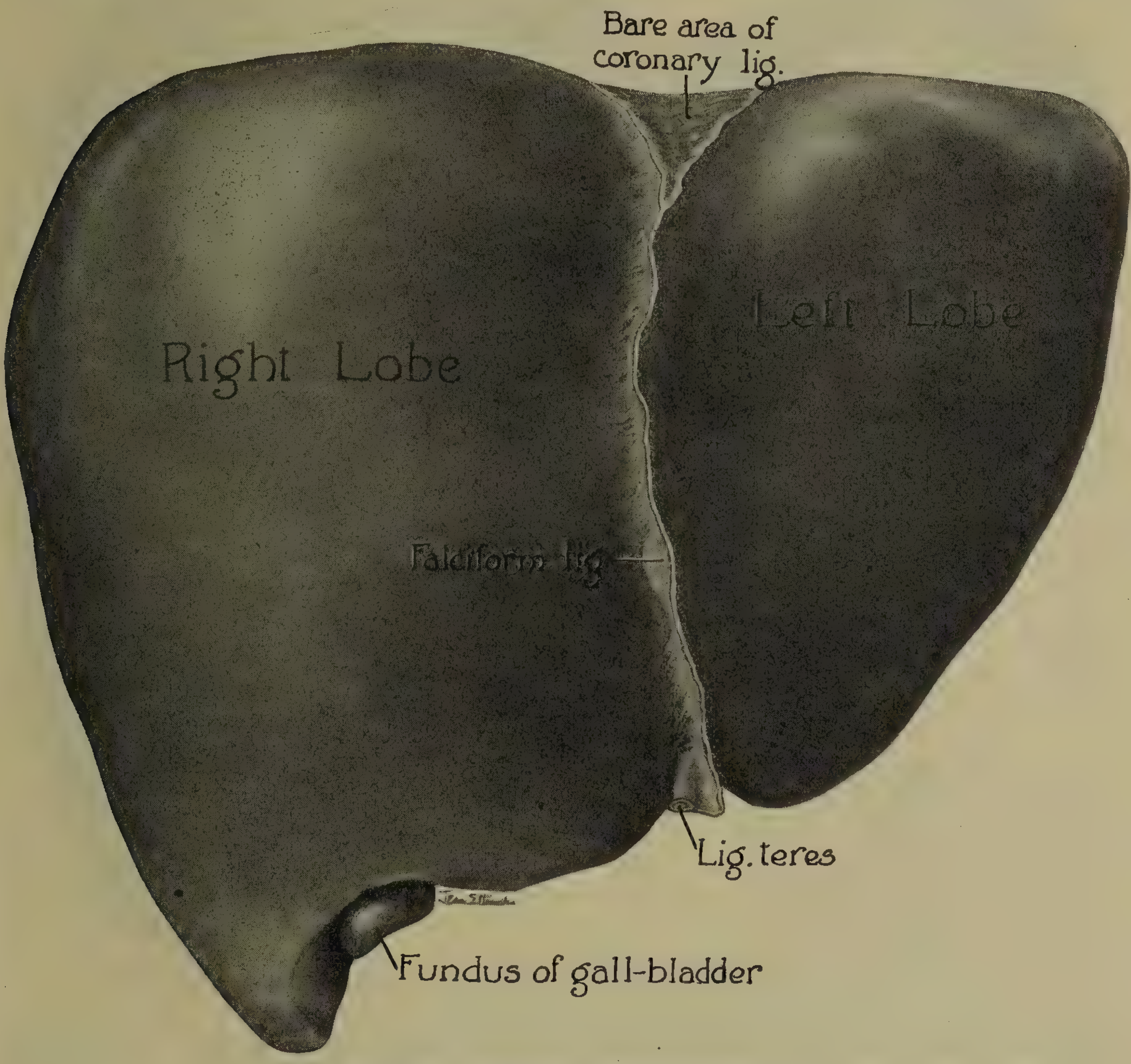


FIG. 1021.—ANTERIOR VIEW OF THE LIVER.

and carbohydrate metabolism. In form it is a variable somewhat irregular mass, roughly comparable to a modified hemisphere occupying the upper right portion of the abdominal cavity (figs. 975, 1003). It presents a convex, rounded upper or *parietal* aspect, which is in contact with the diaphragm and adjacent body walls, and a lower, flattened *visceral* surface, in contact with the abdominal viscera. When viewed from the front, it is somewhat triangular in outline, occupying the right hypochondriac, the epigastric and (slightly) the left hypochondriac regions.

Physical characters.—In weight, the liver averages about 1500 gm. (3⅓ lbs.), but it is exceedingly variable, commonly ranging from 1000 gm. to 2000 gm. Its *relative* weight is also variable, averaging about 2.5 per cent. of the body in the adult male (somewhat higher in the

female). Its *specific gravity* averages 1.056, so that the average weight of 1500 gm. would correspond to a *volume* of 1420 cc. Its *dimensions* are also quite variable. Its greatest *depth* (anterposterior) averages about 15 cm., and its greatest *height* (vertical) is about the same. Its *width* (horizontal) is about 20 cm., while its greatest *length* (measured obliquely from side to side) averages about 25 cm. The *color* of the liver is a reddish-brown. It is firm in *consistency*, but friable, so that it is easily ruptured.

Surfaces and borders.—The most general division of the surface of the liver, as above stated, is into the parietal (diaphragmatic) and the visceral. The parietal surface is again subdivided, usually into two surfaces—posterior and superior.

The **posterior surface** [facies posterior] (pars affixa NK) is triangular (fig. 1022). It is wide on the right, where the right lobe is in contact with the dia-

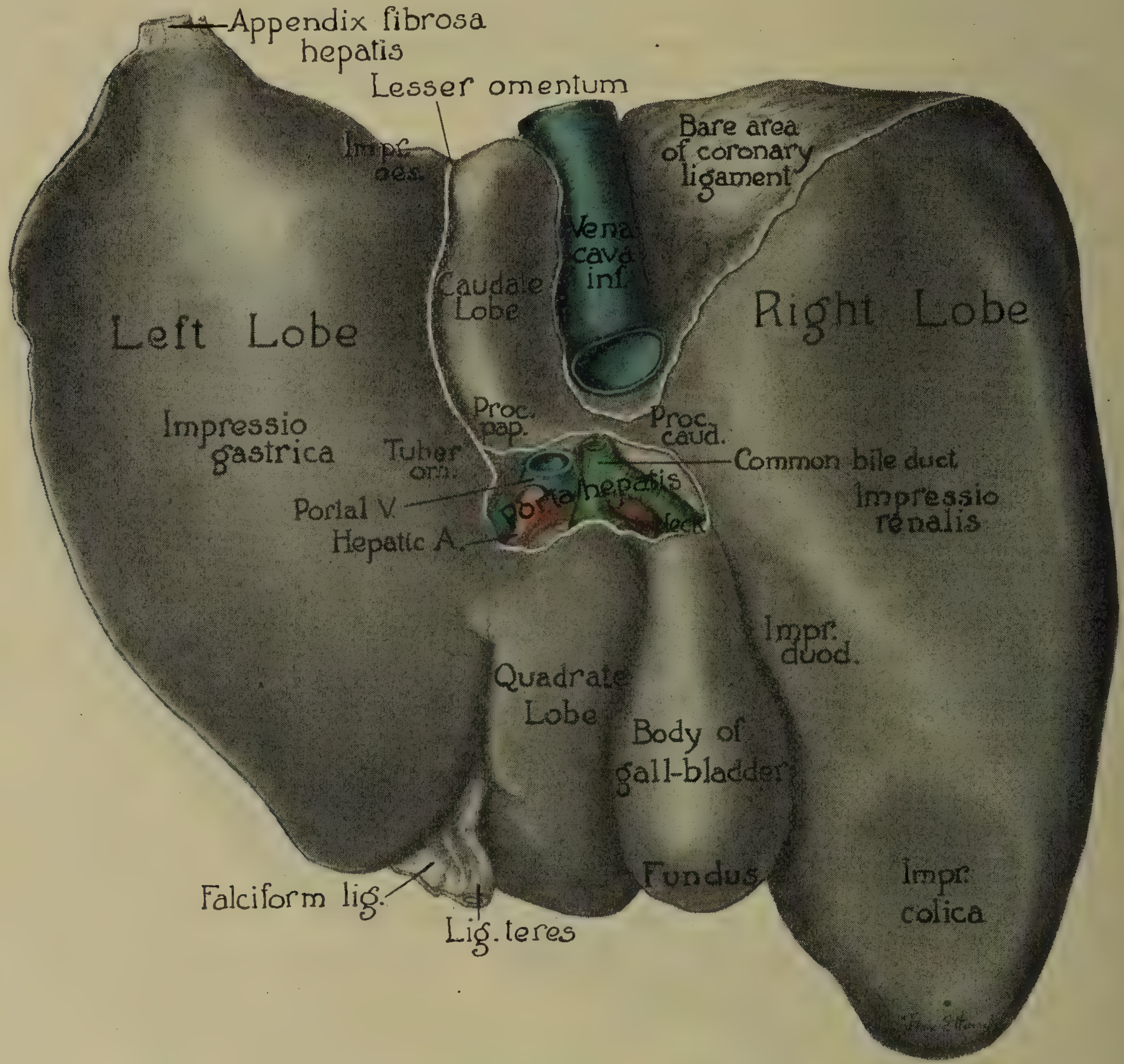


FIG. 1022.—POSTERIOR VIEW (POSTERIOR AND INFERIOR SURFACES) OF THE LIVER.

phragm (corresponding chiefly to the 'bare area' of the coronary ligament), and narrow on the left side, where the posterior margin of the left lobe is likewise attached to the diaphragm. Near the midline is the caudate (Spigelian) lobe, opposite the tenth and eleventh thoracic vertebral bodies, from which it is separated by the diaphragm (chiefly the right crus). On the right of the caudate lobe is the fossa lodging the vena cava (sometimes bridged over), while to the left is the fissure of the ductus venosus, giving attachment to the upper portion of the lesser omentum (relations in cross-section shown in fig. 1023).

The **superior surface** [facies superior] (pars libera NK) is in general convex and molded to the inferior surface of the diaphragm. It extends downward upon the anterior abdominal wall to a variable extent in the epigastric region, including the entire area of the liver visible from the front (fig. 1021). It also presents a broad area extending downward on the right side. Symington

accordingly distinguishes three surfaces corresponding to the superior surface above described, viz., right, anterior and superior surfaces. The superior surface is related above, through the diaphragm, with the base of the right lung, the pericardium and heart, and (on the extreme left) with the base of the left lung. Where it rests upon the liver, the heart forms a shallow fossa [impressio cardiaca].

Of the three more accessible surfaces, *the right lateral* is opposite the seventh to the eleventh intercostal arches, separated from them by the pleura, the thin base of the lung, and the diaphragm. The *superior* surface is accurately fitted with its right and left portions into the hollows of the diaphragm, a slightly depressed area intervening which corresponds to the central tendon. On the left side, in the adult, the limit of the left lobe will be in the fifth interspace, about 7.5 cm. (3 in.) from the midline. The *anterior* surface is in contact with the diaphragm, costal arches, and, between them, the xiphoid cartilage, and, below, with the abdominal wall. Both the superior and anterior surfaces are subdivided by the falciform ligament, an important point in subphrenic suppuration.

The **inferior or visceral surface** [facies inferior] (fig. 1022) faces downward and backward. It is irregularly concave, with impressions due to contact with the underlying viscera. It is divided into three lobes, right, left, and quadrate, whose relations will be described later.

Of the **borders,** the ventral or *anterior* [margo anterior] is the best marked. It forms the inferior boundary of the triangular anterior view of the liver (figs. 975, 1003, 1021), and separates the superior (anterior) from the inferior surface. Slightly to the right of the midline, it usually presents a slight *umbilical notch* [incisura umbilicalis], (incisura hepatis NK) where it is crossed by the falciform ligament. To the right of this there may also be a notch for the fundus of the gall-bladder (fig. 1021). The posterior surface is separated from the superior and inferior surfaces by ill-defined *posterosuperior* and *posteroinferior borders.*

Surface-outline.—The average position of the liver may be outlined upon the anterior surface of the body as follows (fig. 1003): Locate one point on the right mammary (mid-Poupart) line opposite the fifth rib; a second point on the left mammary line about 2 cm. lower, in the fifth interspace; and a third point about 2 cm. below the costal arch (10th rib) on the right lateral wall. A line slightly concave upward, joining the first and second points, defines the uppermost aspect of the liver. A line, strongly convex laterally, joining the first and third points, defines the right side of the liver. Finally, a third line, joining the second and third points, corresponds to the anterior border and defines the lowermost portion of the liver. This line often crosses the midline of the body in the midepigastric (transpyloric) plane, but is subject to many individual variations. In general, it is usually slightly convex downward as it crosses the epigastric region. It usually presents a slight umbilical notch, as before mentioned, and frequently a notch for the fundus of the gall-bladder, which is placed near the right mammary (mid-Poupart) line. The lower and right portion of the anterior border of the liver runs somewhat parallel with the infracostal margin. In the upright position, and in livers larger than usual, it extends 2 cm. or more below the hypochondrium into the right lateral abdominal (lumbar) region (fig. 1003). In the supine position however, the liver recedes about 2 cm. toward the head. The liver of course participates also in the respiratory movements of the diaphragm. Other variations in the position of the liver are mentioned later.

Lobes and fissures.—The superior surface is divided by the falciform ligament into two areas, corresponding to a larger right and a smaller left lobe (fig. 1021). On the posterior and inferior surfaces of the liver (fig. 1022), an H-shaped arrangement of fossæ and fissures completes the demarcation of lobes. The left upright of the H [fossa sagittalis sinistra] corresponds to the prolongation of the line of attachment of the falciform ligament. It includes the umbilical fissure [*fossa venæ umbilicalis*], containing the ligamentum teres, on the inferior surface; and the *fissure of the ductus venosus,* containing the ligamentum venosum and the upper part of the lesser omentum, on the posterior surface of the liver. This left sagittal fossa separates the left lobe of the liver from the right lobe (in the wider sense of the term). The right lobe is further subdivided by the right upright and cross-bar of the H. The right upright [fossæ sagittales dextræ] is made up of the broad *fossa for the gall-bladder* [fossa vesicæ felleæ] on the inferior surface, and the broad *fossa venæ cavæ* on the posterior surface (fig. 1022). These two fossæ are not continuous, but are separated by a narrow strip of liver, the caudate process of the caudate lobe. The cross-bar of the H is formed by the transverse or *portal fissure* [porta hepatis], which encloses the root structures of the liver, joining the right part of the lesser omentum (fig. 1022). The area anterior to the cross-bar of the H corresponds to the quadrate lobe of the inferior surface; that posterior to the cross-bar to the caudate lobe of the posterior surface; while the remainder of the liver, to the right of the H, is the right lobe (in the narrower sense).

The **right lobe** [lobus hepatis dexter] makes up the greater part of the liver. Its relations on the superior and posterior surfaces have already been mentioned. On the inferior or visceral surface (fig. 1022), there appears posteriorly a large concavity [impressio renalis] for the right kidney; medially a faint impression [impressio duodenalis] for the descending duodenum; and inferiorly a variable area [impressio colica] of contact with the right (hepatic) flexure of the colon. The caudate process joins the right with the caudate lobe.

The **left lobe** [lobus hepatis sinister] lies to the left of the left sagittal fissure and the falciform ligament (fig. 1022). It is flattened but variable in form and size, and makes only about one-fifth of the entire liver. In children and especially in early fetal life, it is relatively much larger. At the left extremity, there is usually found in the adult liver a variable fibrous band [appendix fibrosa hepatis] representing the atrophied remnant of the more extensive gland in earlier life. In this fibrous appendix (and in other parts of the liver) the bile-ducts of the atrophied liver substance persist as *vasa aberrantia hepatis*.

The left lobe is related *superiorly*, through the diaphragm, with the heart and the base of the left lung. *Inferiorly* (fig. 1022) it presents a large concavity [impressio gastrica] which is in contact with the anterior surface of the stomach. Above and behind the gastric impression is the rounded *tuber omentale* which is placed above the lesser curvature of the stomach and related, through the lesser omentum, with a corresponding tuberosity on the pancreas. Above the gastric impression is a small inconspicuous groove [impressio œsophagea] for the abdominal part of the esophagus.

The **quadrate lobe** [lobus quadratus] lies, as before mentioned, on the inferior surface of the liver (fig. 1022) in the anterior or inferior area of the H. It is in contact with the pylorus and the first part of the duodenum.

The **caudate or Spigelian lobe** [lobus caudatus; Spigeli] was described on the posterior surface of the liver (fig. 1022). Inferiorly, the caudate lobe, behind the portal fissure, is divided by a notch into two processes. The left or *papillary process* [processus papillaris] is short and rounded, and lies opposite the tuber omentale. In the fetus it is relatively much larger and is in contact with the pancreas. The right or *caudate process* [processus caudatus] is of variable size, and joins the caudate with the right lobe of the liver. It is usually small and inconspicuous. In the fetus, however, it is relatively much larger, and extends downward to a variable extent behind the duodenum and head of the pancreas. In the adult, it forms the upper boundary of the epiploic foramen (of Winslow).

Peritoneal relations.—The liver in the adults is almost entirely surrounded by peritoneum. Although the liver develops together with the diaphragm in the common septum transversum (see p. 50 and fig. 1030), the peritoneum soon extends in between liver and diaphragm, so that they remain in immediate contact only in the so-called 'bare area.' This is an irregular area on the posterior and superior surfaces of the liver (chiefly on the right lobe), the margins of which correspond to the coronary ligament (figs. 981, 1022). The posterior surface of the liver is therefore largely retroperitoneal, excepting the caudate (Spigelian) lobe, which is in contact with the recessus superior of the bursa omentalis (fig. 980). The other surfaces of the liver are almost entirely covered with peritoneum, excepting the lines of attachment of the various peritoneal ligaments, and the fossa for the gall-bladder, which is usually directly in contact with the gall-bladder with no intervening peritoneum.

Ligaments.—The liver is attached by five peritoneal ligaments—coronary, right and left triangular (lateral) and falciform ligaments and lesser omentum—and two accessory ligaments—teres and venosum.

The **coronary** ligament [lig. coronarium hepatis], as before mentioned, corresponds to the reflections of peritoneum from the liver to the diaphragm at the margins of the 'bare area' (figs. 954, 955, 981) on the posterosuperior aspect of the liver.

Within this uncovered area the hepatic veins join the inferior vena cava. The coronary ligament, though somewhat irregular and variable in form, is elongated laterally and roughly quadrangular. At the four angles, the peritoneal layers come together and are prolonged into four ligaments—right and left triangular (lateral) and falciform ligaments and lesser omentum. There is often also a special prolongation of the coronary ligament downward upon the right kidney, forming the *hepatorenal ligament* [lig. hepatorenale]. This lies to the right of the foramen epiploicum.

The **right triangular** (or lateral) ligament [lig. triangulare dextrum] (mesohepaticum laterale dextrum NK) is a short but variable prolongation of the coronary ligament to the right and downward (fig. 981). It connects the posterior surface of the right lobe of the liver with the corresponding portion of the diaphragm.

The **left triangular** (lateral) ligament [lig. triangulare sinistrum] (mesohepaticum laterale sinistrum NK) is a longer, narrower prolongation of the coronary ligament to the left (fig. 981). It connects the posterior aspect of the left lobe of the liver with the corresponding portion of the diaphragm.

The **falciform** ligament [lig. falciforme hepatis] (mesohepaticum ventrale NK) is a double layer of peritoneum representing (as before mentioned) the ventral portion of the primitive ventral mesogastrium (figs. 976, 981, 1021).

Its upper end is continuous posteriorly with the coronary ligament. It passes forward and downward over the superior surface of the liver. From its line of attachment to the liver (between right and left lobes) it passes forward and slightly to the left to the attachment on the anterior body wall. This attachment extends downward slightly to the right of the midline to the umbilicus. The lower margin of the falciform ligament is free, and encloses the round ligament.

The **round ligament** [lig. teres hepatis] is a fibrous cord (chorda venæ umbilicalis NK) representing the obliterated fetal left umbilical vein. It extends upward from the umbilicus enclosed in the lower margin of the falciform ligament (figs. 1021, 1022).

At the anterior margin of the liver it passes backward on the inferior surface, enclosed in a slight peritoneal fold at the bottom of the fossa venæ umbilicalis (sometimes bridged over by liver tissue). It ends by joining the left branch of the portal vein.

The **ligamentum venosum** [lig. venosum; Arantii] (chorda ductus venosi NK) similarly represents the obliterated fetal ductus venosus. It is a fibrous cord lying in the fissure of the ductus venosus, and extends from the left branch of the portal vein upward to the left hepatic vein near its opening into the vena cava. The ligamentum venosum lies within the hepatic attachment of the lesser omentum.

The **lesser omentum** [omentum minus] has already been discussed in connection with the peritoneum. It represents the dorsal part of the primitive ventral

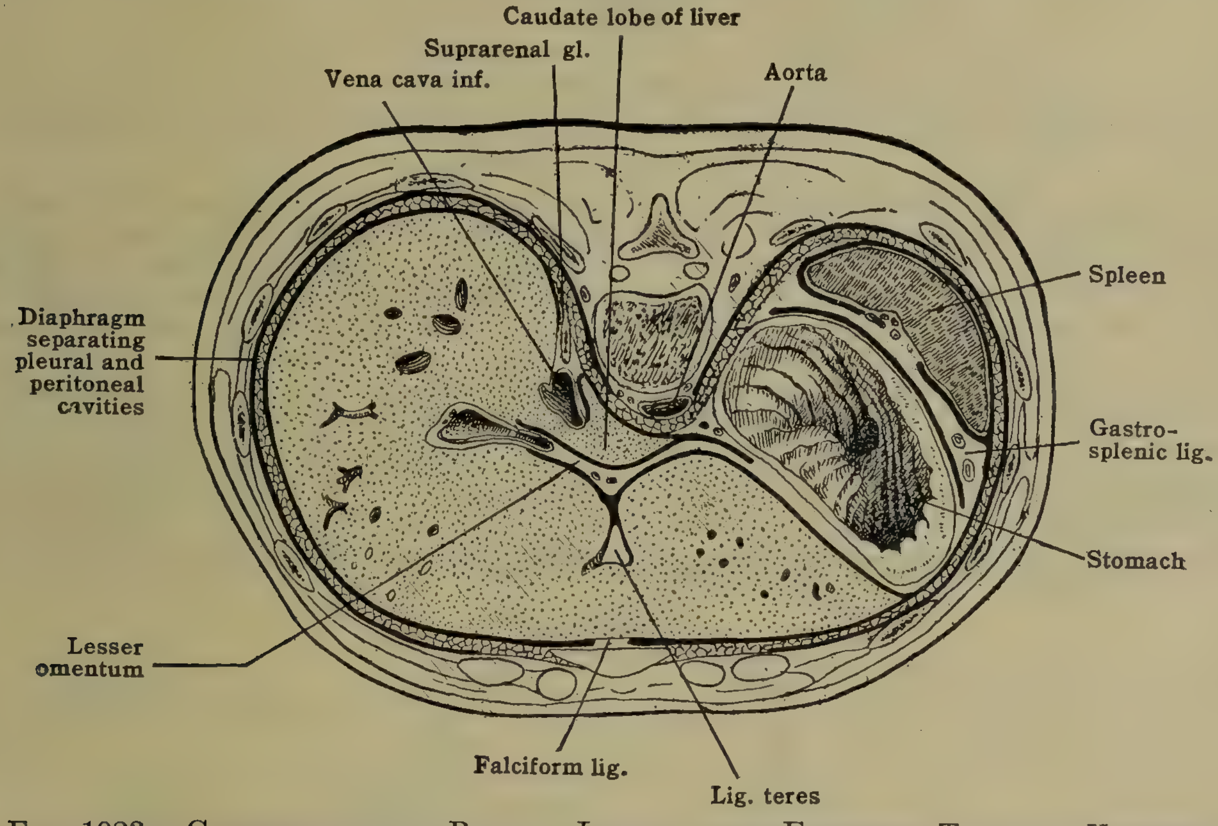


FIG. 1023.—CROSS-SECTION OF BODY AT LEVEL OF THE ELEVENTH THORACIC VERTEBRA. (Poirier-Charpy.)

mesogastrium extending from the stomach to the liver. It includes two parts, as shown in fig. 983.

The upper and larger part forms the *gastrohepatic* ligament [lig. hepatogastricum], connecting the liver (fossa ductus venosi) with the lesser curvature of the stomach. The upper part of this ligament is somewhat thicker [pars densa], the lower part [pars flaccida] thinner and more transparent. The relations of the lesser omentum in cross-section of the body are shown in figs. 979, 1023. The lower and right portion of the lesser omentum extends beyond the pylorus and connects the portal fissure with the duodenum, forming the *hepatoduodenal* ligament [lig. hepatoduodenale] (fig. 981). Its right free margin forms the anterior boundary of the epiploic foramen (of Winslow). Between its layers are located the root structures of the liver. A special prolongation of the hepatoduodenal ligament sometimes extends downward to the transverse colon, forming the *hepatocolic* ligament [lig. hepatocolicum].

Fixation of the liver.—The liver is to a certain extent fixed in place by means of its various ligaments, and especially posteriorly through the attachment of the hepatic veins to the inferior vena cava. On account of the close apposition of the liver to the diaphragm, the atmospheric pressure also helps in its support. Finally, the support of the liver, as well as of the abdominal viscera in general, is dependent to a considerable extent upon the tonic contraction of the abdominal muscles, which exerts a constant pressure upon the abdominal contents.

Blood-vessels.—The liver receives its *arterial* supply of blood from the hepatic artery, a branch of the celiac, which passes up between the two layers of the lesser omentum, and dividing into two branches, right and left, enters the liver at the portal fissure. The right branch gives off the cystic artery to the gall-bladder. The liver receives a much larger supply of blood from the *portal vein*, which conveys to the liver blood from the stomach, intestines, pancreas, and spleen. It enters the portal fissure, and there divides into two branches. Below this fissure the hepatic artery lies to the left, the bile-duct to the right, and the portal vein behind and between the two (fig. 1022). These three structures ascend to the liver between the layers of the lesser omentum in front of the epiploic foramen. At the actual fissure the order of the three structures from before backward is—duct, artery, vein (figs. 1024).

The *hepatic veins*, by which the blood of the liver passes into the inferior vena cava, open usually by two large and several small openings into that vessel on the posterior surface of the gland at the bottom of the fossa venæ cavæ.

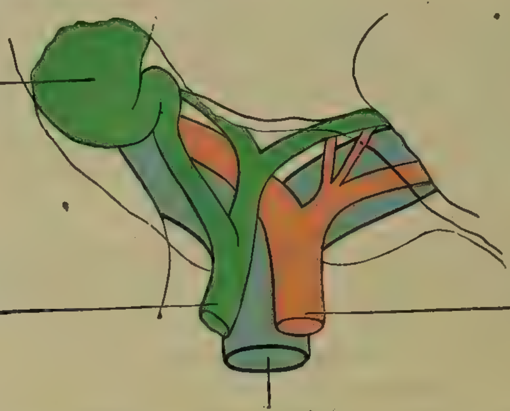


Fig. 1024.—Relation of Structures at and Below the Transverse or Portal Fissure. Anterior View. (Thane.)

Lymphatics.—The lymphatics are divided into a deep and a superficial set. The *deep set* runs with the branches of the portal vein, artery, and duct through the liver, leaving at the portal fissure, where they join the vessels of the superficial set. The efferent deep vessels after leaving the portal fissure pass down in the lesser omentum in front of the portal vein, through the chain of hepatic lymphatic nodes, and ultimately end in a group of nodes at the upper border of the neck of the pancreas, in which the pyloric lymphatics also terminate.

The *superficial set* begins in the subperitoneal tissue. Those of the *upper surface* consist: (1) Of vessels which pass up, principally, in the falciform ligament and right and left triangular ligaments, through the diaphragm, and so into the anterior mediastinal nodes, and finally into the right lymphatic duct. Some lymphatics of the right triangular ligament pass to the posterior mediastinal lymph-nodes and into the thoracic duct. (2) Of a set passing downward over the anterior border of the liver to the hepatic nodes in the portal fissure, and over the posterior surface to reach the posterior gastric and celiac nodes. On the lower surface, the lym-

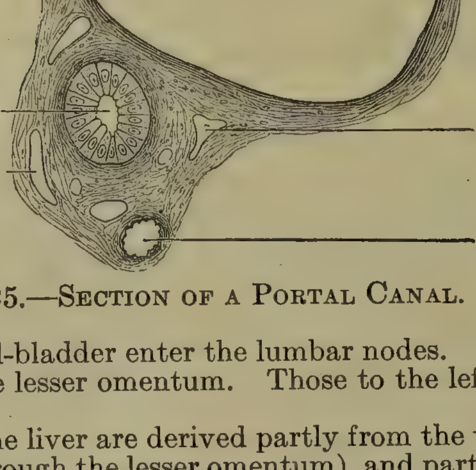


Fig. 1025.—Section of a Portal Canal. (Quain.)

phatics to the right of the gall-bladder enter the lumbar nodes. Those around the gall-bladder enter the hepatic nodes of the lesser omentum. Those to the left of the gall-bladder enter the superior gastric nodes.

Nerves.—The nerves of the liver are derived partly from the vagi (those from the left vagus entering from the stomach through the lesser omentum), and partly from the celiac plexus of the sympathetic (including right vagus branches) through a plexus accompanying the hepatic artery. The terminations, so far as known, are chiefly to the walls of the vessels and of the bile ducts.

Structure of the liver.—The liver is, for the greater part, covered by peritoneum, beneath which is found the fibroelastic layer known as Glisson's capsule. At the portal fissure, Glisson's capsule passes into the substance of the liver, accompanying the portal vessels, the branches of the hepatic artery, and the bile-ducts. The liver-substance is composed of vascular units

measuring from 1 to 2 mm., and known as liver-lobules. They appear as indistinct polygonal areas in sections and on the hepatic surface. These lobules are in part (man) separated by a small amount of interlobular connective tissue. In this connective tissue are found the terminal branches of the portal vessels, the hepatic artery, and the bile-ducts (figs. 1025, 1026). The branches of the portal vessels which encircle the liver lobules are known as the interlobular veins. From these are given off hepatic capillaries, which anastomose freely, but have in general a direction toward the center of the lobule, and unite to form the central or intralobular veins; these in turn unite to form the sublobular veins, and finally the hepatic veins.

The liver is a modified compound tubular gland. The liver-cells are arranged in anastomosing cords and columns occupying the spaces formed by the hepatic capillaries. The bile-ducts have their origin in so-called bile-capillaries [ductus biliferi], situated in the columns of liver-cells; they anastomose freely and pass to the periphery of the lobules to form the primary divisions of the bile-ducts, and these unite to form the larger bile-ducts. The branches of the portal vessel are accompanied in their course through the liver by the branches of the hepatic artery and the bile-ducts, surrounded by extensions of Glisson's capsule forming the so-called portal canals (fig. 1025). The branches of the hepatic vein are solitary, their walls are thin and closely adherent to the liver substance, hence they remain wide open on sectioning the liver.

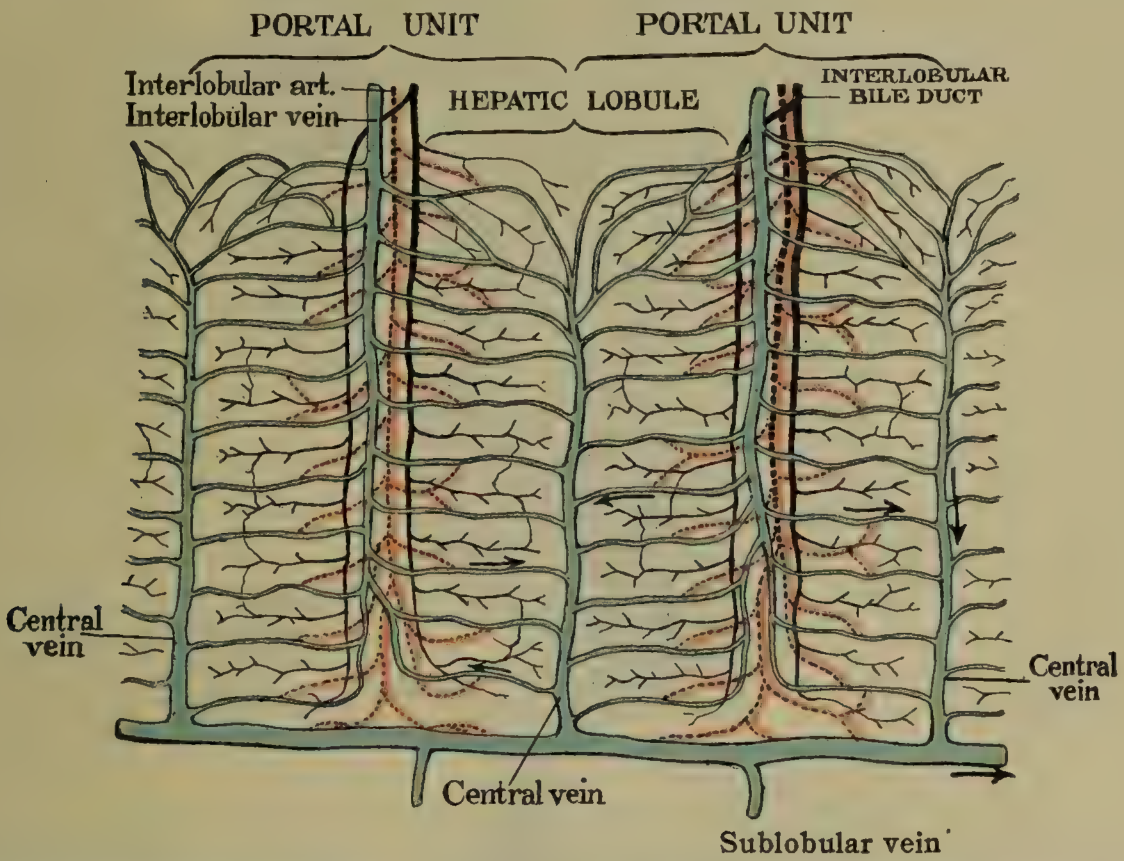


FIG. 1026.—DIAGRAM OF THE PORTAL UNIT AND VASCULAR RELATIONS OF THE HEPATIC LOBULE. (After Szymonowicz.)

While it is customary to describe thus the liver-lobules, it would be more logical to consider as the real lobules what Mall has described as the 'portal units.' Each portal unit includes the territory supplied by one interlobular branch of the portal vein, and drained by the accompanying bile-duct. The relations of the ordinary lobules and the portal units are evident in fig. 1026. The portal unit corresponds more clearly to the lobule of other glands, where the duct is in the center of the lobule.

Bile-passages.—The bile-passages, which transmit the bile from the liver to the duodenum, include the gall-bladder, the cystic duct, the hepatic ducts, and the common bile-duct.

The **gall-bladder** [vesica fellea], which retains the bile, is situated between the right and quadrate lobes on the lower surface of the liver. It is pear-shaped, and (when full) is usually seen projecting beyond the anterior border of the liver (figs. 1021, 1022), coming in contact with the abdominal wall opposite the ninth costal cartilage at the lateral margin of the right rectus muscle (fig. 1003). It extends upward and backward, toward the portal fissure.

It measures 7 to 10 cm. in length. It is 2.5 to 3.5 cm. across at the widest part, and will hold about 35 cc. (1¼ oz.). The broad end of the sac is directed forward, downward, and to the right, and is called the *fundus*. The narrow end, or *neck* [collum vesicæ felleæ], which is curved first to the right, then to the left, lies within the lesser omentum at the portal fissure. The intervening part is called the *body* [corpus vesicæ felleæ].

The fundus of the gall-bladder lies opposite to the right ninth costal cartilage, close to the lateral edge of the rectus. This point corresponds to the site of intersection of the lateral vertical and transpyloric lines (fig. 1003). It is near the hepatic flexure of the colon and the first part of the duodenum, into either of which, but particularly the latter, large gall-stones impacted in the neck of the gall-bladder occasionally ulcerate. A distended gall-bladder as it enlarges tends to extend downward or obliquely toward the umbilicus from the above point where it emerges from under the costal margin.

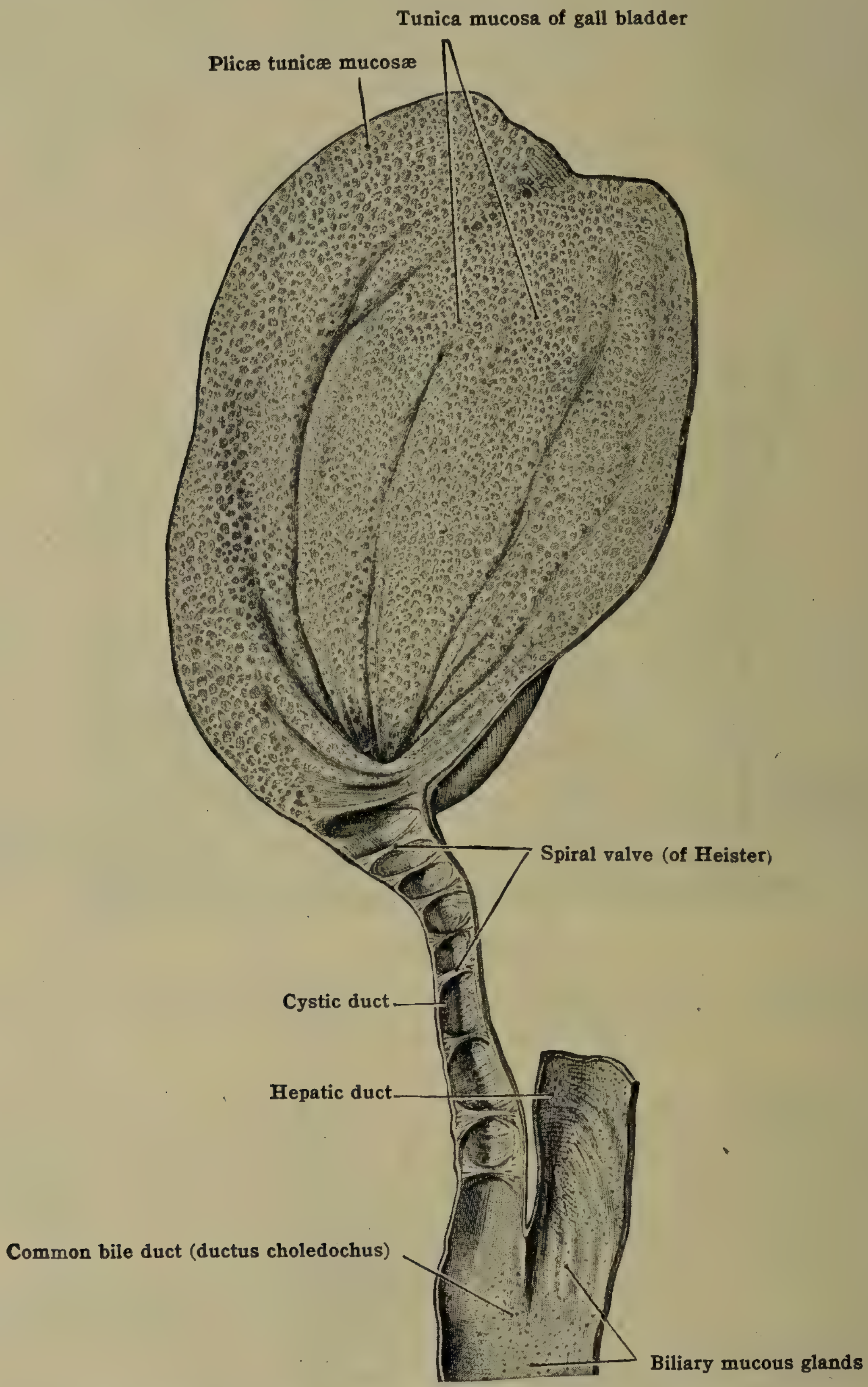


Fig. 1027.—Interior of the Gall-bladder and Ducts. (From Toldt's Atlas.)

The *upper surface* of the gall-bladder is in contact with the liver, lying in the fossa between the right and quadrate lobes. It is attached to the liver by fibrous connective tissue. The lower surface is covered by peritoneum, which passes over its sides and inferior surface. Occasionally it entirely surrounds the gall-bladder, forming a sort of mesentery attaching to the liver. The *lower surface* comes into contact with the first part of the duodenum and the transverse colon, and sometimes with the pyloric end of the stomach. These parts *post mortem* are found stained with bile.

The neck of the gall-bladder opens into the *cystic duct* [ductus cysticus]. This is a tube about 3.5 cm. long and 3 mm. wide, which unites with the hepatic duct to form the ductus choledochus; it is directed backward, to the left and down-

ward as it runs in the lesser omentum, accompanying the right branches of the hepatic artery and of the portal vein (fig. 1024). It joins the hepatic duct at an acute angle, and presents a spiral valve [valvula spiralis; Heisteri], formed by its mucous coat (fig. 1027). This spiral valve is supposed to keep the lumen open for the flow of bile. It adds to the difficulty of passing a bougie from the gall-bladder down into the common duct.

The *hepatic duct* [ductus hepaticus] begins in the portal fissure with a branch from each lobe, right and left (that from the left receiving also the ducts from the caudate lobe); it is directed downward and to the right in the lesser omentum (hepatoduodenal ligament), the right branch of the hepatic artery being behind and the left branch to the left. It is from 3 to 5 cm. long; its diameter is about 4 mm. Uniting with the cystic duct, it forms the *common bile-duct* [ductus choledochus].

It should be emphasized that the cystic duct runs parallel and rather close to the right and common hepatic ducts (figs. 1024, 1029). Injury or ligation of the hepatic duct sometimes occurs in the removal of the gall-bladder, through failure to realize the close proximity of these ducts.

The **ductus choledochus** or **common bile-duct** is about 7.5 cm. in length and 6 mm. in width. It passes down between the layers of the lesser omentum, in front of the portal vein, and to the right of the hepatic artery (fig. 1024); it then passes behind the first part of the duodenum, then between the descending duodenum and the head of the pancreas, being almost completely embedded in the latter. The ductus choledochus ends a little below the middle of the descending duodenum by opening into that part of the intestine on its left side and somewhat behind (figs. 1029, 1034).

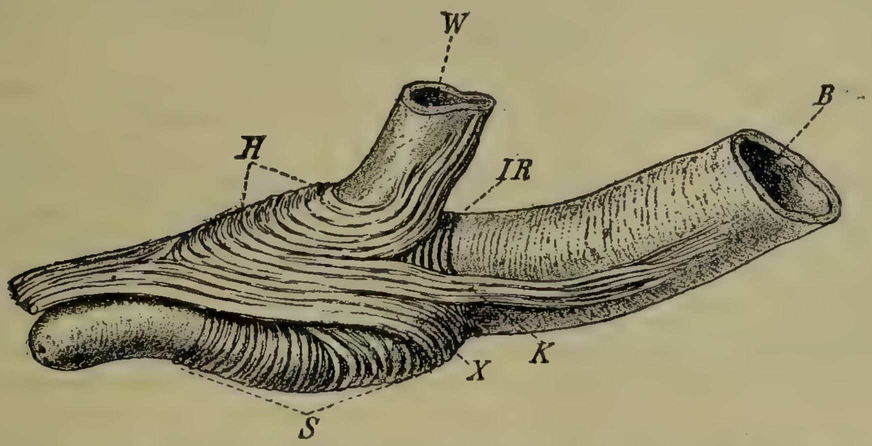


Fig. 1028.—Macerated Duodenal Portion of the Common Bile-duct, Showing Oddi's Sphincter. *B*, common bile-duct. *W*, pancreatic duct (of Wirsung). *S*, *IR*, sphincter fibers of bile-duct. *H*, sphincter fibers of pancreatic duct. (Hendrickson.)

The pancreatic tissue completely surrounds the common bile duct in 75 per cent. of all cases (Bunger); this may account for the jaundice that occurs in chronic interstitial pancreatitis.

Along the common bile duct are a few small lymph-nodes (fig. 1029), the enlargement or calcification of which may be of clinical importance. The common bile-duct pierces the intestinal wall very obliquely, running through the wall obliquely for a distance of about 1 to 2 cm. There is a slight constriction at its termination. The pancreatic duct is generally united with the ductus choledochus just before its termination, and there is a slight papilla (papilla major) at their place of opening on the mucous surface of the duodenum. This papilla is about 8 or 10 cm. from the pylorus. After the pancreatic duct has entered the bile-duct there is (in about half the cases) a dilation of the common tube called the **ampulla of Vater** (fig. 1029).

In its oblique course through the duodenal wall, the common bile-duct is accompanied by the pancreatic duct, the two together usually causing the plica longitudinalis duodeni. Circular muscle fibers join with bundles of longitudinal fibers at the lower part of the ducts and form a sphincter, known as 'Oddi's sphincter' (fig. 1028). Contraction of the sphincter probably closes the orifice of the common bile-duct, so that (except during digestion) the bile is backed up into the gall-bladder.

Structure of the gall-bladder.—The wall of the gall-bladder is made up of three coats—mucosa, fibromuscular and serosa.

1. The *mucosa* (fig. 1027) is raised into folds bounding polygonal spaces, giving the interior a honeycomb appearance. It is lined with columnar epithelium, and contains a few tubular mucous glands and lymph-nodules, and is limited externally by a poorly developed muscularis mucosæ. At the neck the mucous membrane forms valve-like folds which project into the interior. This layer contains an anastomosis of blood-vessels, the capillaries being most numerous in the folds of the mucosa. There is also a fine plexus of lymphatics.

2. The *fibromuscular coat* consists of interlacing bundles of smooth muscle and fibrous tissue not definitely arranged, the muscular bundles running longitudinally and obliquely. This layer contains the principal blood-vessels and lymphatics, and also a nerve plexus.

3. The *serosa*, formed by the peritoneum, is found only on the sides and lower surface.

The bile *ducts* consist of a fibromuscular and a mucous layer. In the fibromuscular layer are smooth muscle-cells which are chiefly circular, together with white fibrous tissue and elastic fibers. The lining mucosa has many mucous glands. In the cystic duct the mucous membrane is raised into folds (spiral valve of Heister), which are crescentic in form, and directed so obliquely as to surround the lumen of the tube in a spiral manner.

The development of the liver.—For the earlier stages, see Section I, p. 50. The definite hepatic lobules are not differentiated until after birth. The process of the development of the lobules is very complicated, the vascular arrangement being shifted repeatedly (Mall).

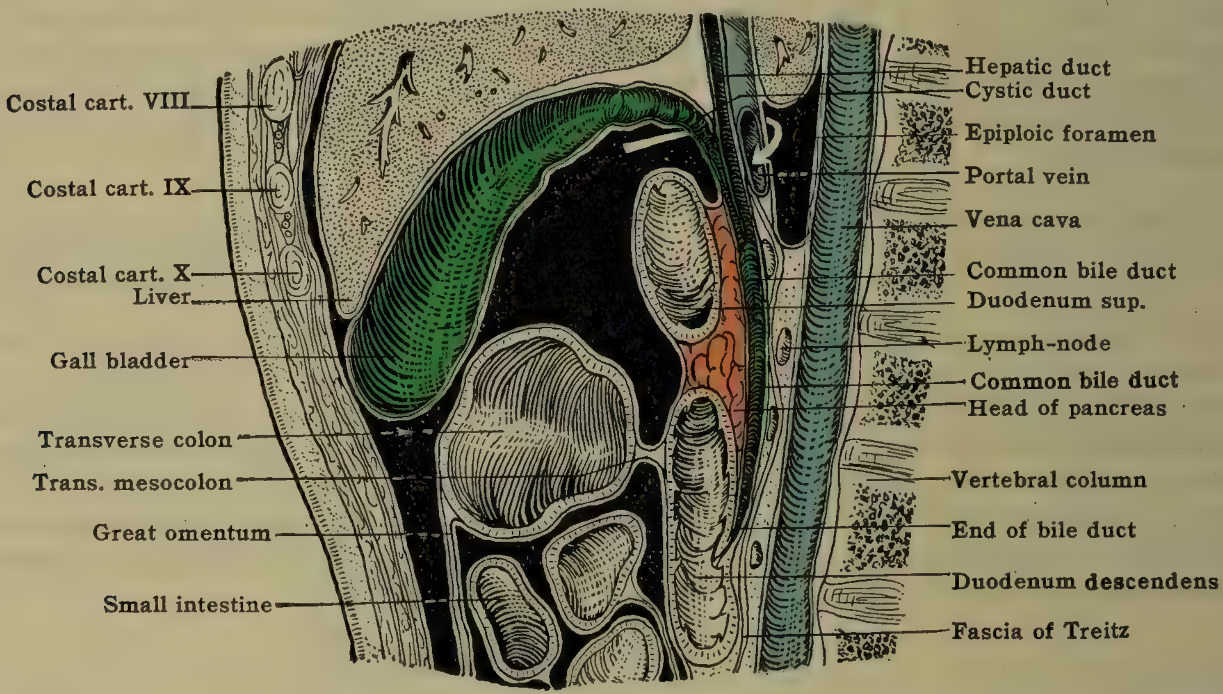


Fig. 1029.—Relations of Gall-bladder and Bile-ducts in Sagittal Section. (Semidiagrammatic.) (After Testut and Jacob.)

The embryonic liver rapidly enlarges, filling the upper portion of the abdominal cavity, and extending along its ventral wall to the region of the umbilicus. During the enlargement it outgrows the transverse septum (fig. 1030), and there are developed grooves representing an infolding of the peritoneum covering the transverse septum, and which in part separate the developing liver from that part of the septum destined to form the diaphragm, and also from the ventral abdominal wall. These grooves appear at the sides and also ventral to the liver, but do not completely separate the liver from the diaphragm, nor do they meet in the median line. A portion of the liver, therefore, remains uncovered by peritoneum, and continues attached to the

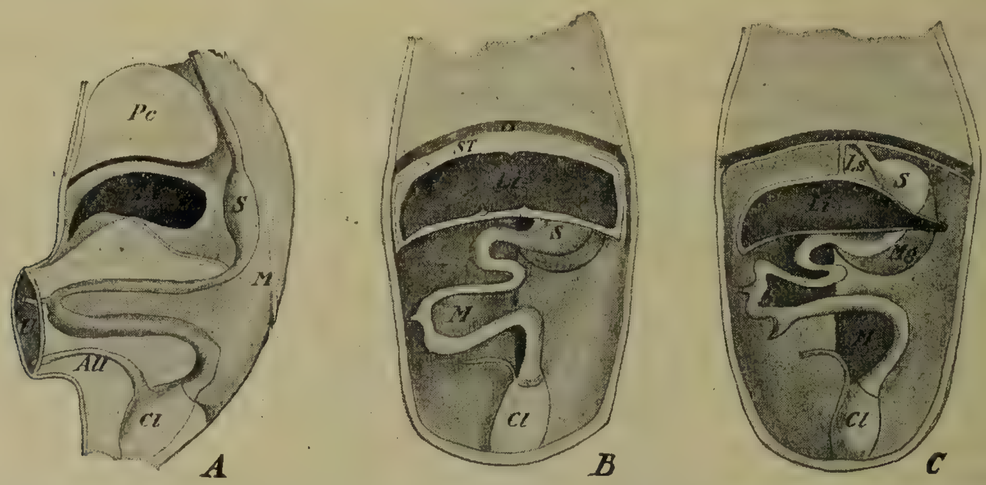


Fig. 1030.—Diagram: (A) A Sagittal Section of an Embryo Showing the Liver enclosed Within the Septum Transversum; (B) A Frontal Section of the same; (C) Frontal Section of a Later Stage when the Liver has Separated from the Diaphragm.

All, Allantois; *Cl*, cloaca; *D*, diaphragm; *Li*, liver; *Ls*, falciform ligament of the liver; *M*, mesentery; *Mg*, mesogastrium; *Pc*, pericardium; *S*, stomach; *ST*, septum transversum; *U*, umbilicus. (McMurrich.)

diaphragm at the 'bare area' of the liver. Around this area the peritoneum of the liver is reflected onto the diaphragm, forming the coronary ligament, with right and left extensions, designated as the right and left triangular ligaments. Where the grooves fail to meet in the anterior midline, there persists a fold of peritoneum, the falciform ligament, which represents the ventral portion of the primitive ventral mesentery and attaches the liver to the ventral abdominal wall. The dorsal portion of the ventral mesentery (mesogastrium) persists between the liver and stomach to form the lesser omentum. The developing liver early comes into intimate

relation with the omphalomesenteric (vitelline) veins, and later the umbilical veins. The developmental history of these veins and their relation to the developing liver is discussed elsewhere (see p. 37). After birth the left umbilical vein forms the hepatic ligamentum teres, situated in the free edge of the falciform ligament. The ductus venosus likewise atrophies to form the ligamentum venosum. For the growth of the liver and gall-bladder, see p. 50.

Variations of the liver and bile-passages.—Many variations of the liver have already been mentioned. In *size*, both relative and absolute, it is subject to marked individual variations, as well as according to age and sex (previously described). In *form*, the liver is also quite variable. There are two extreme types: (1) in which the liver is very wide, extending far over into the left hypochondrium, but relatively flattened from above downward; and (2) in which it extends but slightly to the left, being somewhat flattened from side to side, and elongated vertically. This type may occur as a result of tight lacing, in which the liver is frequently deformed. The part projecting below the right costal margin may form the so-called '*Riedel's lobe.*' All intermediate forms between these two types occur. Its *position and relations* will also vary necessarily according to differences in size and shape. For example, in the wide type and also in enlarged livers, the left lobe may extend over upon the spleen, a relation which is constant during prenatal life. The liver is relatively large during infancy. It may be displaced downward by pleuritic effusions or tight lacing. Associated with the general state of visceroptosis, there may also be a descent of the liver (hepatoptosis or 'floating liver)'. There are likewise occasional displacements of the liver with rotation forward or to the right (Bourcart).

There may be *supernumerary fissures*, dividing the liver into additional lobes, as many as 16 having been described in an extreme case (Moser). These extra fissures often correspond to fissures which are normal in other mammals. There may also be *accessory lobes*, usually small, and connected with the main gland by stalks. Any one of the normal lobes may be *atrophied* or absent. There may also be *abnormal grooves* on the parietal surface of the liver. Of these, there are two varieties: (1) *costal* grooves, due to impressions of the overlying ribs and costal cartilages; and (2) *diaphragmatic* grooves, due to wrinkles in the diaphragm. These grooves most frequently occur in females. The *appendix fibrosa* has already been mentioned. There are numerous variations in the *vascular* arrangements, as well as in the *peritoneal* relations (particularly in connection with the coronary ligament).

The *bile-passages* are even more variable than the liver proper. Anomalies occur in about 10 per cent. of all cases (Mentzer). The *gall-bladder* is variable in size and capacity (25 to 50 cc. or more), as well as in its position and relations. The fundus projects to a variable extent beyond the anterior margin of the liver so as to come into contact with the abdominal wall in a little more than half the cases, but is often retracted. The *fossa* of the gall-bladder is of variable depth, rarely so deep that it reaches the superior surface of the liver. The peritoneum usually covers only the sides and inferior surface of the gall-bladder, but occasionally surrounds it entirely, forming a short 'mesentery.' In rare cases the gall-bladder is bifid or double (Boyden), and is occasionally absent. There are numerous variations in the *bile-ducts*. Rarely the hepatic ducts may communicate directly with the gall-bladder. The point at which hepatic and cystic ducts unite is variable, which affects the relative lengths of these and the ductus choledochus. The latter may open into the duodenum separately, instead of with the pancreatic duct.

Comparative.—The liver arises in all vertebrates as an outgrowth of the entodermic epithelium of the intestine just beyond the stomach. In amphioxus it remains a simple saccular diverticulum, but in higher forms becomes a compound tubular gland. The tubular character becomes masked, however (in amniota, and especially in mammals), by the abundant anastomosis between the tubules, forming what is called a 'solid' gland. The relations with the portal venous system are constant. The liver frequently stores large quantities of fat, and may even undergo a complete fatty metamorphosis (lamprey). The color of the liver is usually reddish-brown, but may be yellow, purple, green or even vermilion (due to bile pigments). In *size*, the liver is variable, but is usually relatively larger in anamniota. Among mammals, there is great variation according to diet, the liver being relatively larger in carnivora, smaller in herbivora, and intermediate in omnivora (including man). It is also relatively larger in *small* animals (including young and fetal stages), probably on account of their more intense metabolism. There are typically two lobes, right and left, in the vertebrate liver. These are frequently subdivided, however, especially in mammals, which often present numerous lobes.

The **gall-bladder** is typically present, as in man, but varies in form, size and position. It may be completely buried in the liver. In some species it is absent, in which case the hepatic ducts open directly into the duodenum by one or more apertures. The hepatic and cystic ducts typically unite to form a common bile-duct, as in man, but there are numerous variations in the detailed arrangement of the ducts (Mentzer).

THE PANCREAS

The **pancreas** (figs. 994, 995, 1031, 1032, 1033) is an elongated gland extending transversely across the posterior abdominal wall behind the stomach from the duodenum to the spleen. Through the pancreatic ducts, opening into the descending duodenum, flows its secretion [succus pancreaticus].

The pancreas is grayish-pink in color. Its average length (*in situ*) is 12 cm. to 15 cm.; average weight about 85 gm. (extremes 60 gm. to 100 gm. or more). Its specific gravity, 1.047, is about the same as that of the salivary glands.

In *position*, the pancreas lies in the epigastric and left hypochondriac regions. In *form* it somewhat resembles a pistol, with the handle placed to the right and the barrel to the left. The pancreas is accordingly divided into a *head*, lying

within the duodenal loop; a *body*, extending to the left; and a *tail*, or splenic extremity.

The **head** [caput pancreatis] is a discoidal mass somewhat elongated vertically and flattened dorsoventrally. It forms the enlarged right extremity of the pancreas and lies within the concavity of the duodenum (figs. 994, 995, 1031). Its *relations* are as follows: Its *posterior* surface is placed opposite the second and third lumbar vertebræ, and is in contact with the aorta, the vena cava, the renal veins and right renal artery. The common bile-duct is also partly embedded in this surface. Its *anterior* surface is crossed by the transverse colon, above which is the pyloric extremity of the stomach, and below which are coils of small intestine. Upon this surface are also the pancreaticoduodenal and (in part) the superior mesenteric vessels.

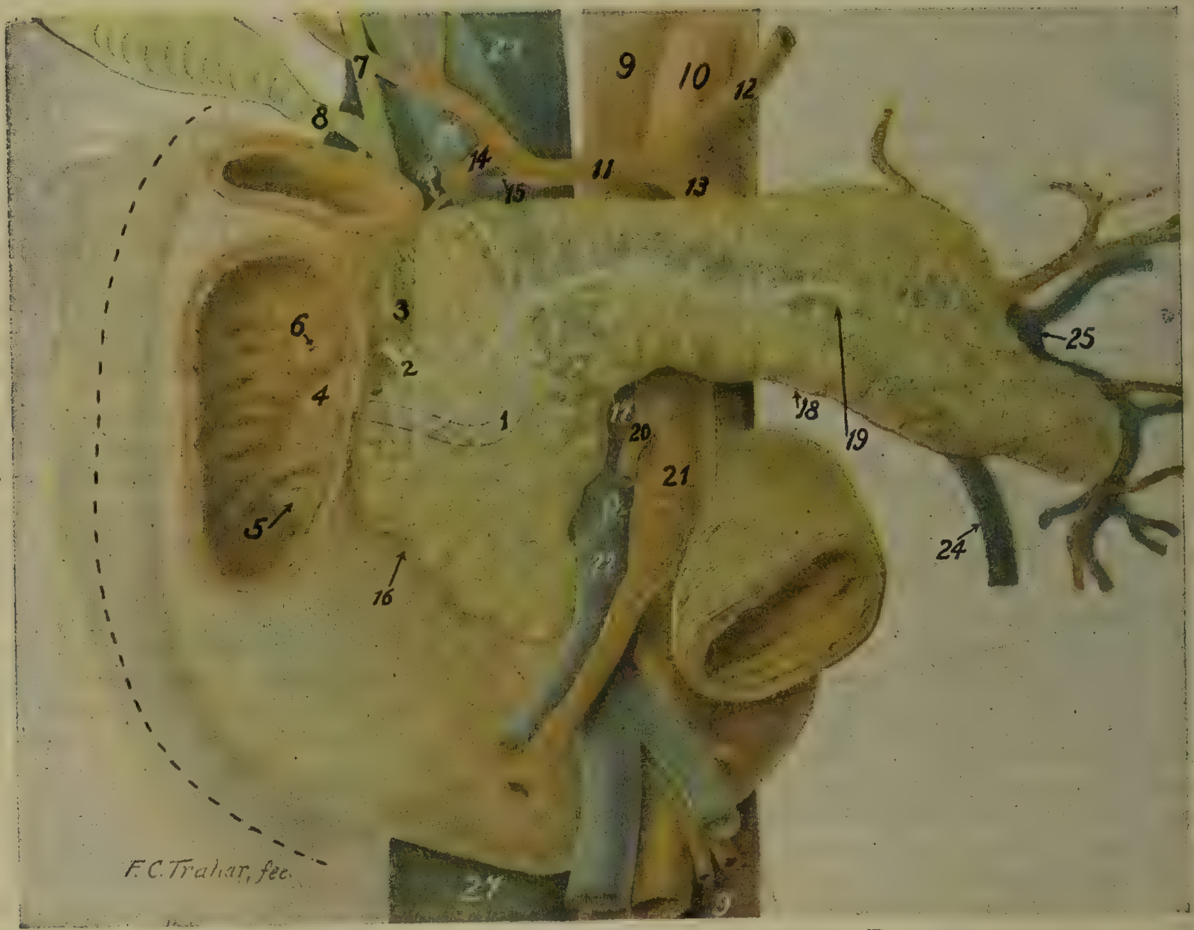


FIG. 1031.—ANATOMY AND RELATIONS OF THE PANCREAS.

1, main duct of Wirsung. 2, accessory duct of Santorini. 3, common bile-duct. 4, plica longitudinalis duodeni. 5, papilla major. 6, papilla minor. 7, hepatic duct. 8, cystic duct. 9, abdominal aorta. 10, celiac artery. 11, hepatic artery. 12, left gastric artery. 13, splenic artery. 14, gastroduodenal artery. 15, right gastric artery. 16, superior pancreatoduodenal artery. 17, inferior pancreatoduodenal artery. 18, inferior pancreatic artery. 19, pancreatica magna artery. 20, middle colic artery. 21, superior mesenteric artery. 22, superior mesenteric vein. 23, middle colic vein. 24, inferior mesenteric vein. 25, splenic vein. 26, portal vein. 27, vena cava.

Black dotted line indicates site for mobilizing duodenum. White dotted line (including 22) represents position of uncinate process running behind mesenteric vessels. (Coffey; in Binnie's Regional Surgery.)

The *margin* of the head of the pancreas is C-shaped, corresponding to the inner aspect of the duodenal loop, with which it is closely related. *Superiorly* the margin is in contact with the pylorus and first part of the duodenum; *on the right,* with the descending duodenum and the terminal portion of the common bile-duct; *inferiorly*, with the horizontal, and *on the left,* with the terminal ascending portion of the duodenum.

The lower and left portion of the head of the pancreas is hooked around behind the superior mesenteric vessels, forming the **processus uncinatus** or pancreas of Winslow. A groove, the *pancreatic notch* [incisura pancreatis], is thus formed for these vessels. The morphology of this process is explained later under development (fig. 1033).

In the adult condition, the head of the pancreas is largely *retroperitoneal.* The only portions covered by peritoneum are (1) a small area above the attachment of the colon, and in relation with a pocket-like recess of the bursa omentalis, and (2) a small area below the transverse colon, that is in relation with coils of small intestine. The mesentery of the small intestine begins where the superior mesenteric vessels pass downward from in front of the processus uncinatus.

The junction of the upper and left aspect of the head with the body of the pancreas is called the *neck*. This is a somewhat constricted portion grooved *posteriorly* by the superior mesenteric vessels, the vein here joining with the splenic to form the portal vein (fig. 995). *Anterior* to the neck is the pyloric portion of the stomach. The upper portion of the neck (together with a variable area on the left end of the body) projects above the lesser curvature of the stomach. This projection [*tuber omentale*] is related, through the lesser omentum, with a similar tuberosity on the left lobe of the liver. The anterior aspect of the neck is covered with peritoneum of the bursa omentalis (lesser sac), and is continuous with the anterior surface of the body of the pancreas (figs. 994, 1031).

The **body** [corpus pancreatis] is the triangularly prismatic portion of the pancreas extending from the neck on the right to the tail on the left. Its *direction* is transversely to the left and (usually) somewhat upward (fig. 1032). It is therefore usually placed at a somewhat higher level than the head, opposite the first lumbar vertebra. It presents three surfaces—anterior, posterior, and inferior—and three borders—superior, anterior, and posterior.

Of the **surfaces**, the **anterior** [facies anterior] faces forward and somewhat upward. It is covered with the peritoneum of the posterior wall of the bursa omentalis (lesser sac), and forms a slightly concave area which is in contact with the posterior surface of the stomach (figs. 672, 980, 982). The **posterior** surface [f. posterior] of the body of the pancreas is flattened and retroperitoneal. From right to left it crosses the anterior aspect of aorta, left suprarenal body and left kidney. The splenic vessels also run along the posterior surface, the artery, which is above, corresponding more nearly with the superior border. The **inferior** surface [f. inferior] is usually the narrowest of the three. It is covered by peritoneum (continuous with the lower layer of the transverse mesocolon) and is in contact with the duodenojejunal flexure medially and with coils of jejunum laterally.

Of the **borders**, the **superior** [margo superior] is related with the splenic artery along its whole length from its origin in the celiac, and the **posterior** [margo posterior] separates posterior and inferior surfaces. The **anterior** border [margo anterior] is sharp and prominent. It gives attachment to the transverse mesocolon (fig. 672), whose upper layer (belonging to the lesser sac) is continuous with that on the anterior surface of the pancreas, and whose lower layer (belonging to the greater sac) is continuous with that on the inferior surface.

The **tail** of the pancreas [cauda pancreatis] is at the left extremity of the body. It is variable in form, but usually somewhat blunted and upturned. It is almost invariably in contact *laterally* with the medial aspect of the spleen, and *inferiorly* with the splenic flexure of the colon. The splenic vessels often cross from above in front of the tail of the pancreas on their way to join the spleen (fig. 1033).

A cyst originating in the pancreas may 'point' toward the anterior abdominal wall by three routes (which may also be used to reach the pancreas and to establish drainage):—(1) Above the stomach through the lesser omentum; (2) between stomach and transverse colon through the great omentum; (3) below the transverse colon through the transverse mesocolon. The posterior aspect of the head of the gland, with the third part of the common bile duct may be exposed by incising the peritoneum on the lateral margin of the second part of the duodenum, and turning the gut medially toward the midline.

Ducts.—The pancreas has usually two ducts, the main pancreatic duct and the accessory duct. The *major pancreatic duct* (*of Wirsung*) [ductus pancreaticus; Wirsungi] begins in the tail of the pancreas, and extends to the right within the body of the pancreas, about midway between upper and posterior borders, but nearer the posterior surface (fig. 1031). It runs a slightly sinuous course receiving branches all along, which enter nearly at right angles. It is largest in the head of the pancreas (diameter about 3 mm.) where it turns obliquely downward, to end, with the common bile duct, in the descending duodenum.

As the pancreatic duct approaches the duodenum, it is joined by the common bile-duct, the two running side by side. They pass obliquely through the wall of the duodenum for a distance of about 15 mm. (usually causing a fold of the mucosa, the plica longitudinalis duodeni). They terminate finally, either by a common aperture, or separately, on the duodenal *papilla major*, as described in connection with the interior of the duodenum (fig. 1031). The common aperture is somewhat narrow, but just preceding this the lumen is frequently dilated, forming what is called the *ampulla of Vater*. A gall-stone impacted in the ampulla may cause a flow of bile backward along the duct of Wirsung, and so give rise to acute pancreatitis (Opie).

The *minor* or *accessory pancreatic duct* (of Santorini) is usually present (fig. 1031), but variable. This duct is small, and lies within the head of the pancreas, terminating in the papilla minor of the duodenum.

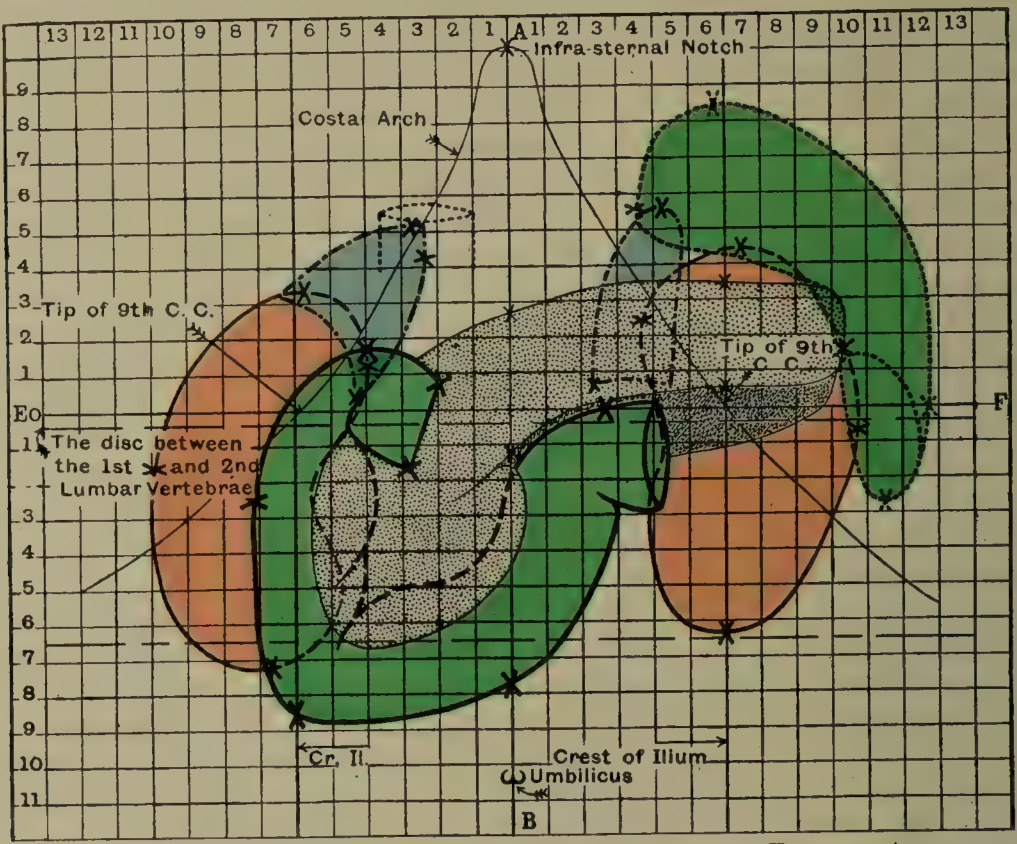


FIG. 1032.—OUTLINE SHOWING THE AVERAGE POSITION OF THE DEEPER ABDOMINAL VISCERA IN 40 BODIES, ON A CENTIMETER SCALE (reduced to 0.36 natural size). *EF*, midepigastric or transpyloric line. A B, midline. (Addison.)

At its left end, it usually joins the main duct in the neck of the pancreas. From here it extends nearly horizontal across to the upper part of the descending duodenum and, piercing its wall, usually ends upon the small *papilla minor*, about 7 cm. below the pylorus and 2 cm. above the papilla major. The relations of the ducts are explained by the development.

Blood-vessels.—The pancreas receives blood chiefly from the splenic artery through its pancreatic branches, and from the superior mesenteric and hepatic by the inferior and superior

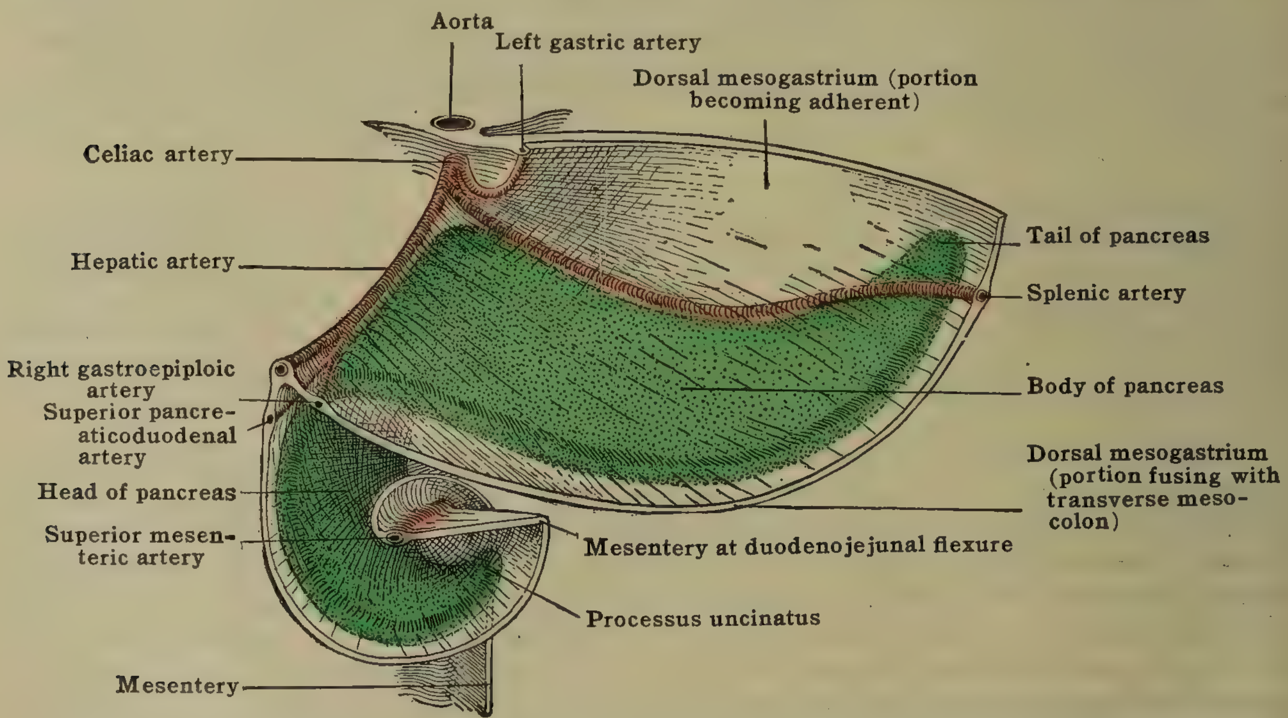


FIG. 1033.—DIAGRAM SHOWING THE RELATIONS OF THE PANCREAS TO THE PRIMITIVE MESENTERY. (Poirier-Charpy.)

pancreaticoduodenal arteries, which form a loop running around, below, and to the right of its head (fig. 1031). The blood is returned into the portal vein by means of the splenic and superior mesenteric veins.

Lymphatics.—The lymphatics terminate in numerous glands which lie near the root of the superior mesenteric artery, above and below the neck of the pancreas. All the lymphatics drain ultimately into the celiac glands.

Nerves.—These are branches of the celiac plexus which accompany the arteries entering the gland. The main part of the celiac plexus lies behind the pancreas.

Minute anatomy.—In many respects, the pancreas resembles the salivary glands in structure, hence its German name 'Bauchspeicheldrüse' ('abdominal salivary gland'). The gland proper is racemose (or tubuloracemose) in structure. The thin-walled intercalary ducts, often invaginated to form centroacinar cells, are characteristic. The lobules are very loosely joined by areolar tissue, and there is no distinct fibrous capsule around the gland. The most important of the distinctive characters of the pancreas is the presence throughout the gland of numerous small interlobular cell-masses of varied form and size—the *islets of Langerhans* (fig. 1034). The total number of islets in the human pancreas varies from 200,000 to 1,750,000 (Maximow-Bloom). These have no ducts, but are richly supplied with blood-vessels. They are ductless glands whose secretion (insulin) is of great importance in sugar metabolism, and their removal or disease produces diabetes. They are derived embryologically from the same entodermal anlage which gives rise to the pancreatic gland proper, and often remain attached to the ducts. The islets are numerous in late fetal stages and continue to arise up to the fourth year in the human pancreas (Nakamura). Under abnormal conditions, islets may arise even in adults, as buds from the smaller pancreatic ducts, but not through transformation of the acini.

Development of the pancreas.—The earlier stages of development of the pancreas are described in Section I, p. 50. Of the adult gland, only the lower portion of the head is derived from the primitive ventral anlage, although the duct of the latter drains nearly the entire adult

Fig. 1034.—Section of Human Pancreas, Magnified, Showing Several Islets of Langerhans. (Radasch.) *a*, interlobular connective tissue, containing an interlobular duct, *c*. *b*, capillary. *d*, interlobular duct. *e*, alveoli. *f*, islet of Langerhans.

gland. The upper part of the head of the pancreas, and all of the body and tail are derived from the dorsal anlage; although most of its duct later joins with the duct of Wirsung to form the main pancreatic duct, only a small part persisting as the accessory duct of Santorini.

During the early stages in the development of the pancreas the entodermal buds from which it forms grow into the mesoduodenum, and later the dorsal mesogastrium. With the rotation of the stomach and the consequent change in the position of the mesogastrium and its dartial fusion with the abdominal wall (see *General morphogenesis*, p. 1232), the pancreas assumes a retroperitoneal position. This is illustrated by fig. 1033. The head of the pancreas is involved in the rotation of the primitive intestinal loop around the superior mesenteric artery, as shown in fig. 1033. This accounts for the position and the hook-like form of the processus uncinatus. Following this rotation, the duodenum and the head of the pancreas become pressed backward against the posterior abdominal wall, where they become adherent, with fusion and obliteration of the primitive peritoneum. The body of the pancreas, extending into the dorsal mesogastrium (fig. 976), is similarly caught in the pouch-like downgrowth of the latter to form the bursa omentalis (lesser sac), and is thereby carried over to the left side. When the posterior layer of the primitive bursa fold becomes fused with the posterior abdominal wall, the enclosed pancreas is likewise fixed and becomes retroperitoneal. Of these obliterated peritoneal layers of the embryo, only certain layers of fascia remain as their representatives in the adult. From the lower aspect of the pancreas downward, the posterior layer of the bursa fold becomes fused with the transverse mesocolon, so that in the adult the latter appears to arise from the anterior border of the pancreas (fig. 980).

Variations.—Aside from minor fluctuations in size and form, the variations of the pancreas are chiefly congenital and of embryonic origin. Cases of *accessory or supernumerary pancreas* are not rare. They are usually of small size and have separate ducts. They may occur along the wall of the duodenum, or even in the stomach or jejunum. They are perhaps in some way connected with the numerous intestinal diverticula which occur in the embryo. *Divided pancreas* differs from the accessory in that a mass of the pancreas becomes separated from the

main gland, connected only by a duct. This occurs oftenest in the region of the tail (sometimes extending into the spleen) or of the processus uncinatus, forming what is termed a 'lesser pancreas.' Sometimes a ring of glandular tissue from the head of the pancreas surrounds the descending duodenum, forming an *annular pancreas.* Variations in the *direction* of the body are numerous; it may be horizontal, ascending or bent in various ways. These are doubtless congenital variations, as similar types have been described in the fetus (Jackson). It has been experimentally demonstrated that varying degrees of distention of the stomach and intestines affect profoundly the *form of the body* of the pancreas. When the stomach alone is distended, the pancreas is flattened anteroposteriorly, the inferior surface being practically obliterated. When *both* stomach and intestines are distended, the pancreas is flattened from above downward, and extends forward like a shelf, the posterior surface being much reduced (Jackson). Numerous variations in the *ducts* are easily understood from their complicated development. The accessory duct (of Santorini) is in the fetus as large as the main duct (of Wirsung), the preponderance of the latter being established later. The accessory duct in the adult may be larger than usual, and retain its primitive drainage, or even drain the entire gland in rare cases where the duct of Wirsung is absent. Or the accessory duct may be rudimentary or (rarely) absent. Similar variations occur in the main duct of Wirsung. Rarely the pancreas may open into the duodenum by three ducts, probably representing three embryonic anlages. Abnormalities of the pancreas are often associated with duodenal diverticula.

Comparative.—The pancreas, like the liver, is constant throughout the vertebrates. It always arises by budding off from the endodermal epithelium of the intestine, closely associated with the liver. There is typically a triple anlage (rarely multiple, which is perhaps the ancestral type), with one dorsal and two ventral outgrowths. These fuse and form the adult pancreas in a variety of ways. In many of the fishes, the pancreas is very small, diffuse and inconspicuous, sometimes embedded in the liver or intestinal wall. Of the three primitive ducts, usually only two persist (as in man), but often only one, or all three (in birds). All three types occur in mammals. The islets of Langerhans arise from the epithelial pancreas anlage, and appear to be constantly present, even in the lowest vertebrates. Laguesse even considers that phylogenetically they form the most primitive part of the pancreas, but this is doubtful.

References for digestive system.—*General and Comparative:* Quain's Anatomy; Poirier-Charpy, Traité d'anatomie; Rauber-Kopsch, Lehrbuch der Anatomie; Oppel, Mikroskopische Anatomie, Bd. 1–3; also 'Verdauungsapparat' in Merkel and Bonnet's 'Ergebnisse'; Wiedersheim, Bau des Menschen; Huntington, Anatomy of the Peritoneum and Abdomen; von Möllendorff, Handbuch der mikroskopische Anatomie des Menschen, Bd. 5; Maximow and Blum, Textbook of Histology. *Topography:* (adult) Merkel, Topographische Anatomie; (developmental) Jackson, Anat. Rec., vol. 3; (*X*-ray) Moody, Amer. Jour. Anat., vol. 37, Anat. Rec., vol. 43. *Development:* Keibel and Mall's Manual. *Teeth:* Tomes, Dental Anatomy; Bean, Amer. Jour. Anat., vol. 17, 1914; James and Pitts, Proc. Roy. Soc. Med., vol. 5, 1912; Brekhus (Loss of teeth), U. of Minnesota Press, 1928 (also J. Am. Dental Assn., 1929, vol. 16, p. 2237). *Lingual papillæ:* Jurisch, Zeitschr. f. Anat. u. Entw., Bd. 23. *Tonsils:* (lingual) Jurisch, Anatomische Hefte, Bd. 47; (pharyngeal) Symington, Brit. Med. Jour. (Oct., 1910); (palatine) Killian, Archiv. f. Laryngol., Bd. 7. *Esophagus:* Goetsch, Amer. Jour. Anat., vol. 10. *Stomach:* (form) Cunningham, Trans. Royal Soc. Edinb., vol. 45; (radiography) Cole, Archives Roentgen Rays, 1911; Forssell, Fortschr. auf dem Gebiete der Röntgenstr., Ergängungsband 30, 1913; Mills, Amer. Jour. Roentg., Apr. 1917; Müller, Ergeb. d. Anat. u. Entw., Bd. 23. *Intestines:* Van der Reis u. Schembra, Ergeb. d. Anat. u. Entw., Bd. 27, Schaller, Zeitschr. f. Anat. u. Entw., Bd. 85. *Vermiform process:* Berry and Lack, Jour. Anat. and Phys., vol. 40; Wakeley and Gladstone, Jour. Anat., vol. 63. *Rectum:* Symington, Jour. Anat. and Phys., vol. 46; Schaller, Zeitschr. f. Anat. u. Entw., Bd. 85. *Liver:* Mall, Amer. Jour. Anat., vol. 5; (displacements) Bourcart, Arch. Anat., Hist. et Embr., vol. 3; (gall bladder) Boyden, Amer. Jour. Anat., vol. 38; Mentzer, Jour. A.M.A., vol. 93. *Pancreas:* (islets) Bensley, Amer. Jour. Anat., vol. 12; (accessory) Moore, Amer. Jour. Path., vol. 5; Ssokalow, Anat. Anz., Bd. 70. (ducts) Baldwin, Anat. Rec., vol. 5; Holzapfel, Anat. Anz., Bd. 69.

SECTION XI

THE RESPIRATORY SYSTEM

By J. Parsons Schaeffer, M.D., Ph.D., Sc.D.

PROFESSOR OF ANATOMY AND DIRECTOR OF THE DANIEL BAUGH INSTITUTE OF ANATOMY OF THE JEFFERSON MEDICAL COLLEGE

RESPIRATION in one form or another is one of the basic characteristics of living things. It consists essentially in the absorption by the organism of oxygen and the discharge of a metabolic waste-product, carbon dioxide. The lungs in air-breathing vertebrates are eminently the seat of the interchange of these gases between the body and the air.

Among unicellular animals the oxygen is taken up directly from the medium—water or air—in which they live, and the carbon dioxide given off into it. With the cells which make up the body of higher animals the principle is the same, but the interchange of gases is indirect. The blood stands as an intermediate element between the cells of the body and the medium inhabited by the animals, and serves as a carrier of the gases between them. Special organs, moreover, are provided for the rapid interchange between the air and blood, which constitute the so-called **respiratory system.**

The respiratory system of air-breathing vertebrates consists of tubular and cavernous organs constructed so as to permit of the atmospheric air reaching the blood circulating in the body. The essential organs in the system are the paired **lungs** located in the **thoracic cavity.** Air is carried to and from the lungs by the **trachea** and **bronchi,** and these simple transmitting tubes are in turn put into communication with the exterior by the mediation of other organs. The latter are, however, specially constructed in adaptation to other functions in addition to those relating to respiration: the **larynx** for the production of the voice, the **pharynx** and **mouth** in connection with alimentation, the several portions of the **nose** functioning in the sense of smell. (For the description of the mouth and pharynx see Section X; for the olfactory organ see Section IX.)

The organs of circulation are always adapted to the form of the respiratory apparatus, and among all higher animals a connection is established between the heart and lungs by the pulmonary artery, which carries venous blood to the latter, and by the pulmonary veins, which convey arterial blood from the lungs to the heart, whence the aorta takes it into the general circulation.

In their origin and development, the respiratory organs are closely associated with or differentiated from the beginnings of the digestive apparatus. Thus, the processes of the early development of the nasal cavity and mouth are interdependent; the origin of the greater part of the larynx, the trachea and lungs is by outgrowth of the entodermal canal.

THE NOSE

The nose will here be described under three main heads as follows: A, the external nose; B, the internal nose or nasal cavity; C, the paranasal or accessory sinuses.

THE EXTERNAL NOSE

The **external nose** [nasus externus], shaped like a triangular pyramid, is formed of a bony and cartilaginous framework covered by muscles and the integument of the face externally and lined within by periosteal and perichondral layers overspread by mucous membrane. At the forehead, between the eyes, is the **root** of the nose [radix nasi], and extending from this, inferiorly and anteriorly, is a rounded ventral border, the **dorsum** of the nose [dorsum nasi], which may be either straight, convex, or concave, and which ends inferiorly at the **apex** of the nose [apex nasi]—the latter either in line with the dorsum nasi, depressed or upturned. The superior part of the dorsum is known as the bridge. Inferiorly,

overhanging the upper lip, is the **base** of the nose [basis nasi] which presents two orifices, the **nares** or nostrils, separated from one another by the movable part of the nasal septum [septum mobile nasi].

The **sides of the nose** [partes laterales nasi] slope from the dorsum laterally and posteriorly, and below terminate on each side in the **margin** of the nose [margo nasi]; posteriorly and inferiorly the sides are expanded and more convex, forming the **alæ nasi.** Each of these is separated from the rest of the lateral surface by a sulcus, and the inferior free margin of each bounds a naris laterally.

Three types of nose, distinguished by differences in the proportion of breadth and length, are shown by the cephalometric nasal index $\left(\frac{\text{greatest breadth} \times 100}{\text{greatest length}}\right)$: the leptorrhine or long, high nose; the platyrrhine or short, low nose; the mesorrhine, a form intermediate between the other two. The leptorrhine type (index below 70) prevails among white races, the platyrrhine

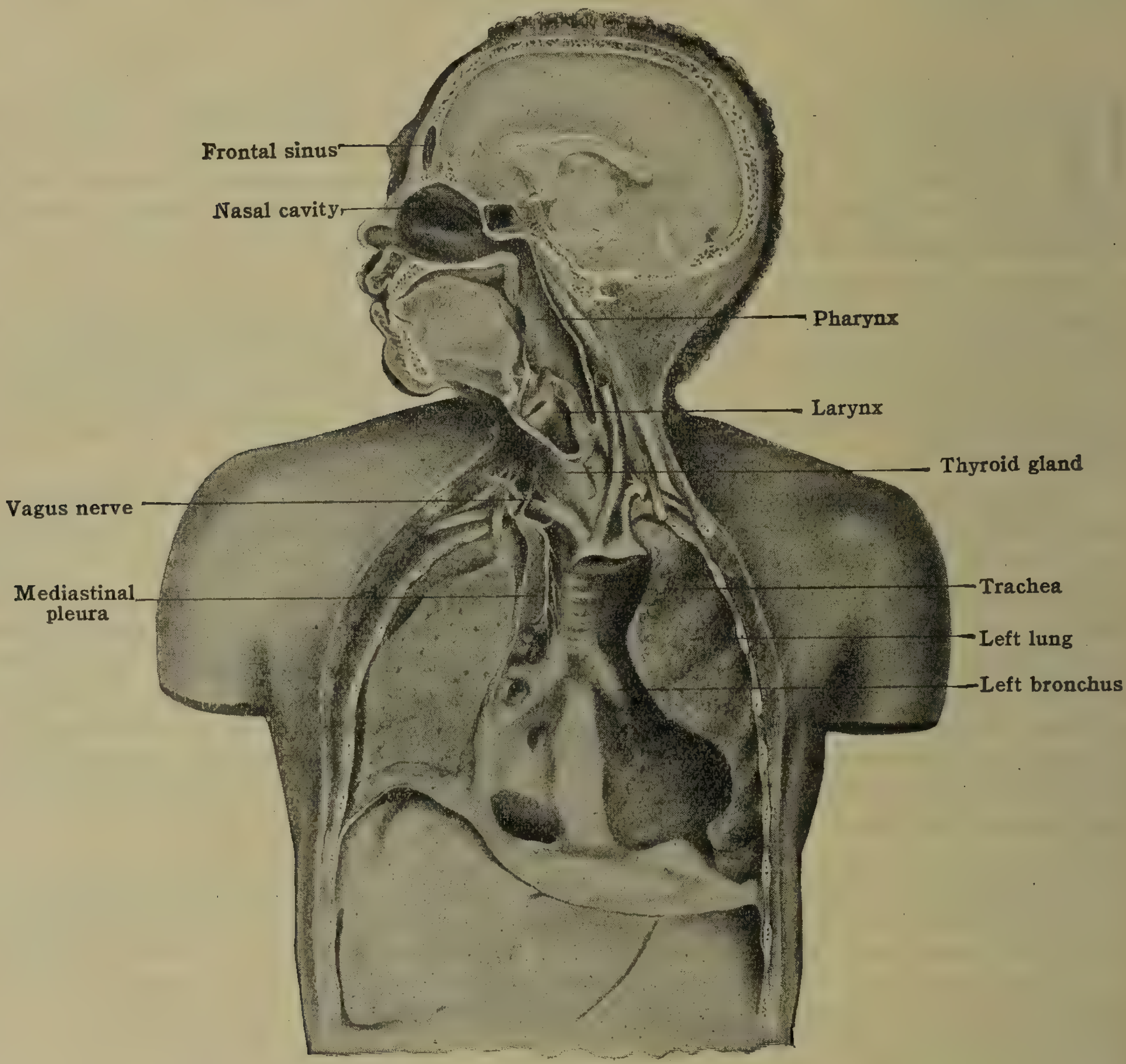


Fig. 1035.—Dissection of a Male Negro, Age 43 Years, to Show the Organs of Respiration in Situ.

(index above 85) in the black peoples, and the mesorrhine (index between 70 and 85) in the red and yellow races. Minor variations in the morphology or shape of the external nose are numerous and of little significance; they represent individual and family characteristics.

The framework of the external nose is formed partly of bone and partly of hyalin cartilage. The bones, which form only the smaller superior part, are the two nasal bones and the frontal processes and anterior nasal spines of the two maxillæ (pp. 113, 128).

The nasal cartilages [cartilagines nasi] (figs. 1036–1038) are located about the piriform aperture and constitute the larger part of the nasal framework. There are five principal cartilages: superiorly, the two *lateral nasal cartilages;* inferiorly, the two *greater alar cartilages,* and the single median *nasal septal cartilage.* Besides these there are the *lesser alar cartilages,* the *sesamoid cartilages,* and the *vomeronasal cartilages* of Jacobson. The **lateral nasal cartilages** (lamina dorsi nasi NK) are triangular and nearly flat lateral expansions of the septal cartilage, placed one on each side of the nose just inferior to the nasal bone. Each presents an ental (deep) and an ectal (superficial) surface and three margins. The medial margin is con-

tinuous in its superior third with the anterior margin of the septal cartilage and with its fellow of the opposite side, but it is separated inferiorly from the septal

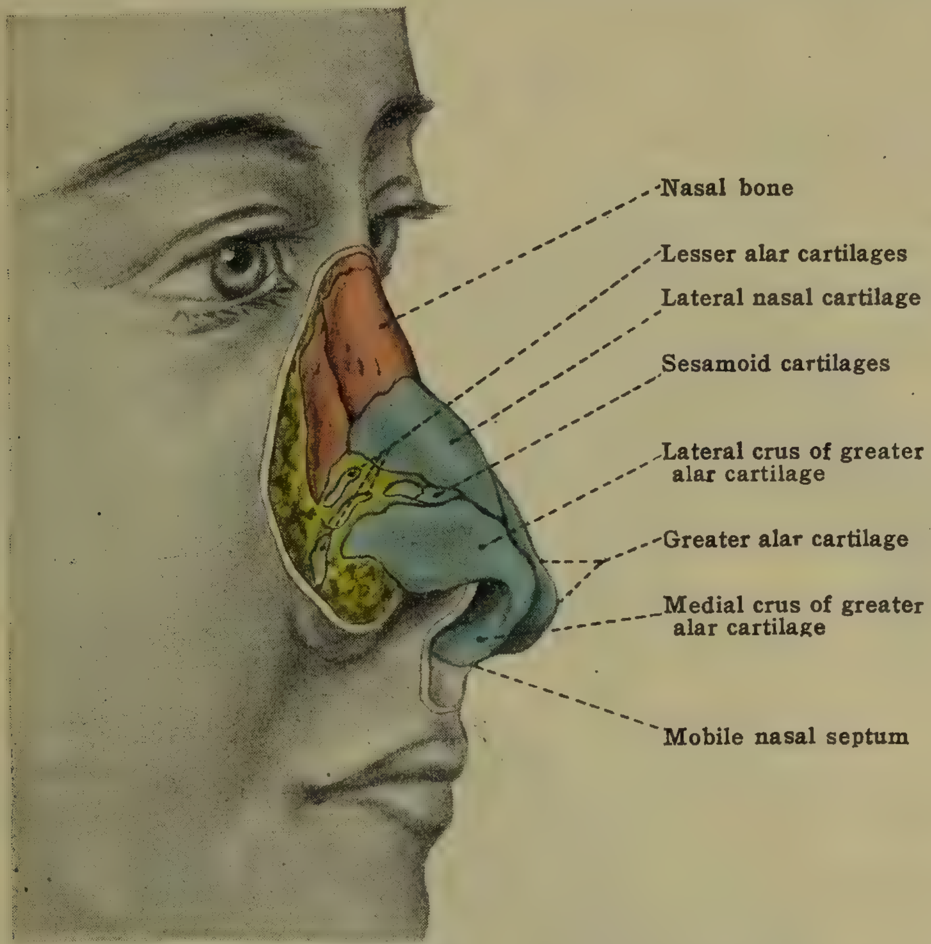


FIG. 1036.—THE CARTILAGES OF THE EXTERNAL NOSE AS DISPLAYED (PROFILE VIEW) AFTER THE REMOVAL OF THE SKIN AND MUSCLES. (Schaeffer.)

cartilage by a narrow cleft. The curved superolateral margin is firmly attached by strong fibrous tissue to the nasal bone and frontal process of the maxilla, and

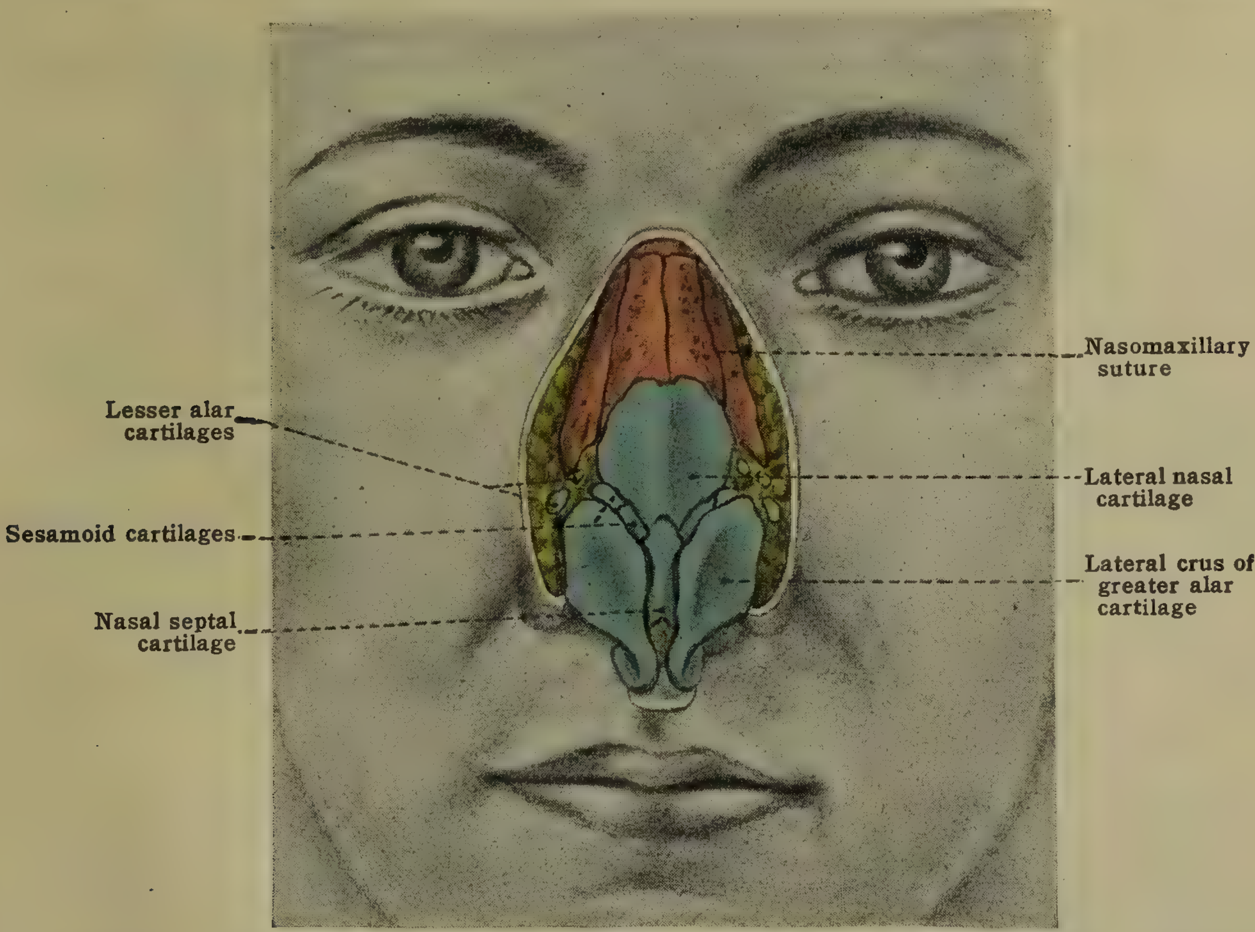


FIG. 1037.—THE CARTILAGES OF THE EXTERNAL NOSE AS DISPLAYED (FRONTAL VIEW) AFTER THE REMOVAL OF THE SKIN AND MUSCLES. (Schaeffer.)

underlies these bones for a considerable distance, especially near the septum. The inferior margin is connected by fibrous tissue to the greater alar cartilage. The

greater alar cartilages [cartilagines alares majores] (cartilago apicis nasi NK), variable in form, are situated one on each side of the apex of the nose (figs. 1036, 1038). Each is thin, pliant, curved, and so folded that it forms a medial and a lateral crus, these crura bound and tend to hold open the related naris. The **medial crus** [crus mediale] is loosely attached to its fellow of the opposite side, the two being situated inferior to the septal cartilage and forming the tip of the nose and the inferior part of the mobile septum. The **lateral crus** [crus laterale] joins the medial crus at the apex of the nose; is somewhat oval in shape, and curves dorsally in the superior and anterior portion of the ala. It is connected posteriorly to the nasal margin of the maxilla by a broad mass of dense fibrous and fatty tissue, and helps to maintain the contour of this part of the nose.

The angle formed by the crura (angulis pinnalis) varies with the shape of the nose; it averages 30°. The greater and lesser alar cartilages together form an incomplete ring around the naris.

A variable number of small cartilages (cartilagines nasales accessoriæ NK), include the **lesser alar cartilages** [cartilagines alares minores] found in the fibrous tissue of each ala, and, in the interval between each greater alar and lateral cartilage, one or more small plates, **sesamoid cartilages** [cartilagines sesamoideæ] (figs. 1036, 1037). Occasionally a posterior extension of the lateral crus of the greater alar cartilage replaces in part or in whole the lesser alar cartilages.

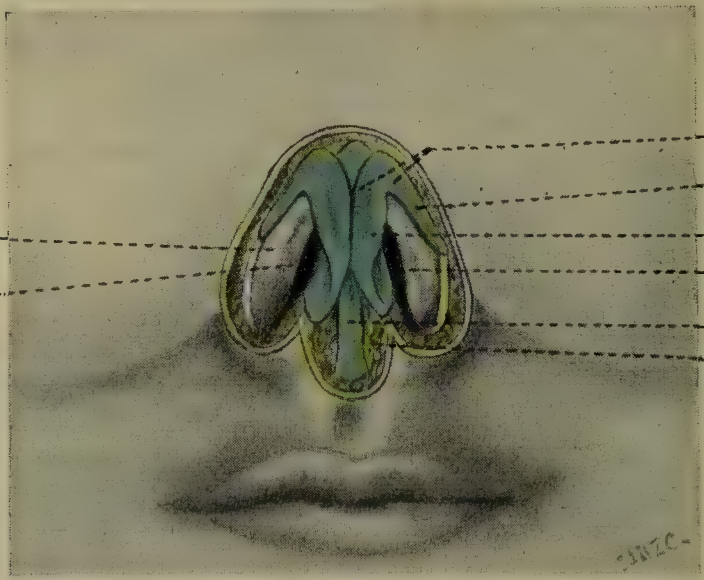


Fig. 1038.—The Cartilages of the Nose as Related to the Nares or Nostrils. (Schaeffer.)

The **cartilaginous portion of the nasal septum** is formed by the septal cartilage, the vomeronasal cartilages, and the medial crura of the greater alar cartilages (described above).

The **septal cartilage** [cartilago septi nasi] (lamina septi NK) (fig. 1039) forms the anterior part of the septum. It is quadrilateral in shape and fits into the triangular interval of the bony septum. Its anterosuperior margin in its upper part meets the internasal suture. Inferior to the nasal bone this margin presents a shallow groove which gradually narrows toward the tip of the nose, the borders of which are continuous superiorly with the lateral nasal cartilages, but separated in their inferior two-thirds by a narrow slit. The lower part of this margin of the septal cartilage is placed between the greater alar cartilages. The anteroinferior margin extends backward from the rounded anterior angle to the anterior nasal spine. Inferiorly it is attached to the medial crus of the greater alar cartilage and to the mobile nasal septum. The posterosuperior margin is attached to the perpendicular plate of the ethmoid, and the posteroinferior margin joins the vomer and the anterior part of the nasal crest of the maxilla, the cartilage broadening out to obtain a wide though lax attachment to the nasal spine.

The revised NK terminology designates as a single cartilage, the *cartilago septodorsalis* including the septal cartilage (lamina septi) and the lateral nasal cartilages (lamina dorsi nasi).

The *shape and size* of the septal cartilage varies with the extent of the ossification of the bony septum. Posteriorly the septal cartilage extends variously between the vomer and the perpendicular lamina of the ethmoid, thus forming the **sphenoidal process of the septal cartilage**. Indeed, the latter may be sufficiently elongated to reach the sphenoid bone—especially in children—and very frequently is the seat of a ridge-like horizontal projection into one or the other nasal fossa, causing septal asymmetry.

The **vomeronasal cartilages** [cartilagines vomeronasales, Jacobsoni] (fig. 1039) are two narrow longitudinal strips, 7 to 15 mm. in length, which lie along the anterior portion of the inferior

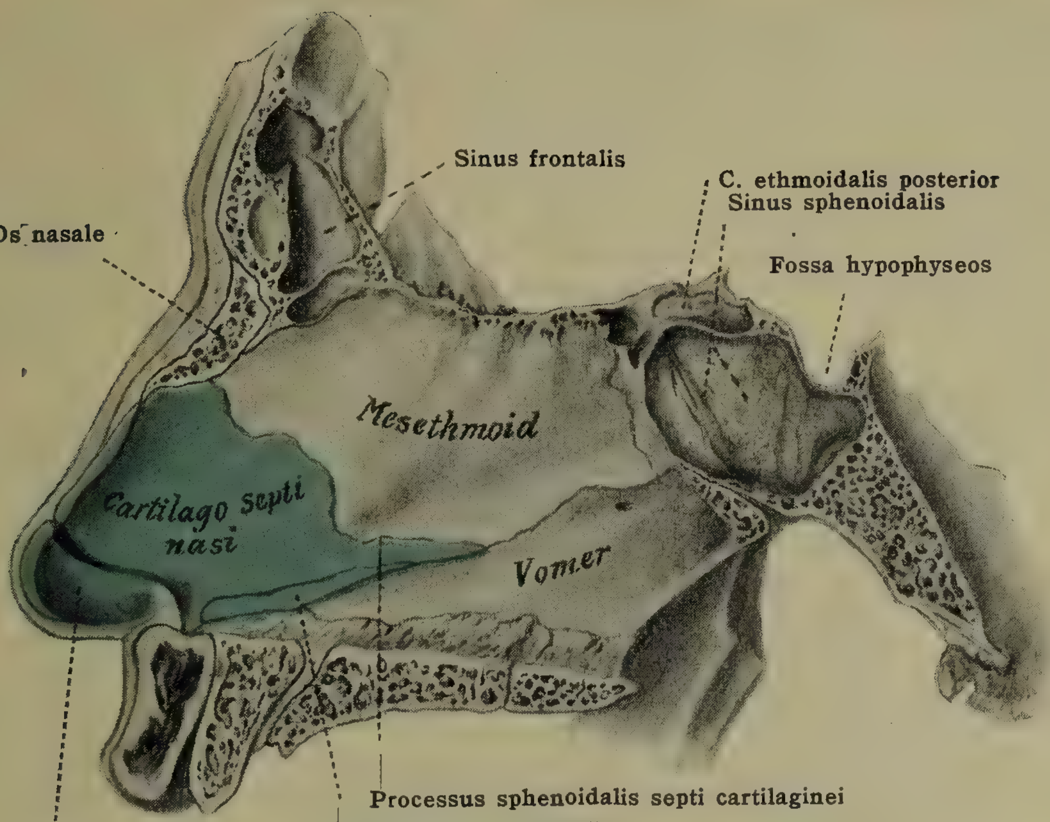


FIG. 1039.—A DISSECTION SHOWING THE OSSEOUS AND CARTILAGINOUS SEPTUM OF THE NOSE. (Schaeffer.)

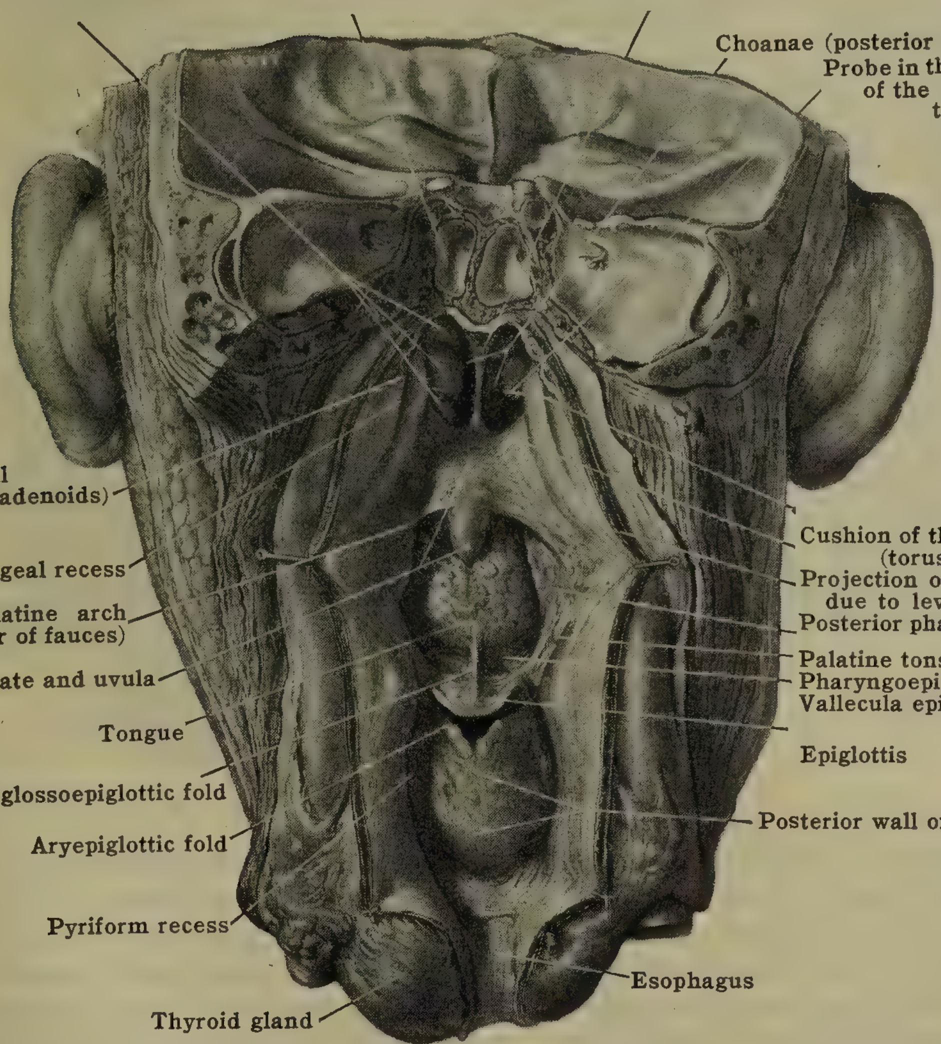


FIG. 1040.—THE POSTERIOR WALL OF THE PHARYNX HAS BEEN CUT THROUGH IN THE MEDIAN SAGITTAL PLANE AND DRAWN LATERALWARD ON EACH SIDE, THEREBY EXPOSING THE PHARYNGEAL CAVITY AND ITS SUBDIVISIONS, NASAL, ORAL, AND LARYNGEAL. (From a preparation in the Daniel Baugh Institute of Anatomy of the Jefferson Medical College.)

border of the septal cartilage. In this position the vomeronasal cartilages are attached to the vomer posteriorly and to the maxilla and the septal cartilage anteriorly. The vomeronasal cartilages are not always differentiated from the septal cartilage. In man these cartilages reach their maximum development in the embryo. They are, however, always most conspicuous in animals in which the vomeronasal organ is well developed, forming a protecting and supporting framework for the organ.

Muscles.—The muscles of the external nose are grouped according to function as dilators and contractors, the latter being comparatively feeble in their action. They are described on p. 401.

Skin.—The skin covering the external nose is thin and freely movable upon the subjacent parts, except at the tip and over the cartilages, where it is much thicker, more adherent, and furnished with numerous exceptionally large sebaceous glands. At the nares it is reflected into the nasal vestibule, becomes modified, and at the limen vestibuli changes to the mucous membrane proper. The hairs on the skin of the nose are very fine, except in the vestibule, where they may be strongly developed.

Vessels and nerves.—The arteries of the external nose are derived from the external maxillary (facial) artery (pp. 618 and 619), the ophthalmic artery (p. 630), and the infraorbital artery (p. 626). The **veins** terminate in the anterior facial vein and the ophthalmic vein (p. 717). The **lymphatics** pass to the submaxillary and parotid lymphatic nodes and to a lesser degree become continuous with the lymphatics of the nasal cavity (p. 781). The **motor nerves** are branches of the facial (p. 1019). The **sensory nerves** are derived from the trigeminal through the frontal and nasociliary branches of the ophthalmic (p. 1009) and infraorbital branch of the maxillary (p. 1012).

THE INTERNAL NOSE

The **internal nose** consists of the nasal cavity and ancillary structures. The general **nasal cavity** [cavum nasi] is the roomy space situated between the floor of the cranium and the roof of the mouth, extending anteriorly into the external

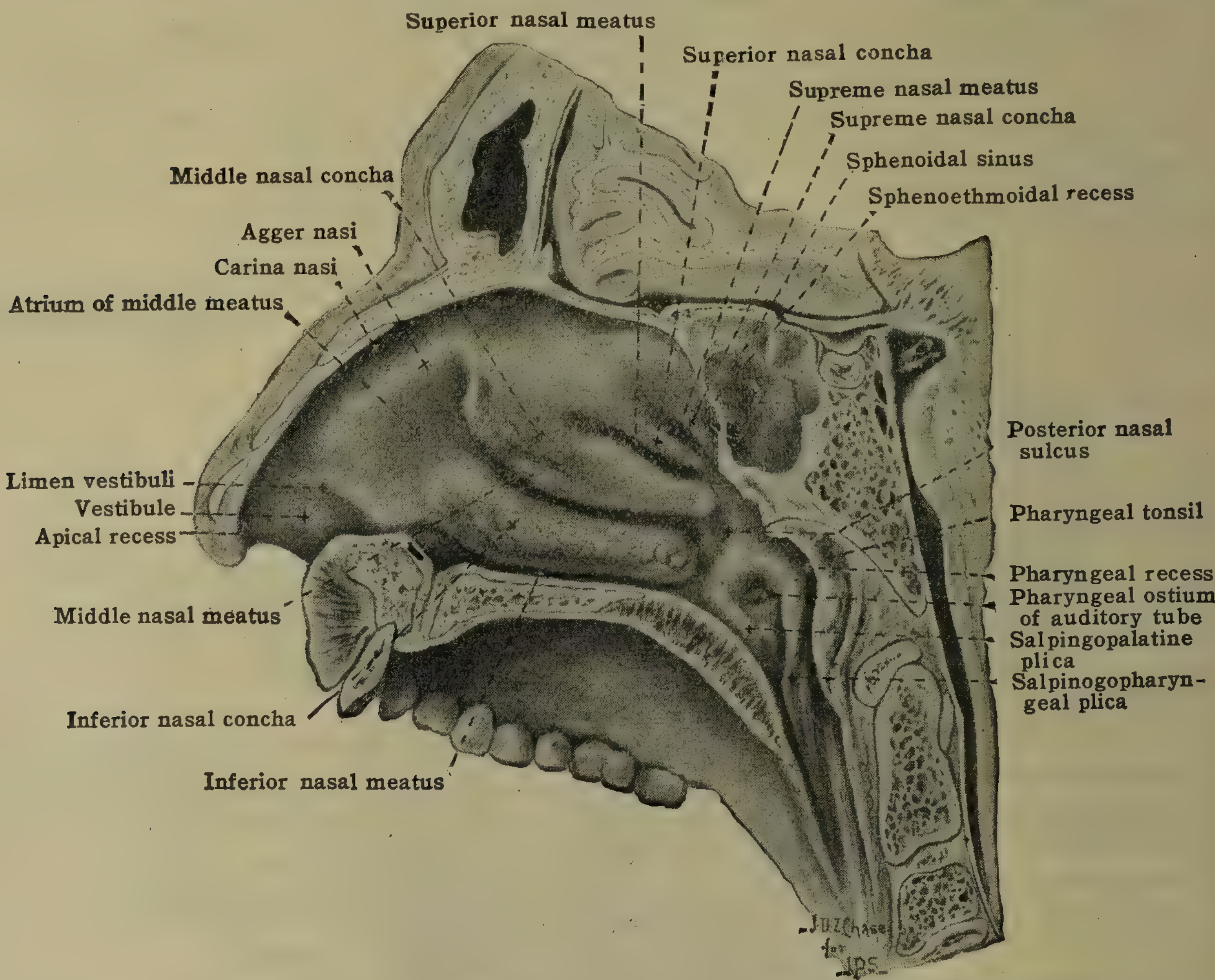


FIG. 1041.—LATERAL WALL OF THE RIGHT NASAL FOSSA AND THE NASAL PHARYNX.

nose and posteriorly to the nasal part of the pharynx. The cavity is divided by a median **septum** [septum nasi] into two more or less symmetrical halves—the **nasal fossæ** [fossæ nasales]. The fossæ are further incompletely divided into **nasal meatuses** [meatus nasi] by the **nasal conchæ** or turbinates [conchæ nasales], and are extended into neighboring bones by the **paranasal** or accessory **sinuses** [sinus paranasales]. The nasal fossæ communicate freely with the exterior through the **nares** (anterior nares) and with the nasopharynx dorsally through the **choanæ** (posterior nares). With the exception of the anterior portion of the nose, where the boundaries are completed by cartilages and membranes, the walls of the nasal cavity are almost wholly of bone as described in the sec-

tion on OSTEOLOGY (pp. 128–130). The walls of the nasal cavity are covered with periosteum and mucous membrane, the latter presenting important histological differences, leading to the division of the nasal cavity into **respiratory** and **olfactory** portions [regiones respiratoria et olfactoria]. The former, the lower and greater portion of the nasal cavity, has especially to do with the function of respiration and the latter, the extreme upper portion of the nasal cavity, is primarily concerned with the function of smell and is, strictly speaking, the **peripheral olfactory organ** (see Section IX for the olfactory organ proper).

The nasal fossæ.—The paired nasal fossæ are roughly triangular in the frontal or coronal plane (fig. 1042). The narrow roof of each fossa may be considered the

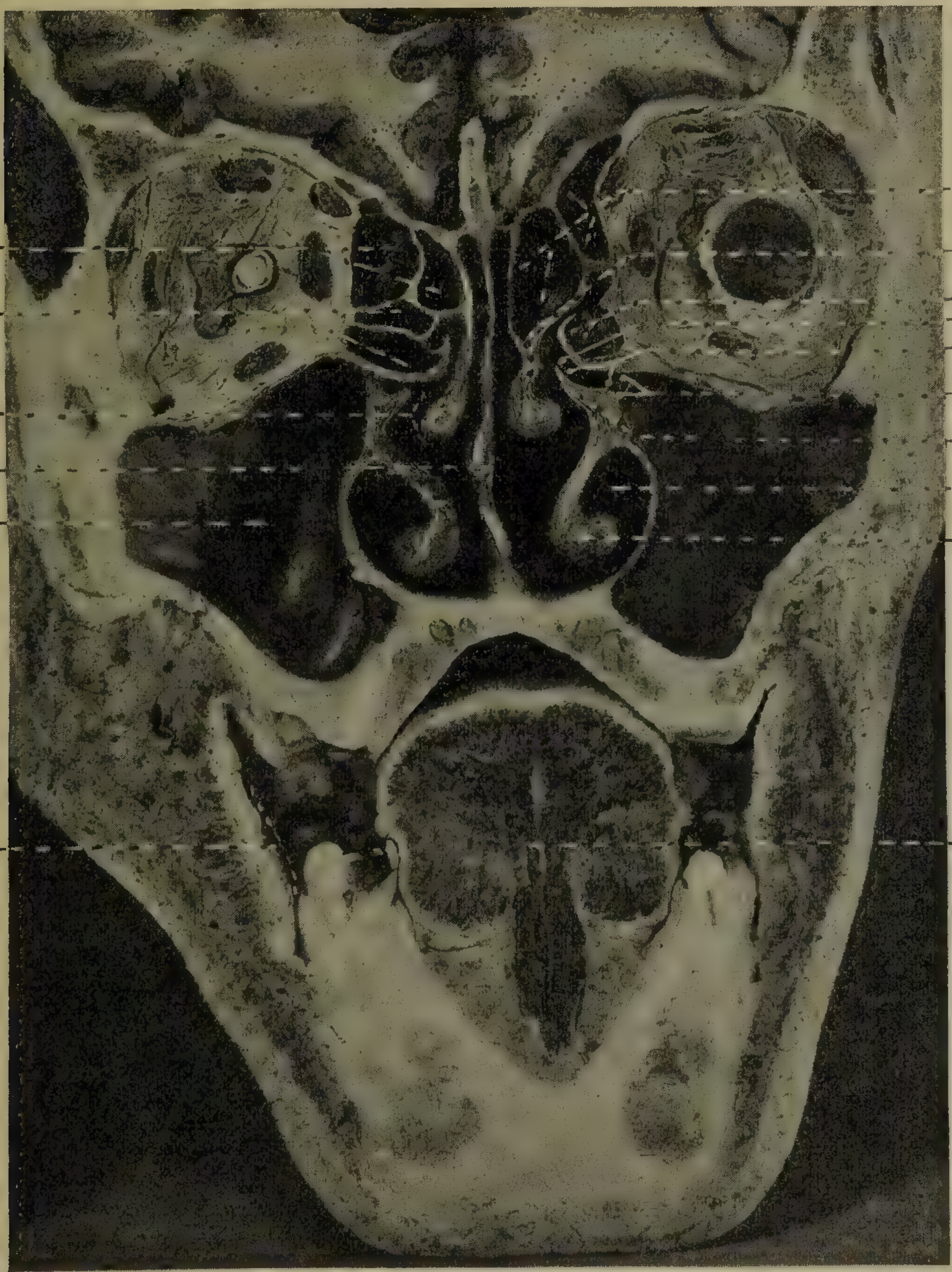


FIG. 1042.—PHOTOGRAPH OF A SEMIFRONTAL SECTION OF THE HEAD IN THE REGION OF THE NASAL FOSSÆ AND THE PARANASAL SINUSES. From a specimen in the Daniel Baugh Insitute of Anatomy of the Jefferson Medical College.

apex of the triangle and the wider floor the base, the mesial or septal wall, normally even and approximately vertical, meeting the floor at nearly a right angle. The lateral wall, the hypotenuse of the triangle, is sloping and configured by the nasal conchæ and meatuses and the encroaching paranasal air sinuses. In sagittal section (fig. 1041) each nasal fossa is quadrangular in shape, the roof being more or less parallel with the floor, the anterior side conforming to the profile of the external nose and forming with the floor at the naris an acute angle, and the posterior side passing from the anterior surface of the body of the sphenoid bone, through the choana of the respective side to the juncture between the hard and soft palates. The posterior limit of the nasal fossa is indicated on the lateral nasal wall by the *posterior nasal sulcus* (fig. 1041).

While there is considerable variation in the dimensions of the nasal fossæ, the following may be taken as representative measurements: The greatest sagittal diameter, measured from the most prominent part of the naris along the floor of the nasal fossa to the posterior border of the hard palate, is 74 mm.; the greatest sagittal diameter, measured along the roof of the fossa, is 35 mm. or less; the greatest vertical diameter, measured from the cribriform plate to the nasal floor, is from 40 to 45 mm.; the width of the roof 3 mm. or less; the width of the floor, measured at the greatest lateral expansion of the inferior meatus, varies from 12 to 23 mm.

The vestibules [vestibula nasi].—The vestibules are the dilated passage-ways leading in from the nares and may be considered antechambers to the nasal fossæ, corresponding more or less to the cartilaginous portion of the external nose and supported by the medial and lateral plates of the greater alar cartilages and adjacent portions of the nasal septum and integument.

The extension of the vestibule into the tip of the nose is often referred to as the *ventricle* of the vestibule, or the *recessus apicis* (fig. 1041). On the lateral wall the vestibule is marked off from the rest of the nasal fossa by a distinct ridge, the *limen nasi* (or limen vestibuli), corresponding to the superior margin of the greater alar cartilage (fig. 1041). At the limen nasi the skin lining the vestibule suffers a transition into the mucous membrane lining the nasal fossa proper. The skin lining the vestibule is beset with large hairs called vibrissæ, and contains sudoriferous and sebaceous glands.

The choanæ (posterior nares).—These are the paired, communicating passage-ways between the nasal fossæ and the nasal pharynx (fig. 1040). The apertures are oval in form with the vertical diameter greater than the transverse, the comparison in size in different individuals being shown by the *choanal index*, $\frac{\textit{transverse diameter} \times 100}{\textit{vertical diameter}}$. They have definite osseous boundaries and are lined with mucoperiosteum continued from the nasal fossæ into the nasal pharynx. The choanæ are located at either side of the free posterior border of the nasal septum and are limited above by the body of the sphenoid and the alæ of the vomer, below by the line of junction of the hard and soft palates, laterally by the medial plates of the pterygoid processes. The osseous boundaries of the choanæ cause the apertures to stand permanently open and free for the transmission of air.

The transverse diameter of each choana varies from 12 to 17 mm. at the floor and from 7 to 10 mm. at the roof. The vertical diameter varies from 24 to 33 mm. The choanal index for the male averages approximately 61 and for the female 64.5. Posterior rhinoscopic examination reveals the choanæ, the nasopharyngeal meatus, the posterior extremities of the nasal conchæ and of the nasal meatuses beneath them.

The nasal septum (fig. 1039).—The medial wall of the nasal fossa is formed by the nasal septum (fig. 1039). It is supported posteriorly by a framework composed of osseous elements [septum osseum] (pars ossea NK), anteriorly by cartilaginous elements (septum cartilagineum) (pars cartilaginea NK) and anteroinferiorly by integument and subcutaneous tela [septum membranaceum; septum mobile nasi]. The nasal mucous membrane covers all portions of both sides of the septum, save the vestibular part, which is invested by integument continued through the nares from the exterior.

The nasal septum is almost always straight and symmetrical in primitive races and Caucasian children, but in a large proportion of Caucasian adults it is deflected to one side or the other. The deviations involve mainly the cartilage and the ethmoid, the vomer being usually but little affected. Too extensive removal of the bony septum in the operation of submucous resection for the relief of this condition may cause sinking-in of the bridge of the nose. Occasionally from four to six oblique mucosal ridges or *septal plicæ* configure the posteroinferior portion of the septum. They are most prominent in the fetus and usually disappear in infancy.

In the anteroinferior portion of the nasal septum slightly above and anterior to the orifice of the nasopalatine or incisive canal is not infrequently encountered a small orifice or ostium leading into a paired, blindly ending tubular sac—the **vomeronasal organ of Jacobson** [organon vomeronasale]. The tubular sac courses backward in the septal mucosa for a distance of from 2 to 6 mm., is lined by epithelium continuous with that of the nasal fossa, and has numerous glands opening into its lumen. The organ is vestigial in man and reaches its height of development during the twentieth week of embryonic life. In some animals it is highly specialized and receives a branch of the olfactory nerve.

The lateral nasal wall.—The lateral wall of each nasal fossa (fig. 1041) is characteristically configured by three or four projecting and overhanging scroll-like laminæ—the **nasal conchæ** or **turbinates** [conchæ nasales]. These incompletely subdivide each nasal fossa into a corresponding number of primary groove-like passageways—the **nasal meatuses** [meatus nasi]. The meatuses are always located below and lateral to the corresponding conchæ. The space

between the nasal conchæ and the nasal septum, into which the nasal meatuses open, is usually referred to as the **common nasal meatus** [meatus nasi communis]. The limited region found posterosuperior to the uppermost nasal concha and anterior to the body of the sphenoid bone is known as the **sphenoethmoidal recess** [recessus sphenoethmoidalis]. It contains on its posterior wall the aperture of the sphenoidal sinus. Midway between the anterior extremity of the middle nasal concha and the inner surface of the dorsum nasi is a ridge-like elevation known as the **agger nasi**, the rudimentary homologue of the nasoturbinal of mammals. The saucer-like depression in advance of the middle nasal meatus and located between the agger nasi and the middle nasal concha is the **atrium of the middle meatus** [atrium meatus medii]. A narrow cleft-like space, the **carina nasi** or **olfactory sulcus** [sulcus olfactorius], is located between the agger nasi and the inner surface of the dorsum nasi, leading from the nasal vestibule to the roof of the nasal fossa (fig. 1041). The carina or sulcus if continued along the roof of the nasal fossa becomes confluent with the sphenoethmoidal recess. The

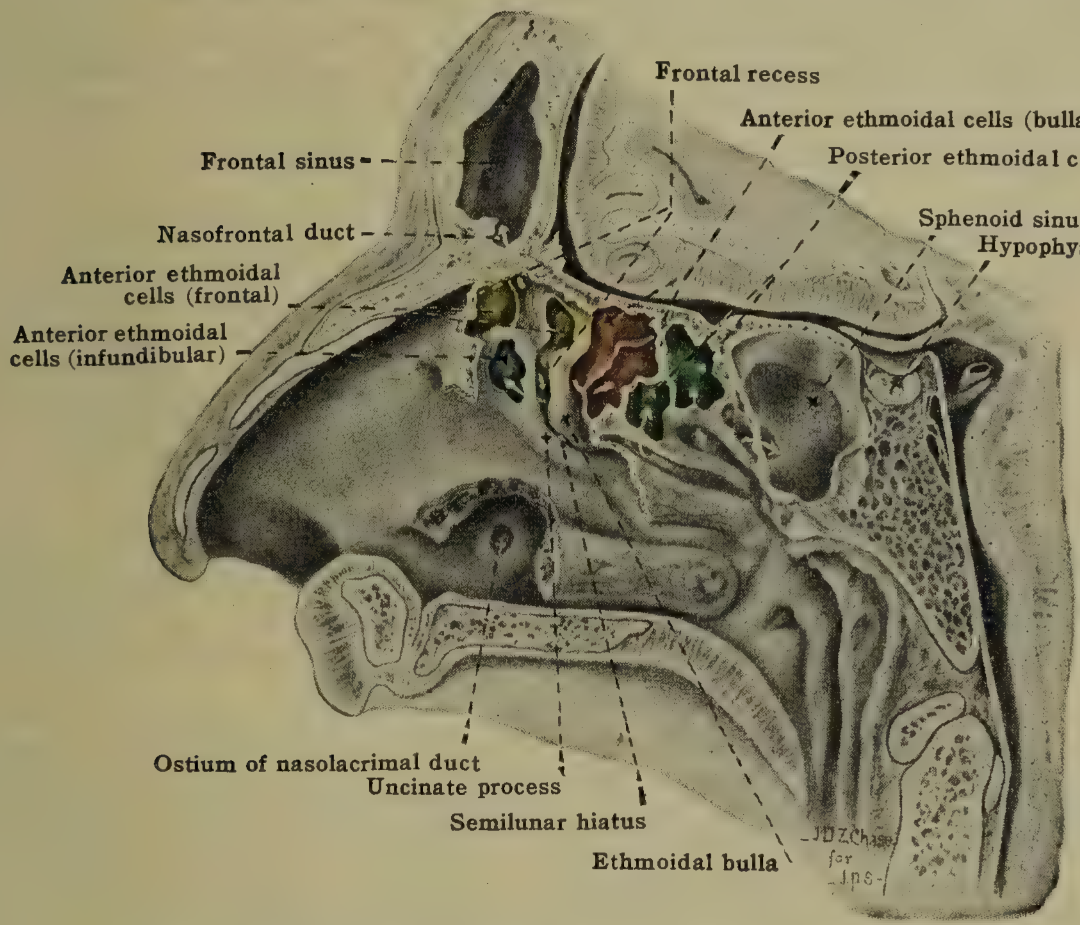


FIG. 1043.—LATERAL WALL OF THE RIGHT NASAL FOSSA.

Same as fig. 1041, with dissection to show the ethmoidal cells and relations. Frontal group of anterior ethmoidal cells, yellow; infundibular, blue; bullar, red; posterior ethmoidal cells green.

lateral wall of each nasal fossa is delimited posteriorly by a shallow furrow, the **posterior nasal sulcus**, that extends from the body of the sphenoid bone to the junction of the hard and soft palates. The region extending from the posterior extremities of the inferior and middle nasal conchæ to the choanæ, and limited by the adjacent lateral and medial walls of the nasal fossa, is the **nasopharyngeal meatus** [meatus nasopharyngeus] (fig. 1041).

The nasal conchæ and meatuses.—The nasal conchæ extend anteroposteriorly on the lateral nasal wall, converging posteriorly. They have a bony framework (see section on OSTEOLOGY) and are covered by the mucoperiosteum of the nasal cavity. The skeleton of the inferior (maxillary) concha is an independent osseous element, while the middle, superior, and supreme (ethmoidal) conchæ merely represent appendages of the ethmoid. The nasal meatuses are located below and lateral to the corresponding nasal conchæ, the inferior and middle meatuses in large measure being overhung by the related conchæ.

The **inferior nasal concha** [concha nasalis inferior] or maxilloturbinal (figs. 1041, 1042) is an independent, scroll-like lamina of bone covered by a thick mucous membrane, containing numerous venous plexuses, the *plexus cavernosi concharum.*

The concha projects from behind the limen nasi to a point from 10 to 12 mm. in front of the choana. It overhangs the inferior nasal meatus. The **inferior nasal meatus** [meatus nasi inferior] (m. conchæ maxilloturbinalis NK) (figs. 1041–1043) is limited above by the arched attached border of the inferior concha and below by the floor of the nose. It measures from 4.5 to 5.8 cm. in length, beginning variously from 2.5 to 3.7 cm. behind the tip of the nose. The inferior meatus is narrow anteriorly, expanding rapidly in width and height, to narrow again toward the choana.

The *ostium of the nasolacrimal duct* (fig. 1043) is located on the anterior portion of the lateral wall of the inferior meatus, from 15 to 20 mm. behind the limen vestibuli and from 30 to 40 mm. behind the naris. It is located either at the highest point of the inferior meatus or at varying distances (2 to 10 mm.) below this point. The ostium is usually a single opening, but duplication or triplication may occur. The aperture may be located either close to the attached border of the inferior concha, wide-mouthed, standing permanently open, or located lower, slit-like, collapsed and guarded by a fold of mucous membrane, the so-called valve of Hasner [plica lacrimalis, Hasneri].

The **middle nasal concha** [concha nasalis media] (c. ethmoturbinalis major NK) (figs. 1041–1043) is relatively large, hanging valve-like over the middle nasal meatus. It hides or operculates a number of secondary conchæ and furrows in the middle meatus. The contained osseous lamina, a part of the ethmoid bone is covered by a thick mucous membrane, erectile in character.

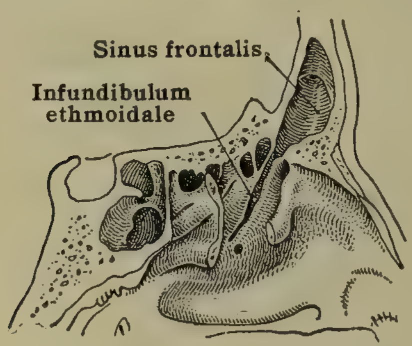


Fig. 1044.—Anatomic Type in Which the Nasofrontal Duct and the Infundibulum Ethmoidale are Continuous. (After J. Parsons Schaeffer.)

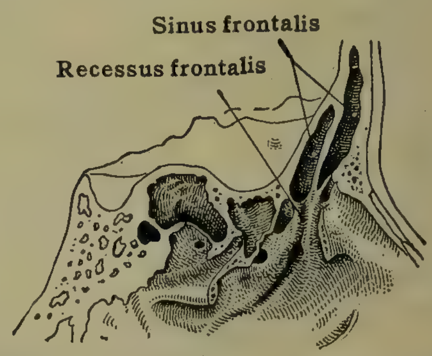


Fig. 1045.—Anatomic Type in Which two Frontal Sinuses are Present, Both Discontinuous with the Infundibulum Ethmoidale. (After J. Parsons Schaeffer.)

The free border of the concha presents a marked genu, giving rise to a short vertical or ascending limb and a larger horizontal or descending limb. The genu very commonly enlarges by the formation of a lobule, surmounted by a secondary nodule. Equally common is the presence of ethmoidal cells in the body of the concha media (see Paranasal Sinuses).

The **middle nasal meatus** [meatus nasi medius] (m. conchæ ethmoturbinalis majoris NK) (figs. 1041–1043) is the most complex and important of the nasal meatuses. It is divided into an *ascending* and a *descending* ramus; the latter, spacious and arched, conforms to the contour of the middle and inferior conchæ; the former, often called the **frontal recess**, is much less roomy and is merely an extension frontalward of the middle meatus proper. On removing or turning upward the middle nasal concha, one discloses on the lateral wall of the descending ramus of the middle meatus immediately below the attached border of the middle concha a conspicuous bleb-like structure—the **ethmoidal bulla**, and below the latter a sharp, crescentic lamella—the **uncinate process**. Between the free border of the uncinate process and the ethmoidal bulla is a crescentic cleft from 15 to 20 mm. long—the **semilunar hiatus**, which in turn leads from the middle nasal meatus into a crescentic groove of variable depth (from 1–12 mm.), the **ethmoidal infundibulum.**

The ethmoidal infundibulum usually ends blindly frontalward by forming one or more anterior ethmoidal air-cells (infundibular cells) (fig. 1043) and ends posteriorly either in a pocket or merges gradually with the middle meatus. Occasionally it is directly continuous with the nasofrontal duct (infundibulum of the frontal sinus) or in the absence of the latter with the frontal sinus proper (fig. 1044). The ethmoidal infundibulum contains in its depth the ostia or apertures of the infundibular group of anterior ethmoidal cells and the ostium of the maxillary sinus (ostium maxillare).

The groove or furrow located between the ethmoidal bulla and the attached border of the middle nasal concha is the *suprabullar furrow or recess.* It contains the apertures or ostia of most of those anterior ethmoidal cells sometimes classed as middle ethmoidal cells (bullar group of anterior ethmoidal cells).

The lateral wall of the middle nasal meatus between the attached border of the uncinate process and the inferior nasal concha is at places wholly membranous, and presents the *accessory maxillary ostium* in from 25 to 40 per cent. of cases, communicating directly between the middle meatus and the maxillary sinus.

The anterosuperior portion of the middle nasal meatus, i. e., the vertical or ascending ramus (frontal recess) is a pouch-like extension communicating with the frontal group of anterior ethmoidal cells (fig. 1043) and the frontal sinus. Occasionally the ethmoidal infundibulum and the duct of the frontal sinus or the frontal sinus proper are continuous channels and groove the lateral wall of the frontal recess (fig. 1044); but usually the ethmoidal infundibulum and the nasofrontal duct are anatomically discontinuous channels (figs. 1043, 1045).

The **superior nasal concha** [concha nasalis superior] (c. ethmoturbinalis minor NK) (fig. 1041) is a short thin lamina of bone which projects from the lateral ethmoidal mass and slightly overhangs the superior nasal meatus. The mucous membrane covering the concha is thinner and less erectile in character than that of the middle and inferior conchæ. The **superior nasal meatus** [meatus nasi superior] (m. conchæ ethmoturbinalis minoris NK) (figs. 1041, 1043) is a narrow channel-like depression below the related concha and approximately half the length of the middle nasal meatus. Not infrequently an accessory concha molds the lateral wall of the superior meatus and divides the latter into superior and inferior recesses. The latter recesses and the anterior end of the superior meatus receive the ostia or apertures of the posterior ethmoidal cells.

The **supreme nasal concha** [concha nasalis suprema] (c. ethmoturbinalis minima NK) (figs. 1041, 1043), found bilaterally or unilaterally in approximately 60 per cent. of bodies, is the smallest of the conchæ. It projects only slightly medialward from the posterosuperior part of the lateral nasal wall, overhanging the **supreme nasal meatus.** The latter, found in a corresponding number of bodies, is a shallow, short furrow which (in about 75 per cent. of cases) contains the ostium or aperture of a posterior ethmoidal cell (fig. 1043).

Immediately above and behind the supreme concha, or the superior concha in those cases in which the former is wanting, is the **sphenoethmoidal recess** (figs. 1041, 1043). The latter lies in the angle between the ethmoid and the anterior surface of the body of the sphenoid bone. Posteriorly the recess receives the ostium of the sphenoidal sinus (figs. 1041, 1043).

The roof of the nasal fossa.—The roof of the nasal fossa (fig. 1041) may be considered as a cranially arched structure with the cribriform plate forming the horizontal middle portion; the body of the sphenoid bone together with the wing of the vomer and the sphenoidal process of the palate bone, the curved posterior portion; and the frontal and nasal bones, the curved anterior portion. The entire framework is covered with nasal mucous membrane.

Anteriorly the roof of the fossa is very narrow, but it gradually widens as the choanal aperture is approached. The greatest breadth of the cribriform plate (roof proper) is approximately 5 mm. Cranially the cribriform plate supports the olfactory lobe of the brain (fig. 1042) and is perforated by foramina for the passage of the olfactory nerves, etc. Anteriorly, close to the crista galli, is a longitudinal fissure (the nasal fissure) for the transmission of the anterior ethmoidal branch of the nasociliary nerve and the anterior ethmoidal vessels.

The floor of the nasal fossa.—The osseous framework of the nasal floor (figs. 1041, 1042) is formed by the palatal processes of the maxillæ and the horizontal processes of the palate bones. Mucous membrane covers the framework. The floor of each nasal fossa is essentially horizontal in the sagittal plane, a distinct elevation appearing just inside the limen nasi, and concave in the frontal plane.

Approximately 2 cm. behind the inner margin of the nostril, each nasal fossa contains a slight depression in its floor which leads into a funnel-shaped tube of mucous membrane—the **nasopalatine canal** [canalis incisivus] or incisive canal of Stenson, located in the anterior palatine canal in the hard palate. The right and left nasopalatine canals may join and pass through the stem of the Y-shaped anterior palatine canal or incisive foramen as a common channel; however, more commonly each retains its individuality (Schæffer). The canals end in the roof of the mouth at the side of the palatine papilla. In the adult the lumina of the nasopalatine canals are usually obliterated by impervious cords of epithelial cells, but occasionally remain open (fig. 1041). They are the remnants of the wide embryonic communication [ductus incisivus] between the nasal and oral cavities, which persist throughout life in many animals.

THE PARANASAL SINUSES

The **paranasal sinuses** [sinus paranasales] (s. nasales NK) begin from the third to the fourth fetal month as evaginations from the mucosa of the nasal meatuses proper or their secondary furrows. The sphenoidal sinus, on the contrary, is primarily a constriction from the posterosuperior region of the nasal fossa and is, therefore, not an outgrowth from a nasal meatus. The evaginating sacs wander into neighboring portions of the nasal walls, and by a joint growth of the

sacs and an absorption of bone ultimately pneumatize large portions of the ethmoid, frontal, maxillary, and sphenoid bones, in the formation of the *ethmoidal cells, frontal sinuses, maxillary sinuses,* and *sphenoidal sinuses,* respectively.

Although many of the paranasal sinuses grow far from the point of initial evagination, the initial or primary points of outgrowth persist in the adult as the ostia or apertures of communication between the sinuses and the nasal fossa. The location, form and relations of the paranasal sinuses as found in the dried skull (in which the ostia may be considerably larger) have been briefly described in the section on OSTEOLOGY. Their relations are of great clinical importance.

The maxillary sinus [sinus maxillaris] (antrum of Highmore).—The adult maxillary sinus is located in the body of the maxilla and is, as a rule, the largest of the pneumatic paranasal chambers (figs. 1042, 1046). It follows in the main the shape of the body of the maxilla and may be described as having a roof, a floor, and three walls. The *medial wall* or base forms part of the lateral wall of the nasal cavity, and the *apex* extends into the zygomatic process of the maxilla, or beyond it into the maxillary border of the zygomatic bone. The *anterior wall* of the maxillary sinus corresponds to the anterior or facial wall of the maxilla; the *posterior wall* to the infratemporal surface of the maxilla; the *roof* to the orbital surface of the maxilla, and the *floor* to the alveolar process of the maxilla. A thin mucous membrane, continuous through the aperture of the sinus with that lining the nasal fossa, lines the maxillary sinus throughout.

In very many instances the maxillary sinus is not a simple pneumatic cavity or chamber, but is incompletely divided into subcompartments and recesses by osseous and membranous septa. Sometimes a posterior ethmoidal cell grows into the body of the maxilla at the confluence of its orbital and infratemporal surfaces and encroaches on the maxillary sinus proper, the condition simulating doubling of the maxillary sinus. Rarely two true maxillary sinuses appear in the maxilla, both in communication with the ethmoidal infundibulum of the middle nasal meatus (Schaeffer).

The number of teeth that bear direct relations to the floor of the maxillary sinus varies with the degree of excavation of the alveolar process of the maxilla. The teeth most constantly in intimate relationship with the maxillary sinus are the three molars and the second premolar; or, when the sinus is small, the second and third molars only. The majority of maxillary sinuses have their floors at varying distances below the level of the floor of the nasal fossa.

The maxillary sinus communicates with the deep aspect of the posterior half of the infundibulum ethmoidale by means of an oval or elongated aperture or ostium, the **ostium maxillare.** The ostium is very disadvantageously placed as a drainage opening, since it is located at the highest point in the medial wall of the cavity and opens into the narrow infundibulum ethmoidale (described above). The ostium maxillare is sometimes double (fig. 1042).

In more than one-third of specimens the maxillary sinus contains an additional aperture, the **ostium maxillare accessorium,** which communicates directly with the middle nasal meatus proper. The aperture is usually located between the posterior third of the processus uncinatus and the adjacent part of the attached border of the inferior nasal concha. It is more advantageously placed for drainage than is the constant aperture.

Measurements of 150 specimens of the adult maxillary sinus gave as the average the following (Schaeffer): posterosuperior diagonal, 38 mm.; anterosuperior diagonal, 38.5 mm.; superoinferior, 33 mm.; anteroposterior, 34 mm.; mediolateral, 23 mm. Increase in capacity of the maxillary sinus is not infrequently observed as the result of more extensive excavation of the bony processes of the maxilla, e. g., the alveolar, palatal, frontal and zygomatic. A lessened capacity may be due to unusually thick sinus walls, bulging sinusward of the facial and nasal walls, and the retention of certain teeth.

The frontal sinus [sinus frontalis].—The paired frontal sinuses (figs. 1043, 1046) are located between the outer and inner laminæ (tables) of the frontal bone and are extremely variable in size, shape, and type (cf. p. 141). They develop variously as a direct extension of the whole frontal recess of the middle nasal meatus, from one or more anterior ethmoidal cells which have their points of origin in the furrows of the frontal recess, or occasionally from the anterior extremity of the ethmoidal infundibulum. The frontal sinuses are usually asymmetrical, one frequently encroaching markedly upon the confines of the other, with a corresponding displacement of the intervening septum [septum sinuum frontalium].

Seldom, indeed, are the frontal sinuses simple chambers, being more or less divided into subcompartments or recesses by incomplete bony partitions. Supernumerary frontal sinuses are extremely common, each with an independent connection with the nasal cavity. As many as six frontal sinuses have been observed in one skull. Rarely one or both sinuses are wholly

wanting. It is a well established fact that prominence of the superciliary and frontal eminences has no bearing on the presence or size of the frontal sinus.

The typical frontal sinus may be said to be pyramidal, occupying the squama frontalis or vertical portion of the frontal bone. The pyramidal shape, however, of the sinus is very commonly greatly modified by the extension of the cavity into the pars orbitalis of the frontal bone

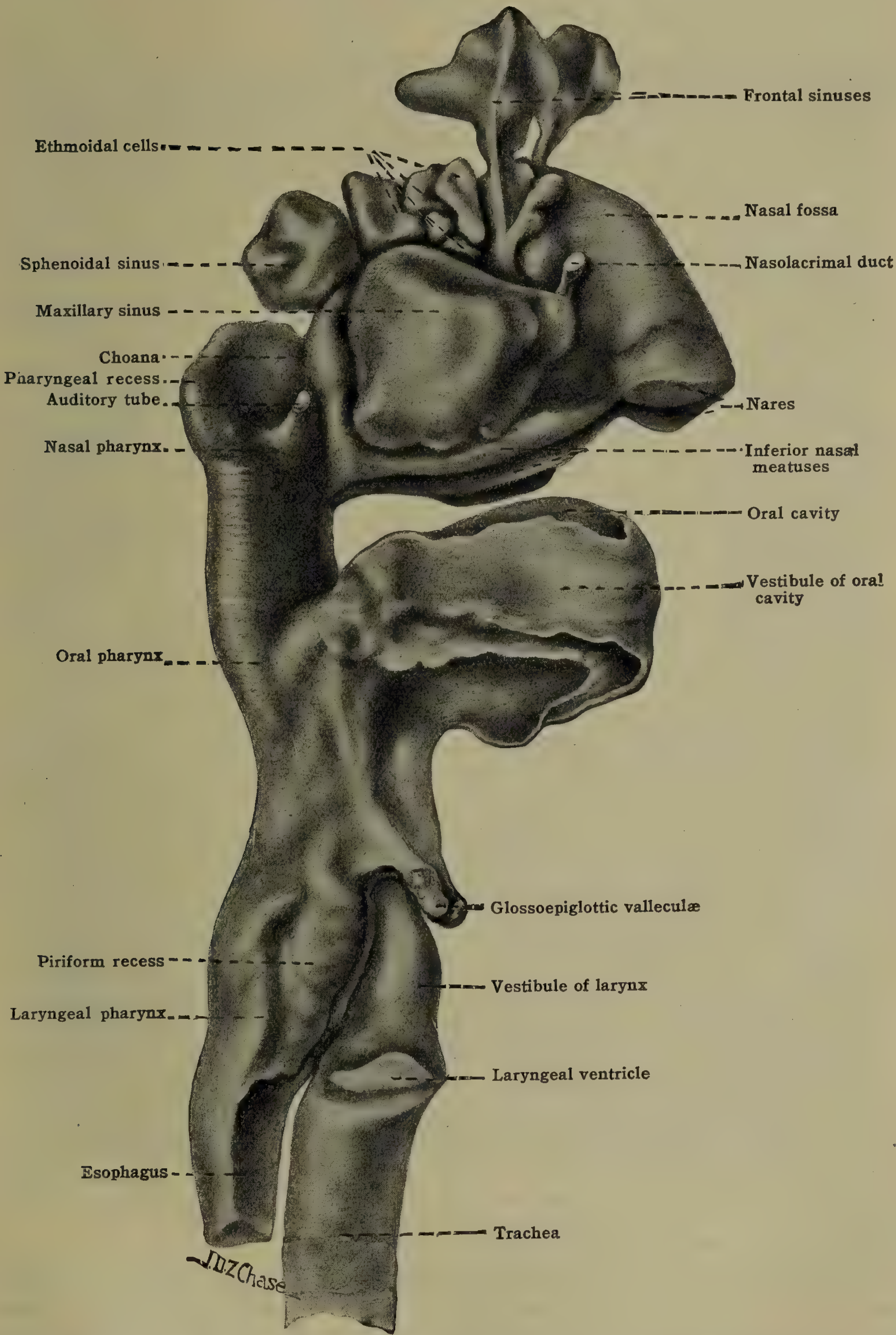


FIG. 1046.—CAST OF THE NASAL FOSSÆ, PARANASAL SINUSES, ORAL CAVITY, PHARYNX AND LARYNX. Lateral view. After a cast by J. P. S. and C. H. H. in the Daniel Baugh Institute of Anatomy of the Jefferson Medical College.

Often it does not invade far into the vertical portion of the frontal bone, but grows extensively into the orbital portion. There may be a total absence in one or the other portion.

The frontal sinus usually communicates with the pouch-like **frontal recess** of the middle nasal meatus, either by means of a constricted canal, the **nasofrontal**

duct (infundibulum of the frontal sinus), with proximal and distal **frontal ostia,** or by a fairly large, direct, single **frontal ostium** communicating between the frontal recess and the frontal sinus.

Occasionally the nasofrontal duct, or the frontal sinus proper in the absence of a duct, is directly continuous with the infundibulum ethmoidale (fig. 1044). Usually, however, the infundibulum ethmoidale and the nasofrontal duct are discontinuous channels (figs. 1043, 1045). In approximately one-half of the latter cases the relationship is so intimate that secretions from the frontal sinus readily drain into the infundibulum ethmoidale, thence by way of the ostium maxillare into the sinus maxillaris. The efficiency of the nasofrontal duct as a drainage channel is in direct ratio to its length, diameter and directness. Often anterior ethmoidal cells encroach upon it, causing it to be constricted and sinuous in its course. Many frontal sinuses have no true nasofrontal duct, the sinus itself opening into the frontal recess by a direct single frontal ostium.

In a recent study of a large series of adult frontal sinuses average measurements were found as follows: height, 27.9 mm.; width, 23.25 mm.; depth, 19.25 mm. The combined volume of the right and left frontal sinus averaged 14 cc. (range 1–45 cc.). The frontal sinus is ethmoidal in topography before it is frontal.

One usually cannot be certain which of the potential rudiments are to develop into the frontal sinus until the latter half of the first year of postnatal life. By the end of the second year the frontal sinus has eroded into the vertical portion of the frontal bone, measuring 5 × 3 × 4 mm. and by the sixth year measures 8 × 4 × 6 mm.

The ethmoidal cells [cellulæ ethmoidales] (sinus ethmoidales NK).—The ethmoidal air-cells (figs. 1042, 1043, 1046) are primarily extensions or evaginations of the nasal mucous membrane from the middle, superior and supreme nasal meatuses, or from their secondary furrows and recesses. The ethmoidal cells by their growth ultimately honeycomb the lateral masses of the ethmoid bone and collectively form the paired *ethmoidal labyrinths* which occupy the space between the upper part of the nasal fossæ and the orbits, as shown in figs. 1042, 1047.

Very commonly the ethmoidal cells extend into certain of the nasal conchæ and the secondary folds of the related meatuses, forming the *conchal cells;* and into neighboring bones, forming *ethmofrontal, ethmomaxillary, ethmosphenoidal* and *ethmopalatine* cells. A very thin mucous membrane, directly continuous with that of the respiratory region of the related nasal meatuses, lines the cells. Often the osseous boundaries are deficient.

The ethmoidal cells are divided into two primary groups, the anterior and the posterior ethmoidal cells. The **anterior group** (s. ethmoidales frontales NK), from two to eight in number, have their ostia in communication with various parts of the middle nasal meatus. The anterior ethmoidal cells are subdivided into *secondary groups,* viz., the **frontal ethmoidal cells,** opening into the frontal recess of the middle meatus; the **infundibular ethmoidal cells,** opening into the ethmoidal infundibulum of the middle meatus; and the **bullar ethmoidal cells** (often called the middle ethmoidal cells), opening into the middle meatus, either upon or above the ethmoidal bulla, the latter being hollowed out by them (figs. 1042, 1043). The **posterior group** (s. ethmoidales occipitales NK), from one to seven in number, have their ostia or apertures above the middle nasal concha and in communication with both the superior and supreme nasal meatuses.

The supreme meatus is found in about 60 per cent. of adult specimens and 75 per cent. of these receive the ostium of a posterior ethmoidal cell. The superior meatus receives the apertures of posterior ethmoidal cells in practically all cases (fig. 1043).

In a recent study, the number of cells composing the ethmoidal labyrinth was found to vary from 3 to 18. The fewer the cells, the larger are the individual cells, since the ethmoidal labyrinth occupies the entire ethmoidal field whether composed of few or many cells. In the newborn, the anterior group measures on the average 5 × 2 × 2 mm. and the posterior group 5 × 4 × 2 mm. In the adult the anterior group measures on the average 23.6 mm. in height, 22.6 mm. in length, and 11 mm. in width. The corresponding diameters of the posterior group are 20.8 mm., 20.5 mm. and 12 mm., respectively.

The sphenoidal sinus [sinus sphenoidalis].—The paired sphenoidal sinuses (figs. 1043, 1046, 1047) pneumatize the body of the sphenoid and frequently extend into the great wings, the pterygoid processes, and the rostrum of the sphenoid and the basilar process of the occipital bone. Occasionally the sphenoidal sinus may replace certain of the posterior ethmoidal cells, coming into immediate relation-ship with the maxillary sinus. The converse may occur in which one or more posterior ethmoidal cells encroach upon the sphenoidal sinus. The sphenoidal sinuses vary greatly in size and shape and are usually asymmetrical, with corresponding asymmetry of the intervening **sphenoidal septum** [septum sinuum sphenoidalium].

Sphenoidal sinuses may be either very rudimentary or extremely large. The dimensions of the average sinus may be given as follows: height, 20 mm.; width, 18 mm.; length, 12 mm. Conforming with the variations in size, the capacity of the sphenoidal sinus varies from 0.5 cc. to 30 cc., with an approximate average of about 7.5 cc.

The sphenoidal sinus of each side communicates with the sphenoethmoidal recess of the nasal fossa by means of an aperture, the **sphenoidal ostium** [apertura

Fig. 1047.—Photograph of a Horizontal Section through the Eyeballs, Ethmoidal Labyrinths, and Sphenoidal Sinuses.

Especially note the intimate relationship of the optic nerves to the posterior ethmoidal cells and the sphenoidal sinuses. The erectile character of the mucous membrane of the nasal septum and the nasal conchæ and the lacrimal sacs is clearly shown. (After Schaeffer, in Jackson-Coates, 'Nose, Throat & Ear', W. B. Saunders Co.)

sinus sphenoidalis]. The latter is large in the dried skull, but much reduced in the recent and living state by the related mucous membrane.

The ostium sphenoidale is located in the anterior wall of the sphenoidal sinus from 3 to 20 mm. above the floor. It always opens into the posterior wall of the sphenoethmoidal recess above the uppermost nasal concha. The sphenoidal ostium is very disadvantageously placed as an efficient drainage aperture owing to its great distance from the floor of the sphenoidal sinus, averaging 14 mm.

The sphenoidal sinus arises primarily in relation with the posterior cupola of the cartilaginous nasal capsule, the wall of which gives the foundation for the sphenoidal turbinal or

ossicle of Bertin. The posterior cupola or recess is, strictly speaking, the primitive sphenoidal sinus and is demonstrable as early as the fourth month of fetal life. It is only after the ossicle of Bertin fuses with the ethmoid and presphenoid bones, which occurs during the fourth year of infancy, that the sphenoidal sinus begins to excavate the body of the sphenoid. The average sphenoidal sinus of the term fetus has a capacity of from 6 to 8 cubic mm. By the second year the sphenoidal sinus averages 4 × 3.5 × 2 mm.; the fifth year 7 × 6.5 × 4.5 mm.; and by the ninth year 5 × 12 × 10 mm.

Clinical aspects.—The following points of clinical importance should be remembered:—(1) Fracture through the sphenoidal sinuses may lead to bleeding from the nose, which is thus brought into communication with the middle fossa; (2) the walls are frequently uneven and partially blind recesses and diverticula are formed, osseous dehiscences are common; (3) here and in the frontal sinuses very dense exostoses are sometimes formed. Before any operative attack on these sinuses is undertaken, their most important relations should be remembered. Thus above are the optic nerves, the hypophysis (see p. 1431), and posteriorly the pons.

Fig. 1048.—The Mucous Membrane of the Inferior Nasal Concha. (Photograph, from a female aged 40 years.) (After Schaeffer, in Cowdry's 'Special Cytology,' Courtesy Paul B. Hoeber, Inc.)

Externally and laterally lie the cavernous sinus, internal carotid artery, and superior orbital (sphenoidal) fissure and related cranial nerves. Below is the roof of the nasopharynx.

Functions of the paranasal sinuses.—It may be that the paranasal sinuses exert a secondary influence on vocalization and supply a small amount of moisture in the form of mucus to the nasal fossæ. The sinuses may, by lightening the ventral and facial part of the skull, aid in bringing about proper equipoise of the head. There is some phylogenetic evidence that some of the paranasal sinuses at one time had to do with the olfactory function. However, with the marked reduction of the olfactory sense in man, the one conspicuous and probably dominant function remaining is that as an adjunct to respiration, particularly aiding in warming and humidifying the inspired air.

The mucous membrane of the nose [membrana mucosa nasi] completely lines the nasal cavity and inferiorly, at the limen nasi, blends with the skin covering the walls of the vestibule. Posteriorly it joins the mucous membrane of the pharynx and palate. It covers some of the openings which are seen in the bony walls; those apertures, however, which lead into the paranasal sinuses and into the nasolacrimal duct remain patent, although as already stated the bony

openings are much reduced in size. The structure of the nasal mucosa is shown in fig. 1048.

In the nasal cavity the bright rose-red vascular mucous membrane is tightly bound to the periosteum and perichondrium, and is covered with a ciliated columnar epithelium. Numerous large mucous and serous **nasal glands** [glandulæ nasales] pour their more or less watery secretion over the entire surface. A very considerable venous plexus is found in many parts of the nasal mucosa. Over the inferior concha and to a less extent in the mucosa of the middle and superior conchæ, it forms the **cavernous plexuses** of the **conchæ** [plexus cavernosi concharum], contributing to build up about these bodies a true erectile tissue. The thickness which these glands and venous plexuses give to the mucous membrane of the chonchæ causes the marked increase in size of these bodies over that of their bony supports. These plexuses are often involved in severe epistaxis. The region covered by the mucous membrane just described forms the greater part of the nasal cavity, and is known as the **respiratory region** [regio respiratoria]. The mucous membrane of a small area over the superior and supreme conchæ, a small portion of the middle concha and the adjacent septal wall (fig. 1049) has a somewhat different structure. In this area the olfactory nerves are distributed, whence it is known as the **olfactory region** [regio olfactoria], and its mucous membrane, compared with that of the respiratory region, is less vascular, yellow or yellowish-brown in color, and covered by a non-ciliated epithelium. Its cells, specially modified, some of which are directly connected with the olfactory nerve, form the **olfactory organ** [organon olfactus]. Small mucous **olfactory glands** [glandulæ olfactoriæ] occur in the region. The mucous membrane which lines the *paranasal sinuses* throughout is a continuation of the respiratory nasal mucosa; it is, however, paler, less vascular, somewhat thinner, and more loosely attached to the bones. Mucous glands are variously present, but less abundant than in the nasal cavity proper.

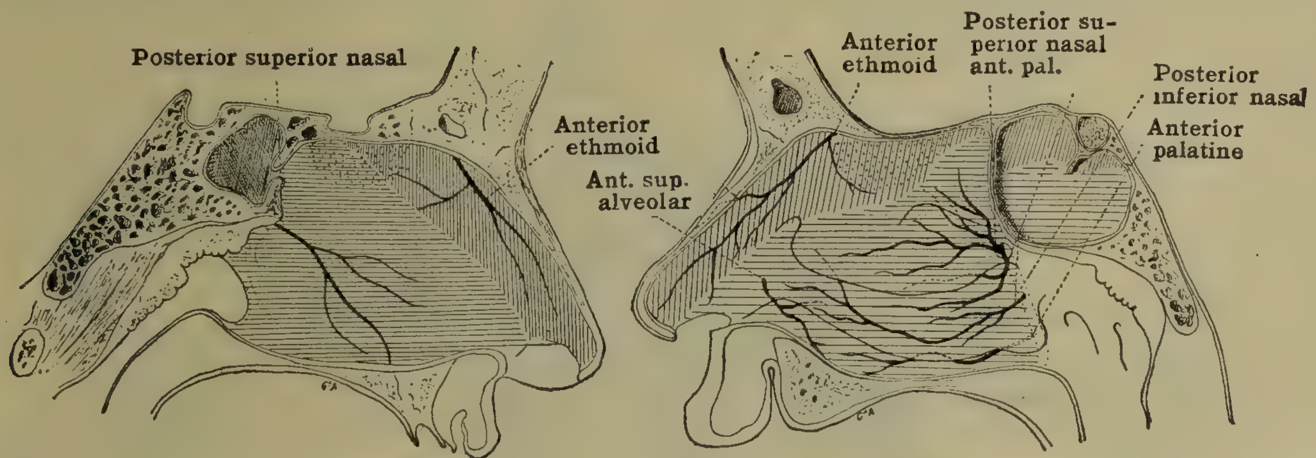


FIG. 1049.—DIAGRAM OF THE DISTRIBUTION OF THE NERVES IN THE NASAL CAVITY. (Poirier and Charpy.)
The olfactory area is represented by dots.

Vessels and nerves.—The **arteries** of the nasal cavity are the sphenopalatine artery from the internal maxillary which, through its posterior lateral nasal branches, supplies a goodly portion of the nasal conchæ (p. 626), and through its posterior septal branches (nasopalatine artery), supplies the inferior and posterior portion of the nasal septum; the anterior and posterior ethmoidal arteries from the ophthalmic (p. 629) supply portions of both medial and lateral nasal walls; the descending palatine artery from the internal maxillary supplies small branches to the posterior portion of the nasal fossa and by its direct continuation (the great palatine artery) passes through the incisive foramen to the anterior portion of the floor of the nasal fossa (p. 626); and the superior labial branch of the external maxillary supplies the vestibule and adjacent parts. The **venous plexuses** of the mucous membrane are drained posteriorly by the sphenopalatine vein to join the pterygoid plexus, superiorly by the anterior and posterior ethmoidal veins to join the superior ophthalmic vein, and anteriorly by small branches to join the facial. The **lymphatics** form a well-developed plexus which is said to communicate indirectly, through the lymph-spaces surrounding the olfactory nerves, with the subdural and subarachnoid spaces. Posteriorly two or more well-developed trunks communicate with the pharyngeal lymphatics, and anteriorly the nasal lymphatics join with the lymphatics of the face. The **olfactory nerves** pass through the cribriform plate of the ethmoid bone and are distributed to the olfactory bulb (p. 1003). The **trigeminal nerve** furnishes the following branches to the nasal cavity: branches from the nasociliary branch of the ophthalmic nerve; the posterior superior and posterior inferior nasal, the nasopalatine and the anterior palatine from the sphenopalatine ganglion (p. 1038); the anterior superior alveolar from the infraorbital division of the maxillary nerve (p. 1012). See also the terminal and vomeronasal nerves (p. 1003).

The development of the nose.—The nasal cavity makes it appearance as a depression on either side of the median line, immediately above the oral fossa, with which the depressions are at first superficially continuous. Later, by the fusion of the maxillary and medial nasal processes (see p. 19), the depressions or nasal pits are wholly separated from the oral fossa. The nasal pits then establish a secondary connection with the roof of the primitive mouth-cavity by an attenuation and ultimate rupture (45-day embryo) of the bucconasal membranes of Hochstetter in the formation of the primitive choanæ or primitive posterior nares. Later the upper portion of the mouth-cavity becomes part of the nasal cavity by the formation of the palatal processes of the maxillæ and palatine bones, so that finally the definitive hard palate is completed and the nasal cavities establish communication dorsally with the pharynx by means

of the choanæ or posterior nares as found in the adult. The wide septum between the nasal pits narrows and becomes the nasal septum proper, dividing the nasal cavity into the paired nasal fossæ.

The lateral walls of the nasal fossæ, at first smooth and even, at an early time show grooves or furrows, the precursors of the nasal meatuses. The furrows delimit folds, the precursors of the nasal conchæ. Later cartilage develops within the epithelially covered mesenchymal conchæ which subsequently, together with that of the lateral nasal walls proper, undergoes ossification. The nasal mucous membrane also evaginates into neighboring bones, giving origin to the ethmoidal cells and the frontal, sphenoidal and maxillary sinuses, the initial points of outgrowth remaining as the ostia or apertures of the adult cells and sinuses.

The paranasal sinuses are preformed in the nasal meatuses and the secondary furrows that mold the lateral walls of the meatuses. This is true of all the paranasal sinuses save the sphenoidal which arises in connection with the posterior cupola of the cartilaginous nasal capsule, and in a sense is primarily a constriction of the nasal mucosa from the most dorsal and cephalic part of the nasal fossa. No paranasal sinus develops from the inferior nasal meatus. The pre-existing spaces from which paranasal sinuses and cells develop are: (1) the suprabullar recess; (2) the bullar furrow; (3) the infrabullar furrow; (4) the ethmoidal infundibulum, all of the descending ramus of the middle nasal meatus; (5) the frontal furrows; (6) the frontal recess, both of the ascending ramus of the middle nasal meatus; (7) the anterior extremity and the superior and inferior recesses of the superior nasal meatus; (8) the supreme nasal meatus; (9) the sphenoethmoidal recess.

THE LARYNX

The **larynx** (figs. 1035, 1050, 1051, 1054), is a tubular organ, the framework of which consists of cartilages and elastic membranes. Its inner surface is covered

FIG. 1050.—VIEW OF INTERIOR OF LARYNX AS SEEN FROM ABOVE DURING INSPIRATION.

with mucous membrane continuous with that of the pharynx above and the trachea below. From the membranes are formed a pair of **vocal folds** which, by

FIG. 1051.—VIEW OF INTERIOR OF LARYNX AS SEEN FROM ABOVE DURING VOCALIZATION.

the passage of air through the larynx, are thrown into vibration and so function in the generation of sound. These folds are affected in respect to their tension and

in their mutual relation by the actions of a system of laryngeal muscles under the control of the vagus nerve and are made thereby, on the one hand, to produce those modifications of the sound involved in the voice and on the other hand to regulate the amount of air passing through the **cavity of the larynx.** The latter communicates above with the pharynx by means of an opening called the **superior laryngeal aperture** [aditus laryngis], and below with the cavity of the trachea. Figure 1050 shows the superior laryngeal aperture with its boundaries, the **epiglottis** and the **aryepiglottic folds**; also the cavity of the larynx where, on the walls right and left, appear the **ventricular** and the **vocal folds** with the chink called the **rima glottidis** separating the latter. The position of the larynx and some of its important parts can be well seen in a midsagittal section (fig. 1052).

THE CARTILAGES OF THE LARYNX

The **laryngeal cartilages** [cartilagines laryngis] are nine in number, three of which (cricoid, thyroid, epiglottic) are single and the rest (arytenoid, corniculate, cuneiform) in pairs.

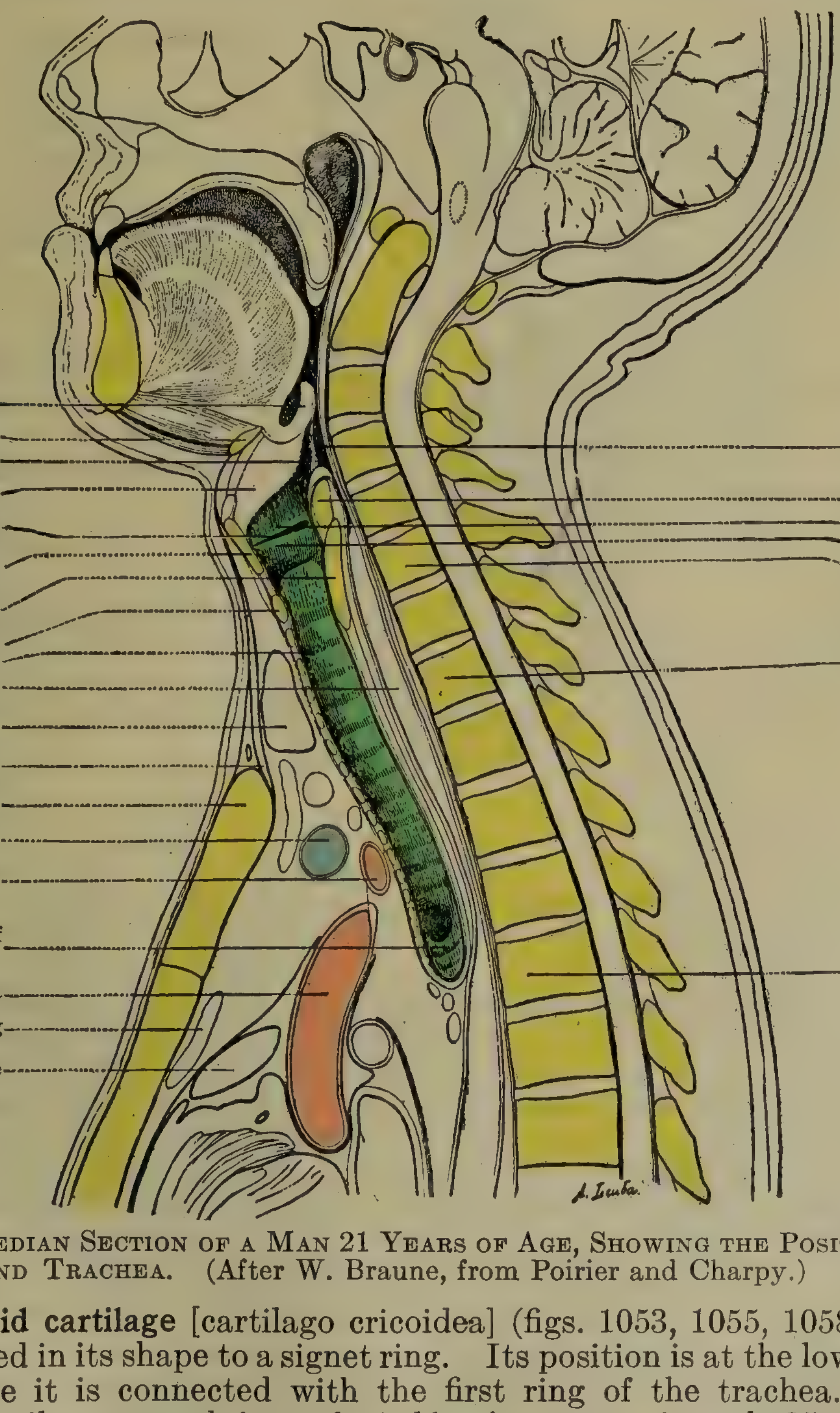


FIG. 1052.—MEDIAN SECTION OF A MAN 21 YEARS OF AGE, SHOWING THE POSITION OF LARYNX AND TRACHEA. (After W. Braune, from Poirier and Charpy.)

The **cricoid cartilage** [cartilago cricoidea] (figs. 1053, 1055, 1058), single, has been compared in its shape to a signet ring. Its position is at the lower end of the larynx, where it is connected with the first ring of the trachea. Posteriorly the cricoid cartilage expands into a broad **lamina,** approximately 25 mm. in height, which enters into the dorsal boundary of the laryngeal cavity, while laterally and ventrally it forms a narrow **arch** [arcus] measuring but 8 mm. On either side of the upper margin of the lamina is the elliptical **arytenoid articular surface** [facies articularis arytænoidea], its long axis parallel with the margin of the cricoid, its steeply sloping surface convex for articulation with the arytenoid cartilage.

The dorsal surface of the lamina presents a vertical median ridge which gives attachment to some of the longitudinal fibers of the esophagus and paired lateral impressions for the attachment of the posterior cricoarytenoid muscles. The arch, weakest in its middle part, presents concave upper and straight lower margins. A circular, elevated **thyroid articular surface** [facies articularis thyreoidea] for articulation with the inferior cornu of the thyroid cartilage is situated upon the side of the cricoid where arch and lamina are continuous. The internal surface is covered by the mucous membrane of the larynx.

The **thyroid cartilage** [cartilago thyreoidea] (figs. 1053, 1055, 1057), single and the largest in the laryngeal skeleton, is composed of two broad **laminæ, right and left,** which meet and are fused ventrally in the midline, forming an angle of 90° with one another in the male and 120° in the female. The laminæ are stout, but their connection at the angle is through a weak strip of cartilage. The upper margin of each lamina is convex, and in front drops abruptly to form in the median line the **superior thyroid notch** [incisura thyreoidea superior]. The ventral edges,

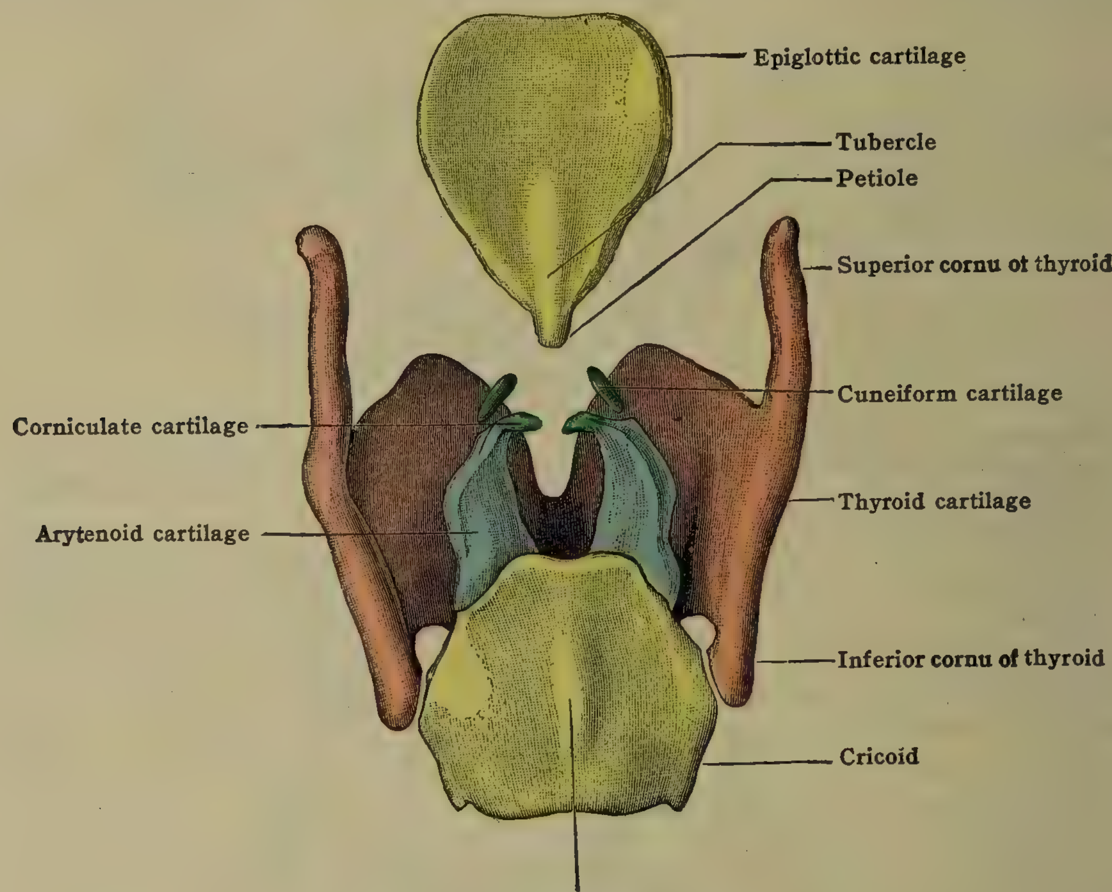


Fig. 1053.—Cartilages of the Larynx Seen from Behind in Their Natural Positions. The Cuneiform Cartilage is Somewhat Higher than Normal. (Merkel.)

meeting in the angle, produce the subcutaneous **laryngeal prominence** [prominentia laryngea] ('Adam's apple'), which is seen on the ventral aspect of the neck. The horizontal inferior margin presents near its middle the **inferior thyroid tubercle** [tuberculum thyreoideum inferius], and in the median line the **inferior thyroid notch** [incisura thyreoidea inferior]. The thick dorsal margin of each lamina is continued above the superior edge in the long **superior cornu** [cornu superius] (c. hyoideum NK), and below the inferior margin in the short **inferior cornu** [cornu inferius] (c. cricoideum NK). The former is directed slightly dorsalward and medialward, and joins with the end of the greater cornu of the hyoid by a ligament. The inferior cornu, curving medialward as it descends, articulates by a flat, circular facet upon the medial side of its extremity with the thyroid articular surface of the cricoid cartilage. The external surface of the lamina affords attachment for muscles and presents in its upper posterior part the **superior thyroid tubercle** [tuberculum thyreoideum superius]; in its lower part the **inferior thyroid tubercle.** The *oblique line* [linea obliqua] extends between the two thyroid tubercles. The internal surface of the thyroid cartilage is smooth.

A **thyroid foramen** [foramen thyroideum], sometimes seen in the upper part of the lamina and giving passage to the superior laryngeal artery, results from the incomplete union of the fourth

and fifth branchial cartilages from which the laminæ are derived. The **oblique line** is commonly present and is regarded by many anatomists as a normal feature of the external surface of the thyroid cartilage. It marks the attachment of the sternothyroid and thyrohyoid muscles. At the insertion of the vocal ligaments in the angle of the laminæ, a small perichondral process is often observed.

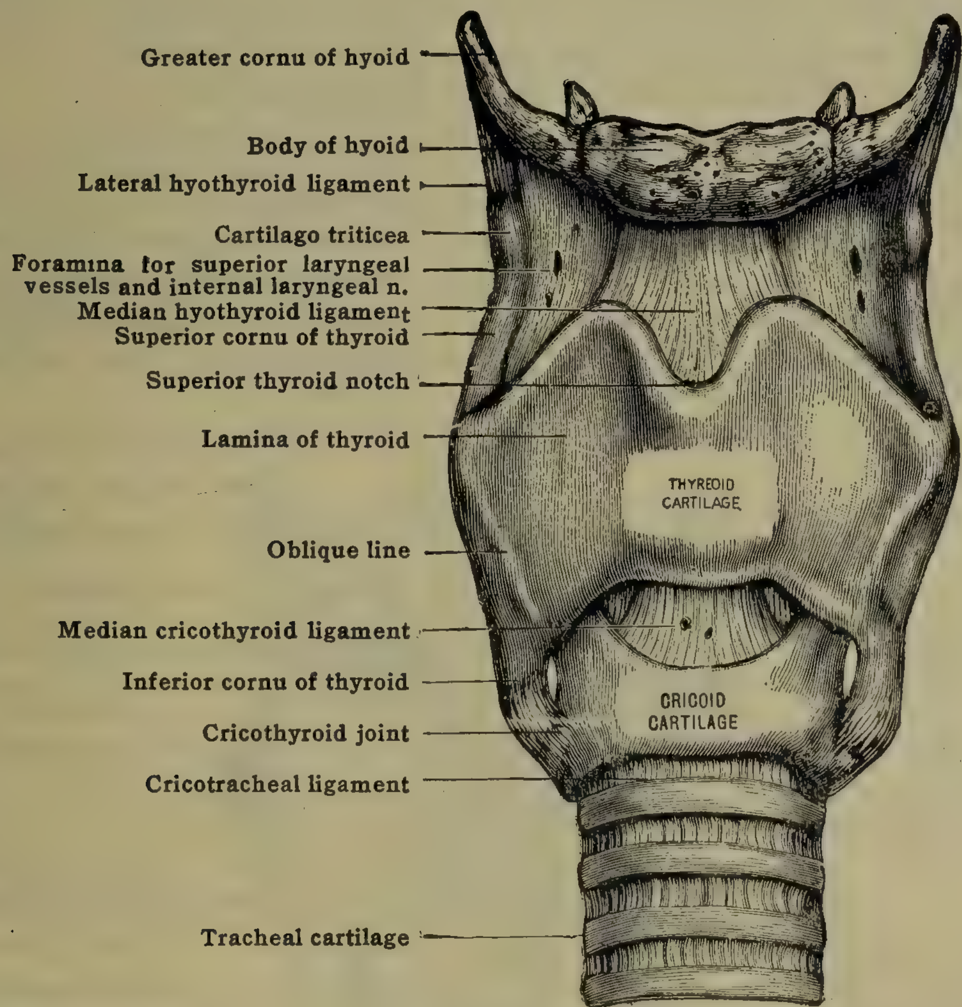


FIG. 1054.—FRONT VIEW OF THE LARYNGEAL SKELETON. (Modified from Bougery and Jacob.)

The **arytenoid cartilages** [cartilagines arytænoideæ] (figs. 1053, 1057, 1058, 1059), paired, surmount the lamina of the cricoid cartilage and give attachment to the vocal ligaments, whose relations and state of tension are altered by the changes in position which these cartilages are almost constantly undergoing.

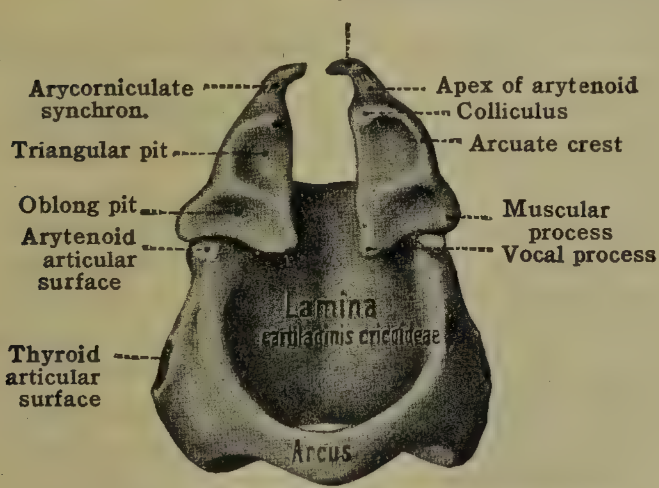


FIG. 1055.—CRICOID AND ARYTENOID CARTILAGES, VENTRAL VIEW. (Rauber-Kopsch.)

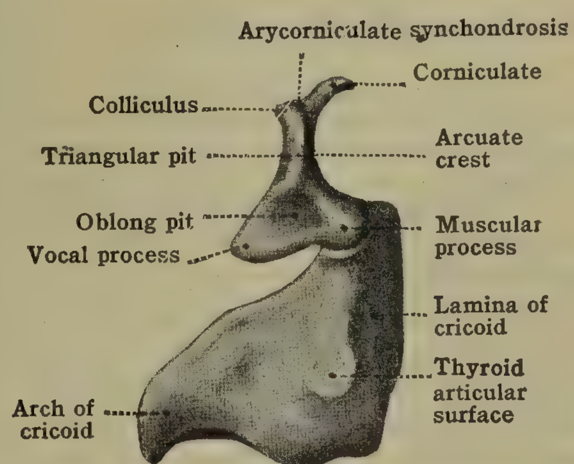


FIG. 1056.—CRICOID AND ARYTENOID CARTILAGES SEEN FROM THE LEFT. (Rauber-Kopsch.)

Each cartilage is pyramidal in form, and molded for the attachment of several muscles. The **apex,** which is above, is bent dorsalward and medialward and is connected with a corniculate cartilage. The **base,** somewhat triangular in shape, presents at the lateral and dorsal part an oval or circular concave **articular surface,** directed medialward and caudalward to meet the arytenoid articular surface of the cricoid cartilage. The lateral angle of the base is prolonged into a stout **muscular process** for the insertion of the cricoarytenoid muscles, while

the anterior angle is extended as a sharp projection, the **vocal process** [processus vocalis], which serves for the attachment of the vocal ligament. The surfaces of the arytenoid are medial, dorsal, and ventrolateral. The narrow **medial surface**, covered by the mucosa of the larynx, is nearly vertical, and faces the corresponding side of the opposite arytenoid, from which it is separated by a small space. The **dorsal surface** is concave for muscular attachment. The **ventrolateral surface** is the largest, and presents an irregular contour.

On this surface a ridge, the **arcuate crest** [crista arcuata], extends horizontally between two hollows—the **triangular fovea** [fovea triangularis] above, which lodges some mucous glands, and a large depression below, the **oblong fovea** [fovea oblonga] for the vocal muscle. The **colliculus** is a small eminence found upon the ventral margin and ventrolateral surface.

The corniculate cartilages (of Santorini) [cartilagines corniculatæ (Santorini)] (figs. 1053, 1055, 1057).—This pair of small conical cartilages is set upon the bent apices of the arytenoids, continuing their curves dorsalward and medialward.

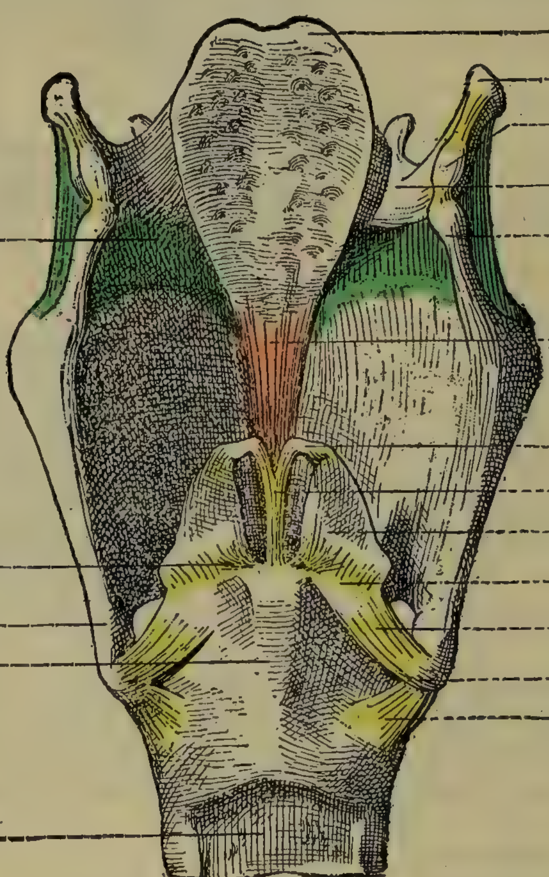


Fig. 1057.—The Laryngeal Skeleton, Dorsal View. (Modified from Poirier and Charpy.)

The corniculate cartilage is not an independent structure in many lower animals, and its continuity with the arytenoid is sometimes met with in man where the two cartilages are normally developed in a continuous mass of tissue.

The **epiglottic cartilage** [cartilago epiglottica] (figs. 1053, 1057, 1061, 1067), unpaired, invested by mucosa behind and partly in front, thin and leaf-shaped, stands behind the root of the tongue and the body of the hyoid. It lies above the thyroid cartilage, in front of the entrance of the larynx. The free upper margin is convex, or notched; the lower end tapers to a short stalk, the **petiole** of the epiglottis [petiolus epiglottidis], to which the thyroepiglottic ligament is attached. The ventral surface is free above and covered by mucosa; in its lower part it is bound to the body of the hyoid, and is separated by a mass of fat from the hyothyroid ligament. Its dorsal surface above is saddle-shaped; below, it is convex, presenting the **epiglottic tubercle** [tuberculum epiglotticum]. To the margins are attached the aryepiglottic folds. The epiglottic cartilage presents numerous small holes and depressions for the accommodation of glands.

The **cuneiform cartilages (of Wrisberg)** [cartilagines cuneiformes (Wrisbergi)] (fig. 1053) lie as small, rod-like bodies in the aryepiglottic folds anterior to the corniculate cartilages. They are variable in form and size and not rarely absent altogether.

These cartilages are parts of the epiglottic cartilage in some mammals where, as in man, they lie in the aryepiglottic folds. Their relations to the arytenoids are regarded as secondary.

Sutton has shown that in the ant-eater a continuous rim of yellow elastic cartilage extends from the sides of the epiglottic cartilage to the summits of the arytenoids. A minute unpaired *interarytenoid* or *precricoid cartilage* is rarely present imbedded in the cricopharyngeal ligament and covered by the pharyngeal mucosa. It is a constant structure in certain mammals. A pair of small *sesamoid cartilages*, also constantly present in some mammals, is occasionally found in man at the lateral margins of the arytenoids, connected with them and with the corniculate cartilages by elastic ligaments.

Structure of the cartilages.—The thyroid, cricoid, and greater part of the arytenoid are composed of hyaline cartilage; the epiglottic, corniculate, and cuneiform cartilages, as well as the apex and vocal process of the arytenoid, are of elastic cartilage. Certain parts of the laryngeal skeleton normally undergo calcification and ossification. Calcification begins at about twenty years of age in the thyroid and cricoid cartilages, and later in the arytenoid. The process begins a little later in the female than in the male, and does not extend so rapidly. The extent to which the cartilages are ossified and the time occupied in the process vary considerably. The elastic elements are not involved in the process.

Topography and clinical aspects.—Below the hyoid is the *thyrohyoid space*, which corresponds to the epiglottis and the upper aperture of the larynx. Thus, if the throat be cut above the hyoid, the mouth would be opened and the tongue cut into; if the thyrohyoid space be cut, the pharynx would be opened and the epiglottis wounded near its base. In the former case the lingual and external maxillary are the vessels most likely to be wounded; in thyrohyoid, the commonest cut-throat, the superior thyroid vessels, and the superior laryngeal nerve. The *laryngeal prominence* and thyroid notch begin about 2.5 cm. (1 in.) below the hyoid and are much more distinct in men than in women or children. The prominence is not marked before puberty, and thus forms a less distinct landmark for tracheotomy, especially in children with short fat necks.

The **cricoid arch**, on the other hand, is always to be made out. It corresponds in horizontal plane to the following:—(1) The sixth cervical vertebra. (2) The junction of pharynx and esophagus. From the narrowing of the alimentary tube here, foreign bodies may lodge and cause dyspnea by pressing on the air-tube in front. The cricoid is taken as the center of the incision in esophagotomy, and also for ligature of the common carotid. (3) The junction of larynx and trachea. (4) The crossing of the omohyoid over the common carotid. (5) The middle cervical ganglion. Above the cricoid is the cricothyroid ligament. In *laryngotomy*, the deepest part of the incision should be kept to the midline for fear of injuring the cricothyroid muscles, and as near the cricoid as possible, so as to avoid the neighborhood of the vocal

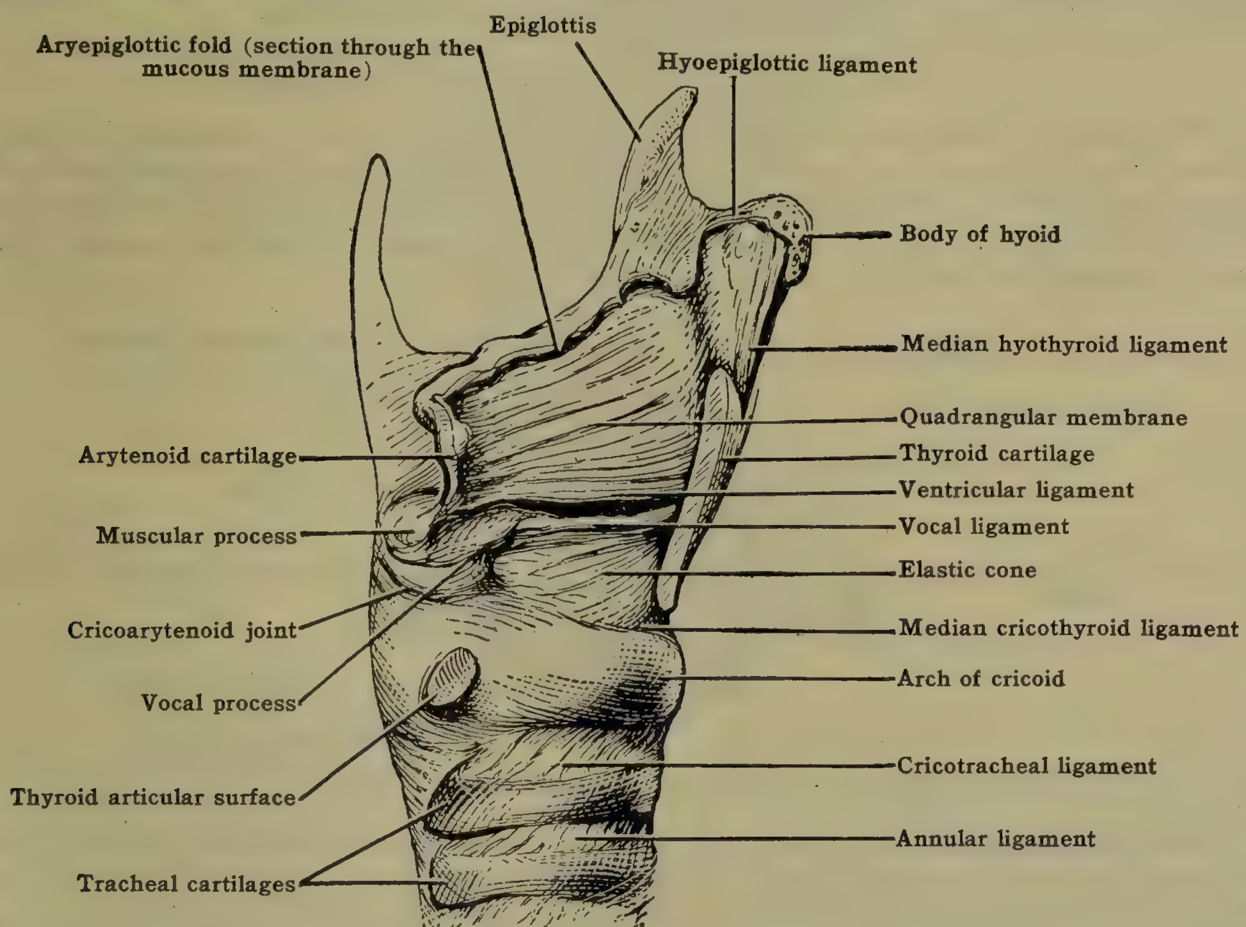


FIG. 1058.—THE LARYNX WITH ITS LIGAMENTS, VIEWED FROM THE RIGHT. (The right lamina of the thyroid cartilage has been removed.) (Spalteholz.)

folds (cords) and the small cricothyroid vessels. The space is always small, and, after middle life, increasingly rigid.

THE JOINTS AND MEMBRANES OF THE LARYNX

(A) THE ARTICULATIONS OF THE LARYNGEAL CARTILAGES

The cricothyroid articulation (figs. 1053, 1055).—The articular surfaces concerned are the thyroid articular surface on the lateral aspect of the cricoid and the

articular surface on the inferior cornu of the thyroid cartilage. The **crico-thyroid articular capsule** attached around the margins of these surfaces and certain accessory bands serve to bind the cartilages together. The capsule is lined by synovial membrane, forming a typical arthrodial joint.

The accessory bands, **ceratocricoid ligaments,** fall into three groups radiating from the inferior cornu: the **ligamenta ceratocricoidea posteriora** upward and medialward to the superior margin of the cricoid; the **ligamenta ceratocricoidea lateralia** downward at the side and back of the capsule; the **ligamentum ceratocricoideum anterius** downward and forward.

A rotary movement about a transverse axis of the cricoid upon the thyroid or *vice versa* and a slight backward and forward gliding are permitted at this joint.

The cricoarytenoid articulation (figs. 1053, 1057, 1058).—The articular surface of the cricoid cartilage and the articular surface of the arytenoid which enter into this articulation are so disposed that at no time do they meet in complete apposition. A loose capsule [capsula articularis cricoarytænoidea] of fibrous and synovial strata attached around the edges of the joint surfaces unites the cartilages and encloses a cavity, forming a typical arthrodial joint.

The **posterior cricoarytenoid ligament,** attached above to the medial surface of the base and muscular process of the arytenoid, and below to the lamina of the cricoid, is important in helping to fix the former cartilage in place upon the sloping arytenoid articular surface of the cricoid and in limiting its movements. Motion at this articulation is very free. The following simple movements of the arytenoid are best understood: (1) gliding of the arytenoid toward or away from its fellow; (2) inclining ventrally and dorsally; (3) rotating on a vertical axis, so that the vocal process sweeps medialward or lateralward and also a little caudalward or cephalad.

The arycorniculate articulation [synchondrosis arycorniculata] is the union of the apex of the arytenoid cartilage with the corniculate cartilage. It is usually formed by connective tissue; rarely in there a joint cavity.

The thyroepiglottic union is accomplished by the strong, elastic **thyroepiglottic ligament** (fig. 1057) connecting the petiole of the epiglottic cartilage with the thyroid cartilage, caudal and dorsal to the superior notch.

(B) The Elastic Membrane of the Larynx

The elastic membrane of the larynx [membrana elastica laryngis] is a name given to a more or less continuous sheet of elastic fibers connected with the deeper parts of the laryngeal mucosa. Its upper part is known as the *quadrangular membrane,* the lower part as the *elastic cone.* A middle region of the elastic membrane lies opposite the ventricle of the larynx.

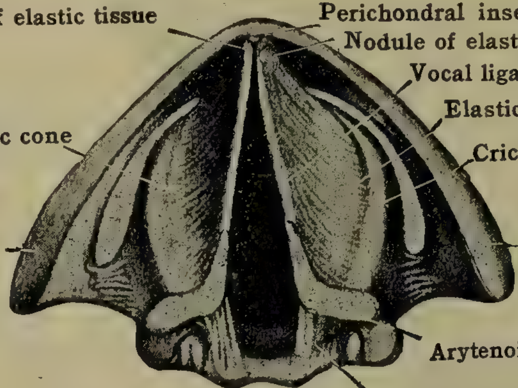


Fig. 1059.—The Elastic Cone Seen from Above. (Modified from Luschka.)

The quadrangular membrane (figs. 1058, 1061) extends from the aryepiglottic folds above to the level of the ventricular folds (false vocal cords) below. The lateral parts of this membrane are widely separated cephalically, but they converge toward the middle line as they descend. Ventrally, the membrane is fixed in the angle of the thyroid laminæ and to the sides of the epiglottic cartilage; dorsally, to the corniculate cartilages and to the arytenoids. The cephalic edge on either side lies within the aryepiglottic fold, which it supports; it slopes caudalward and dorsalward and includes the cuneiform cartilage. The caudal edge, horizontal and in a sagittal plane, is best developed ventrally, where it is attached in the angle of the thyroid a little way from the middle line; dorsally, it is fixed to the medial margin of the triangular fovea of the arytenoid. This caudal free margin, differentiated as the **ventricular ligament** [lig. ventriculare], is enclosed within, and is the support for the ventricular fold.

The elastic cone [conus elasticus] (figs. 1058, 1059) extends from the level of the vocal folds to the cephalic margin of the cricoid cartilage. Its component fibers are attached in the reentrant angle and adjacent caudal margin of the thyroid cartilage, whence they spread caudalward and dorsalward to the cephalic edge of the cricoid arch and to the arytenoid cartilages. The strong ventral portion, perforated by vessels, is the **median cricothyroid ligament** (figs. 1054, 1060). The lateral parts (lateral portions of the cricothyroid membrane) present cephalic free edges, somewhat thickened, which, running horizontally near the middle line from the thyroid angle to the vocal processes, constitute the **vocal ligaments.** These are inserted ventrally into a perichondral process in the thyroid angle; dorsally, they have a wide area of attachment to the cephalic and medial surfaces of the vocal processes of the arytenoids with the elastic fibers of which they are in part continuous. A yellowish, cellular nodule (sometimes cartilage) occurs in the ventral end of each ligament. The vocal ligaments enter into the formation of the vocal folds (true vocal cords).

(C) Connections between the Larynx and Neighboring Structures

The **hyothyroid membrane** [membrana hyothyreoidea] (figs. 1057, 1060, 1061) is a loose, fibrous, elastic sheet, binding together the thyroid cartilage and hyoid bone. It extends from the cephalic margin of the former to the greater

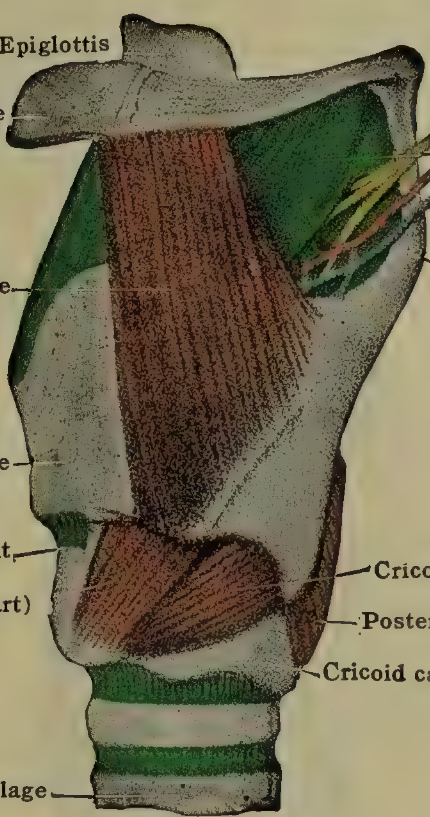


Fig. 1060.—The Larynx Seen from the Left Side. (Modified from Luschka.)

cornua and cephalic margin of the body of the latter. The superior laryngeal artery and vein and the internal laryngeal nerve pass through it from the side. Its dorsolateral edge is cord-like, consisting of elastic fibers which stretch as the **lateral hyothyroid ligament** from the superior cornu of the thyroid to the greater cornu of the hyoid. A small **cartilago triticea** is sometimes present in this band. The middle part, **median hyothyroid ligament,** thick and elastic, extends from the superior thyroid notch upward behind the body of the hyoid to be attached to its cephalic margin, the *hyoid bursa* being interposed between the bone and the membrane.

The cartilago triticea is the remains of a connection between the thyroid and hyoid present in the embryo. It persists in adult life in some lower animals.

The **hyoepiglottic ligament** [lig. hyoepiglotticum] (figs. 1058, 1061) connects the ventral surface of the epiglottic cartilage with the cephalic margin of the body and the greater cornua of the hyoid. It is a broad sheet, lying above a mass of fat which stands between the median hyothyroid membrane and the epiglottis

and spreading laterally to join the pharyngeal aponeurosis in the region of the piriform recess.

The name *glossoepiglottic ligament* is given to the elastic fibers extending between the root of the tongue and the epiglottis within the median glosso-epiglottic fold.

The **corniculopharyngeal ligament** (fig. 1057) extends from the corniculate cartilage caudalward and toward the median line, attaching to the mucosa of the pharynx and joining its fellow behind the arytenoid muscle. From this point a single band, the **cricopharyngeal ligament**, which may enclose a nodule of cartilage (**the interarytenoid cartilage**), descends in the middle line, to be fixed to the cricoid lamina and into the pharyngeal mucosa.

The larynx and trachea are united by fibrous membrane, the **cricotracheal ligament** [lig. cricotracheale] (figs. 1054, 1058), between the inferior margin of the cricoid cartilage and the cephalic margin of the first tracheal ring. Dorsally the ligament is continued into the membranous wall of the trachea.

THE MUSCLES OF THE LARYNX

The muscles of the larynx may be considered under two heads; (1) the *extrinsic* muscles, (2) the *intrinsic* muscles. The former group, described in Section V, come from neighboring parts and are inserted on the larynx, acting upon the voice-box as a whole. They are the *omohyoid, sternohyoid, sternothyroid* and *thyrohyoid* muscles and certain suprahyoid muscles, the *stylopharyngeus, palato-pharyngeus* and the *inferior* and *middle constrictors of the pharynx.* The intrinsic muscles confine themselves exclusively to the larynx and, acting upon its parts, modify the size of the laryngeal aperture (rima glottidis) and the degree of tension of the vocal ligaments. These muscles are composed of striated fibers

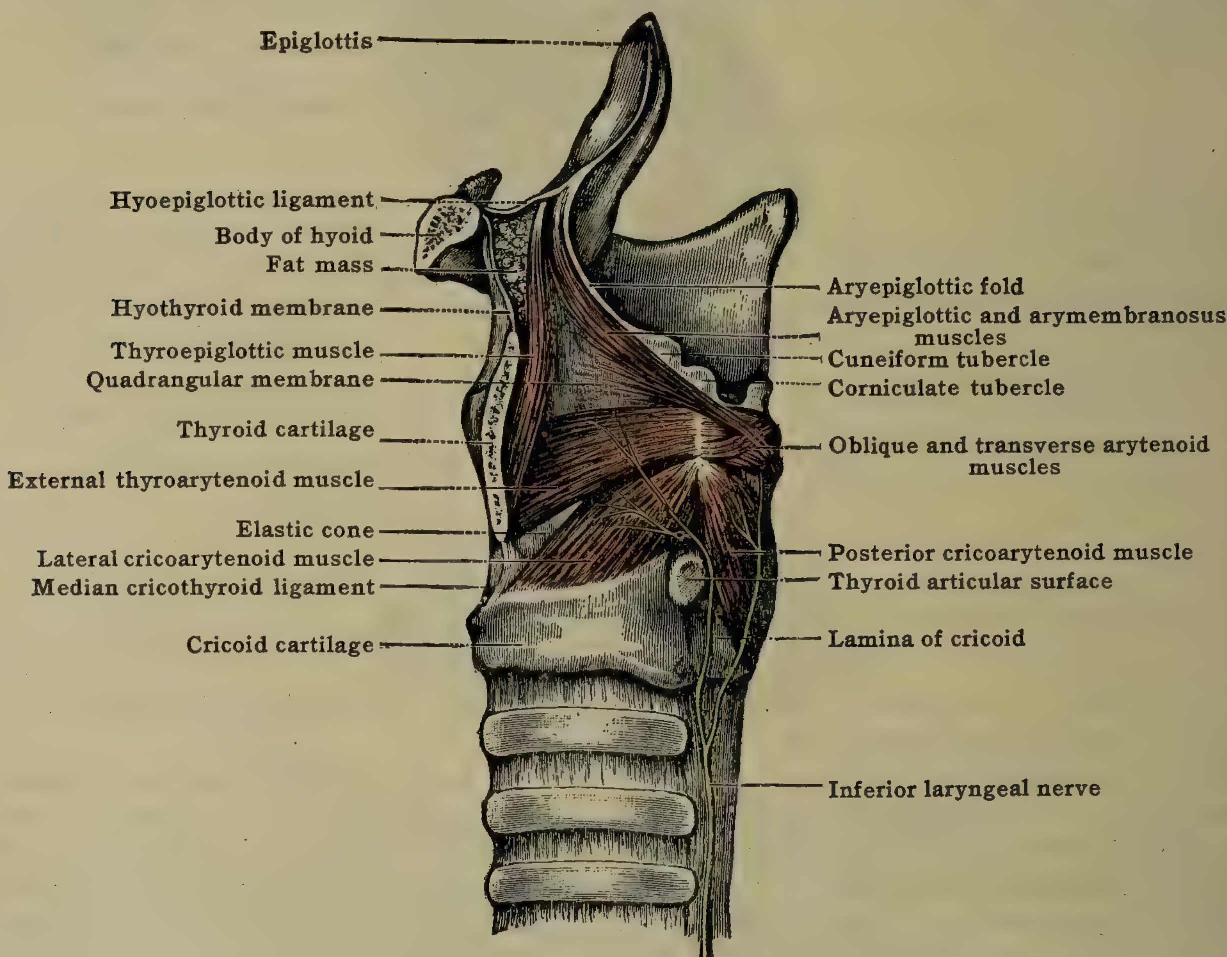


Fig. 1061.—The Muscles and Ligaments of the Larynx Seen from the Side. (The left lamina of the thyroid cartilage has been removed.)

and are supplied by the vagus nerve through its laryngeal branches. The principal intrinsic laryngeal muscles are (1) the *cricothyroid,* (2) the *posterior cricoarytenoid,* (3) the *arytenoid* (transverse and oblique), (4) the *lateral cricoarytenoid,* (5) the *thyreoarytenoid* (external and internal or vocal); all of which, save the transverse arytenoid, are in pairs.

The **cricothyroid muscles** [m. cricothyreoideus] (fig. 1060) are placed one on either side of the outer surface of the larynx in its lower part. Each muscle is partially separated into a ventral **straight** [pars recta] and a dorsal **oblique**

portion [pars obliqua], which together arise from the arch of the cricoid. The fibers of the straight part ascend steeply and are inserted into the caudal margin of the thyroid cartilage. The oblique portion is inserted into the inferior cornu and into the caudal margin and inner surface of the thyroid cartilage.

The straight part elevates the arch of the cricoid, causing the lamina, and with it the arytenoid cartilages, to sink, while the oblique part draws forward the thyroid; thus the vocal ligaments are made tense. The muscle is supplied by the external branch of the superior laryngeal nerve. A connection between the dorsal part of this muscle and the inferior constrictor of the pharynx together with their common nerve-supply indicate their genetic relationship.

The **posterior cricoarytenoid** muscle [m. cricoarytænoideus posterior] figs. 1060–1062), paired, is situated at the back of the larynx, covered by the submucous coat of the pharynx. It is a thick, triangular mass which takes origin from the posterior surface of the cricoid lamina, the two muscles being well separated by the median crest of the cartilage. The lower fibers ascend and the upper ones pass horizontally lateralward and are inserted into the muscular process of the arytenoid cartilage on its dorsal surface and tip.

When these muscles contract, the muscular processes of the arytenoids are pulled dorsalward and caudalward, while the vocal processes travel lateralward and a little upward, so that the rima glottidis is widened and the vocal ligaments made tense (fig. 1062). The innervation is by the posterior branch of the inferior laryngeal nerve.

At the lower margin of this muscle a small slip, the **ceratocricoid muscle,** is sometimes found, extending between the lamina of the cricoid and the inferior cornu of the thyroid.

The **transverse arytenoid** muscle [m. arytænoideus transversus] (pars transversa NK) (figs. 1061–1064) is a single muscle of quadrilateral form, extending across the middle line from the posterior concave surface of one arytenoid cartilage to that of the other. Its anterior surface, between the cartilages, is covered by the laryngeal mucosa; its posterior surface is crossed by the oblique arytenoid.

The arytenoideus transversus approximates the arytenoid cartilages and their vocal processes, thus narrowing the dorsal (respiratory) portion of the rima glottidis. It is supplied by the posterior branch of the inferior laryngeal nerve.

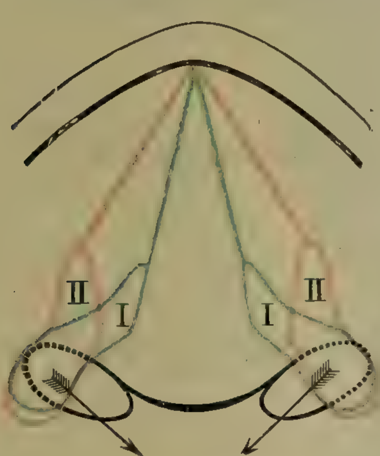


Fig. 1062.—Scheme of Rima, showing Action of Posterior Cricoarytenoid Muscle which Draws the Arytenoid Cartilage from I to II. (Modified from Stirling.)

Fig. 1063.—Scheme Showing Action of the Transverse Arytenoid Drawing Arytenoid Cartilage from Neutral Position I to II. (Modified from Stirling.)

Fig. 1064.–Scheme Showing Action of Thyroarytenoid Drawing the Vocal Processes and the Vocal Ligaments from II to I. (Modified from Stirling.)

The **oblique arytenoid** muscle [m. arytænoideus obliquus] (pars obliqua NK) (fig. 1065) is a paired slender band behind the larynx and under the pharyngeal submucosa. It arises from the muscular process of the arytenoid dorsally, and, ascending obliquely, crosses its fellow in the median line. Some fibers are inserted in the apex of the opposite arytenoid cartilage; other fibers sweep around the apex and accompany the thyroarytenoid to an insertion in the angle of the thyroid cartilage, constituting the *thyreoarytænoideus obliquus.*

The *arymembranosus* and the *aryepiglottic muscles* are inconstant fascicles which for the most part run from the paired oblique arytenoid muscles and expand in the aryepiglottic folds, becoming fixed into the quadrangular membrane and the margin of the epiglottic cartilage (fig. 1061).

The oblique arytenoid and aryepiglottic muscles contract the laryngeal aperture and vestibule of the larynx. They are supplied by the anterior branches of the inferior laryngeal nerve.

The **lateral cricoarytenoid** muscle [m. cricoarytænoideus lateralis] (fig. 1061) arises from the upper margin and outer surface of the cricoid arch and from the elastic cone, whence the fibers extend backward and upward to an insertion on the anterior surface of the muscular process of the arytenoid cartilage. This muscle is inseparable from the thyroarytenoid in about half the cases.

The lateral cricoarytenoids by their contraction cause the vocal processes to move toward the median line and a little downward, so that the vocal ligaments are approximated and slightly stretched. They antagonize the posterior cricoarytenoids. The anterior branch of the inferior laryngeal nerve supplies these muscles.

The **external thyroarytenoid** muscle [m. thyreoarytænoideus (externus)] (pars lateralis NK) (figs. 1061, 1064, 1068), variable in form and in the disposition of its fibers, is closely connected with the preceding. It lies under cover of the thyroid lamina lateral to the laryngeal saccule (ventricular appendix) and elastic cone. Arising within the angle of the thyroid laminæ, the muscle extends upward and backward to its insertion on the ateral margin of the arytenoid cartilage.

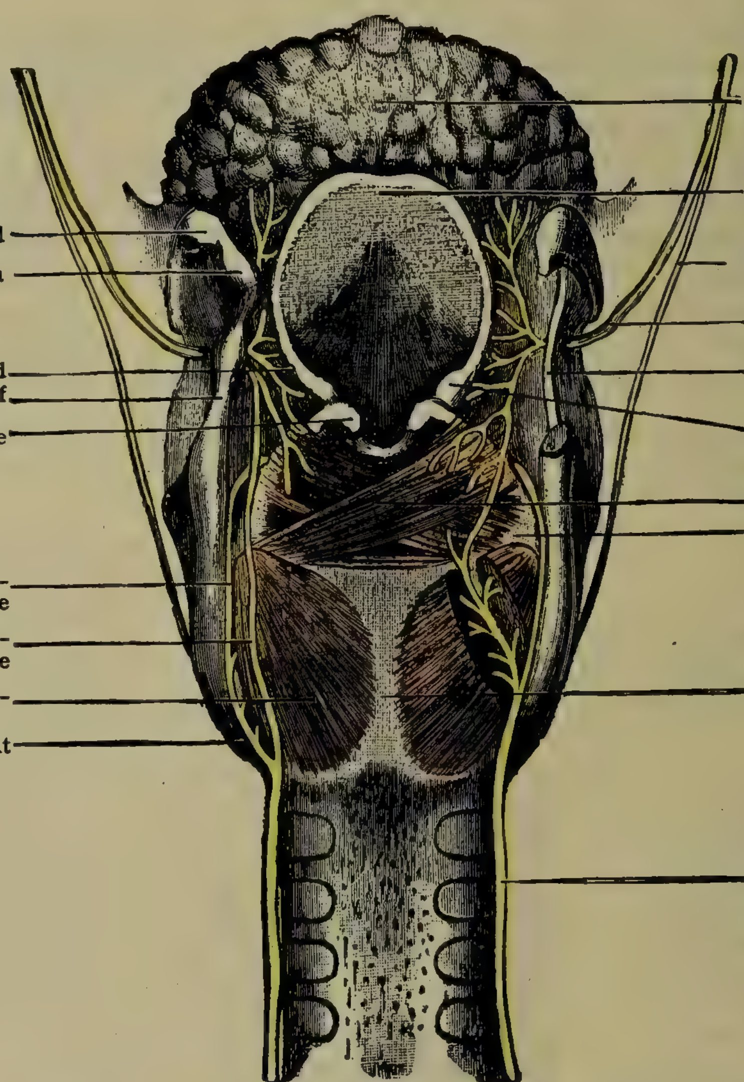


Fig. 1065.—The Muscles and Nerves of the Larynx. Dorsal View.

It draws forward the arytenoid cartilage (and also tilts the cricoid), and rotates it so that the vocal process passes forward, medialward and downward, relaxing the vocal ligament. It is the antagonist of the cricothyroid (fig. 1064). Its nerve-supply is the anterior branch of the inferior laryngeal.

The **vocal muscle** [m. vocalis], (fig. 1068), prismatic in form, is the inner constant part of the thyroarytenoid (pars vocalis NK). It lies in the vocal lip lateral to the vocal ligament. Its fibers run from their origin in the angle of the thyroid laminæ to their insertion in the vocal process and oblong fovea of the arytenoid cartilage.

It draws forward the vocal process, relaxing the vocal ligament. Its nerve comes from the anterior branch of the inferior laryngeal. The insertion of certain fibers of this muscle into the elastic vocal ligament has been observed (*aryvocalis* muscle of Ludwig). D. Lewis has shown that some of the elastic fibers in the vocal ligament are derived from the perimysium of the vocal muscle.

The **ventricular muscle** [m. ventricularis] consists of a few fibers derived from the thyroarytenoid which reach the back of the laryngeal saccule and enter the ventricular fold. The

small *thyroarytenoideus superior* extends from the angle of the thyroid to the muscular process of the arytenoid upon the lateral surface of the main muscle.

The **thyroepiglottic** muscle [m. thyreopiglotticus] is a fairly constant paired muscle closely connected with the thyroarytenoid (fig. 1061). It originates from the inner surface of the thyroid lamina and proceeds upward and backward to end in the quadrangular membrane and in an insertion on the lateral border of the epiglottis.

Summary of the Actions of the Laryngeal Muscles

According to their actions, the laryngeal muscles may be divided into—(*a*) those which effect the tension of the vocal folds; (*b*) those which control the rima glottidis; (*c*) those which effect the closure of the laryngeal aperture and vestibule.

(*a*) The vocal ligaments are made tense by the action of the cricothyroid, the lateral and posterior cricoarytenoid and the transverse arytenoid muscles. The vocal ligaments are relaxed as the result of the action of the external thyroarytenoid and vocal muscles.

(*b*) The rima glottidis is widened by the posterior cricoarytenoid and made narrow by the contraction of the transverse and oblique arytenoids. The lateral cricoarytenoideus also assists in closing the rima glottidis by rotating the vocal processes medialward, and if the posterior cricoarytenoid contracts simultaneously, it aids in the closure. The vocal ligaments are approximated also by the thyroarytenoideus (externus).

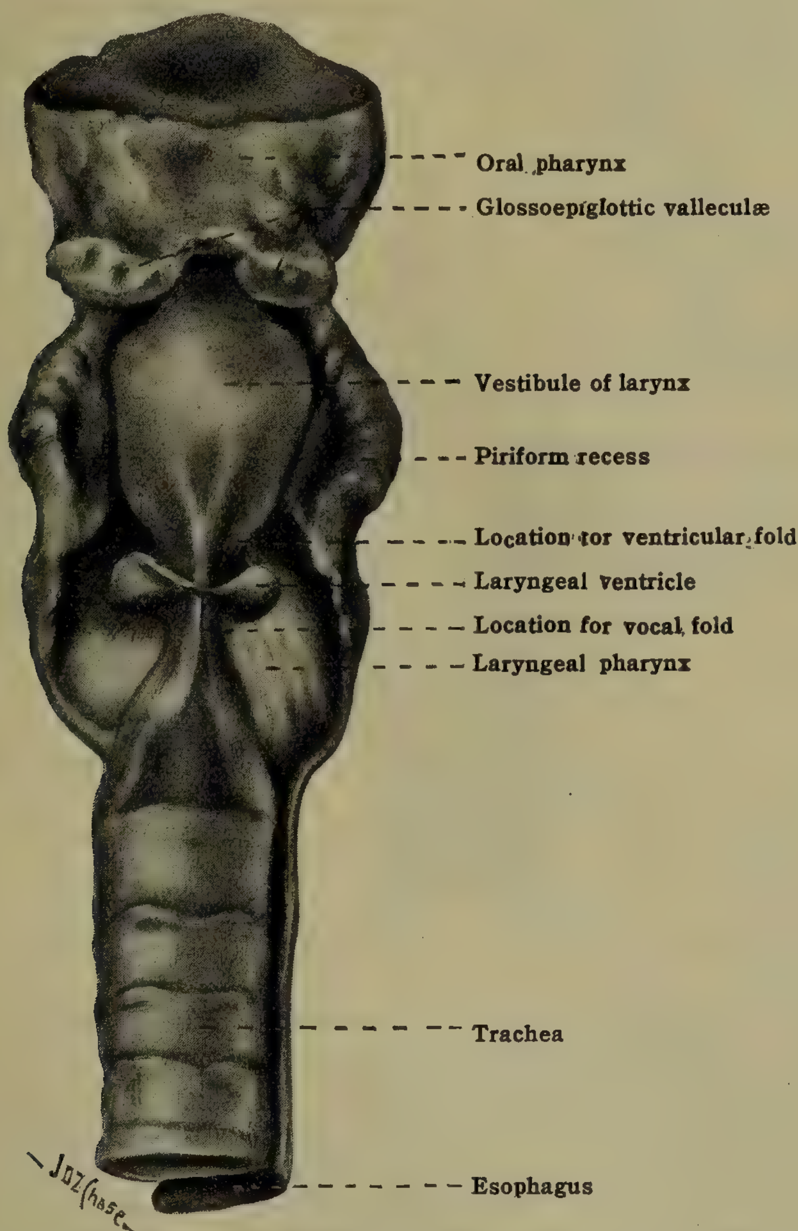


Fig. 1066.—Cast of Larynx, Pharynx, etc. Ventral Aspect. From a cast by J. P. S. in the Daniel Baugh Institute of Anatomy of the Jefferson Medical College.

(*c*) The superior laryngeal aperture (aditus) and vestibule are closed mainly by the transverse arytenoid and thyroarytenoid (externus), by which the arytenoid cartilages are brought into apposition and drawn toward the epiglottis. Together these muscles form a sphincter of the laryngeal vestibule. Other muscles derived from the constrictor group, the oblique arytenoid and aryepiglottic, assist in closing the laryngeal aperture.

CAVITY OF THE LARYNX AND LARYNGEAL MUCOSA

The **cavity of the larynx** [cavum laryngis] is relatively narrow and does not correspond in shape with the outer surface of the organ. Its form is shown in

figs. 1046 and 1066 taken from casts of the laryngeal cavity and the spaces continuous with it. Its walls are covered throughout by the **mucous membrane** of the larynx (figs. 1067, 1068). The mucosa of the larynx is continuous above with the mucous membrane of the pharynx, below with that of the trachea (figs. 1050, 1051). At the root of the tongue the pharyngeal mucosa is reflected backward to the anterior surface of the epiglottis, presenting the **median** and **lateral glosso-epiglottic folds** [plica glossoepiglottica mediana; lateralis]. From the sides of the pharynx it passes medialward, first sinking between the thyroid cartilage laterally and the arytenoid and cricoid medially, lining the walls of the *piriform recess;* then passing over the margin of the aryepiglottic fold to enter the vestibule of the larynx.

At the medial side of the piriform recess a slight fold of the mucosa [plica nervi laryngei] corresponds to the superior laryngeal nerve. Between the root of the tongue and the epiglottis is a depression on either side of the middle line and limited by the median and lateral glosso-epiglottic folds; this is the **epiglottic vallecula** [vallecula epiglottica]. The piriform recess and the epiglottic vallecula are favorite sites for the lodgment of foreign bodies. The **ary-epiglottic fold** [plica aryepiglottica] extends from the side of the epiglottis to the apex of the arytenoid cartilage; within it are fibers of the aryepiglottic and thyroepiglottic muscles and the cuneiform and corniculate cartilages. These cartilages correspond to two rounded eminences on each side of the laryngeal entrance, the **cuneiform** and **corniculate tubercles** [tuberculum cuneiforme (Wrisbergi); tuberculum corniculatum (Santorini)], respectively. Of these, the former is often small and inconspicuous, the latter usually well developed and prominent (fig. 1067).

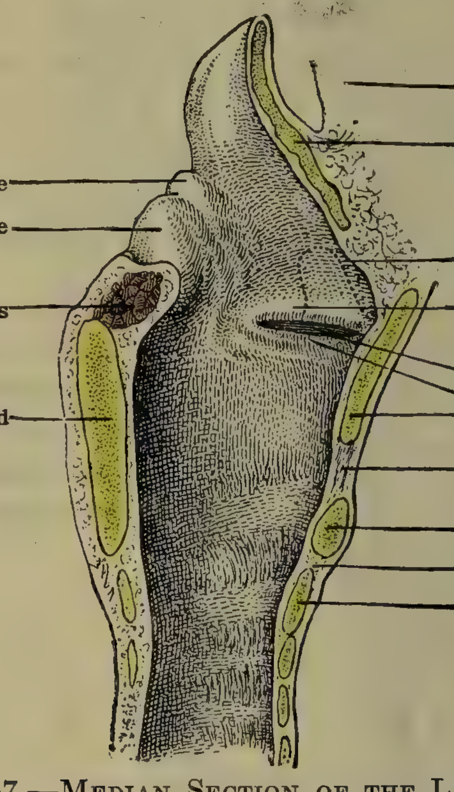


FIG. 1067.—MEDIAN SECTION OF THE LARYNX. (Merkel.)

The cavity of the larynx above the level of the ventricular folds (false vocal cords) is known as the **vestibule** [vestibulum laryngis]. This is wide in its cephalic part, but the sides incline toward the median line in descending, and the cavity becomes narrow transversely in approaching the region of the glottis. Here the cavity is termed the **superior entrance to the glottis** [aditus glottidis superior]. The parts of the framework of the larynx which enter into the walls of the vestibule are: ventrally, the epiglottic and thyroid cartilages with the thyroepiglottic ligament; laterally, the quadrangular membrane, the cuneiform and corniculate cartilages, and the medial surface of the arytenoid cartilage; dorsally, the anterior surface of the transverse arytenoid muscle. The vestibule communicates with the pharynx by the **laryngeal aperture** [aditus laryngis] (figs. 1050, 1051, 1052, 1067), which looks cephalically and dorsally. The form of the aperture is oval or triangular, with the base directed ventrally; here it is bounded by the epiglottis; laterally by the aryepiglottic fold of the mucosa. Dorsally the laryngeal aperture is prolonged as a little notch between the corniculate cartilages and the apices of the arytenoids [**incisura interarytænoidea**], limited behind by a commissure of the mucosa.

The high ventral wall of the vestibule presents a marked convexity, the **tubercle of the epiglottis** [tuberculum epiglotticum], over the thyroepiglottic ligament. The lateral walls, higher ventrally than dorsally, show two slight ridges, separated by a shallow groove, extending caudalward from the cuneiform and corniculate tubercles. The dorsal wall, very low, corresponds to the commissure connecting the arytenoid cartilages.

The **ventricular folds** [plicæ ventriculares] or 'false vocal cords' are prominent rounded folds of mucous membrane extending ventrodorsally, one on each side of the rima vestibuli (figs. 1050, 1051, 1057, 1058). The folds are most prominent in their ventral half, reaching the angle between the laminæ of the thyroid cartilage. They gradually fade away dorsally, but fall short of the dorsal laryngeal wall. Each ventricular fold contains the caudal free edge of the related quadrangular membrane, that is, the *ventricular ligament*, numerous glands, and a few muscle fibers. The folds are not directly concerned in the production of voice.

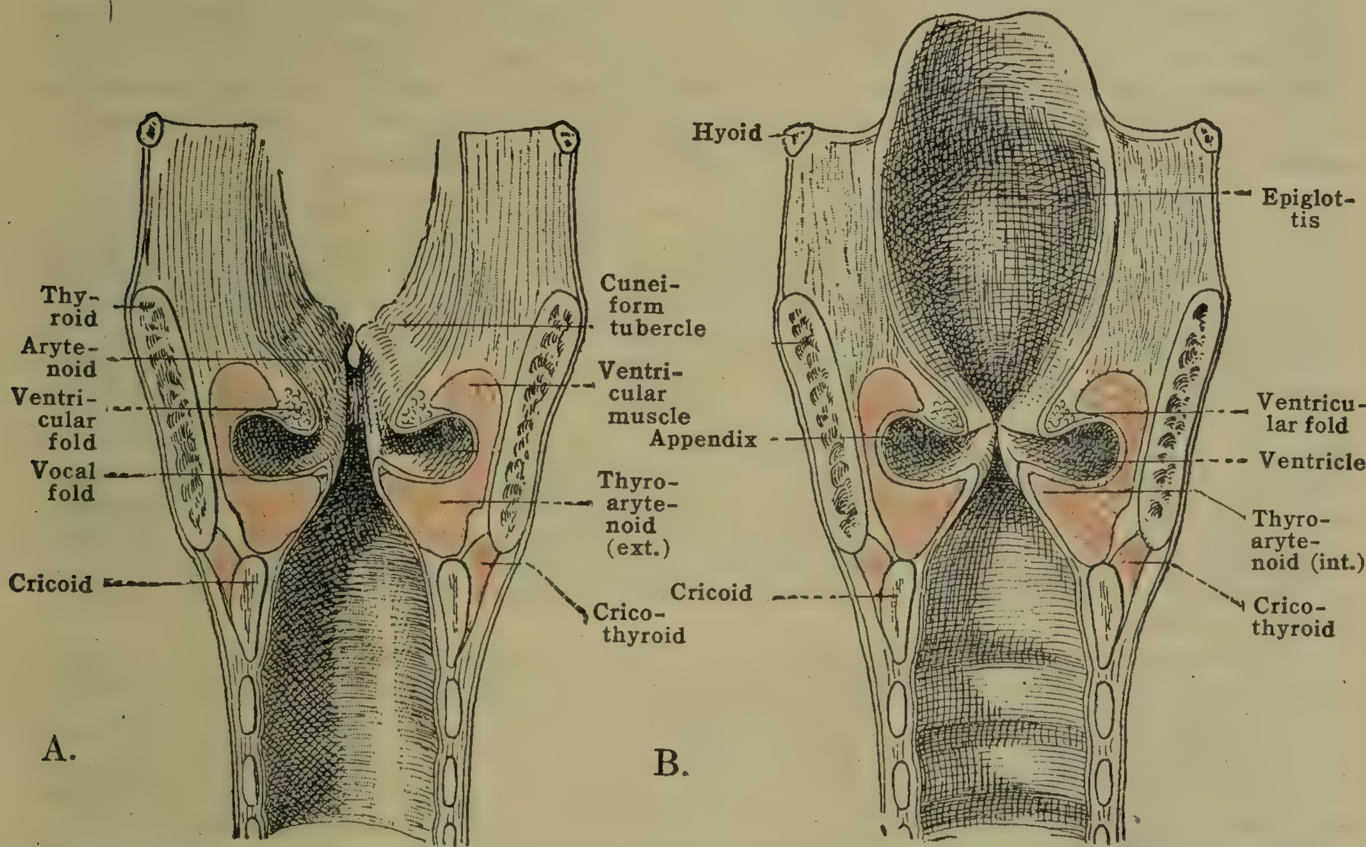


FIG. 1068.—FRONTAL SECTION OF A LARYNX HARDENED IN ALCOHOL. A. Posterior segment. B. Anterior segment. (Poirier and Charpy.)

The interval between the right and left ventricular folds, the **vestibular slit** [rima vestibuli] leads downward to a space between the planes of the ventricular and vocal folds, which extends on each side into the **laryngeal ventricle** [ventriculus laryngis (Morgagni)] (figs. 1046, 1050, 1051, 1066–1068). The latter is a small lateral evagination or pocket of the mucous membrane reaching from the level of the arytenoid nearly to the angle of the thyroid cartilage, and undermining the ventricular fold. It opens into the cavity of the larynx by a narrow mouth, limited above and below by the ventricular and vocal folds. From its ventral part a small diverticulum, the **ventricular appendix** [appendix ventriculi laryngis] extends upward between the ventricular fold medially and the thyroarytenoid muscle and thyroid cartilage laterally. Many mucous glands open into it.

The appendix is occasionally so large as to reach the level of the upper margin of the thyroid cartilage or even the great cornu of the hyoid bone. The laryngeal pouches of some of the apes are remarkably developed and appear to serve in affecting the resonance of the voice. In man, their function, besides that of pouring out the secretion of the glands located within their walls, is not known.

The **vocal folds** [plicæ vocales] or 'true vocal cords' (figs. 1050, 1051, 1067, 1068) are the thin edges of full, shelf-like projections, the vocal lips. The vocal folds correspond in their ventrodorsal extent to their vocal ligaments, and stand nearer the median line than the ventricular folds. In color the vocal folds are pearly white, excepting the ventral end of each, where there is a **yellow spot** [macula flava], produced by a little mass of elastic tissue (sometimes cartilage) in the ligament. The **vocal lip** [labium vocale] on each side forms the floor of the related laryngeal ventricle and contains the upper part of the elastic cone, whose thick-

ened free edge, the vocal ligament, lies in the vocal fold and along the vocal muscle. The two vocal lips with the vocal folds and the intervening space, the rima glottidis, together constitute the sound-producing apparatus, the **glottis.**

The **rima glottidis** (figs. 1050, 1051, 1068) the narrowest part of the laryngeal cavity, is an elongated slit between the vocal folds and the medial surfaces of the arytenoid cartilages, extending from the transverse arytenoid muscle dorsally to the thyroid cartilage ventrally. The portion of the rima between the vocal folds is known as the **pars intermembranacea,** that between the arytenoids the **pars intercartilaginea.** The rima glottidis in easy respiration is narrow and has the form of a long triangle; in labored breathing it is widely open and lozenge-shaped.

Below the level of the vocal folds is the space called the **inferior entrance to the glottis** [aditus glottidis inferior] (fig. 1068), which is narrow from side to side above, wide and circular in section below—altogether somewhat funnel-shaped. Its walls are formed by the elastic cone and by the arch and lamina of the cricoid cartilage. The lining mucosa is separated from the elastic cone by numerous glands and loose connective tissue, a condition favorable to the development of edema; below it is continuous with the mucosa of the trachea.

By means of the **laryngoscope** a more or less complete picture of the laryngeal aperture and the cavity of the larynx can be obtained (figs. 1050, 1051). Cranialward there appear the root of the tongue with the epiglottic valleculæ and glossœpiglottic folds leading dorsalward to the epiglottis; dorsal to the latter, the triangular aperture of the larynx, bounded laterally by the aryepiglottic folds. Farther lateralward appear the piriform recesses, as transverse fissures behind the laryngeal aperture. Within the aryepiglottic folds are seen the prominent corniculate tubercles on either side of the interarytenoid commissure and just ventral, the variable cuneiform tubercles. Within the vestibule the epiglottic tubercle rises upon the ventral wall, while laterally appear the ventricular folds overhanging the slit-like openings of the laryngeal ventricles. Below this level the vocal folds stand out on either side, approaching nearer the median plane than do the ventricular folds and conspicuous by their pearly whiteness. The form and extent of the rima glottidis and of its divisions, the intermembranous and intercartilaginous parts, can be inspected. Far down, the cricoid cartilage and ventral wall of the trachea may appear and under favorable conditions a glimpse of the bifurcation of the latter can be obtained.

The **mucous coat of the larynx** [tunica mucosa laryngis] in general is covered by a ciliated epithelium; the vocal lips, and, exceptionally, small areas of the mucosa of the laryngeal surface of the epiglottis and the ventricular folds possess a covering of flat, non-ciliated cells. The attachment of the mucosa to the underlying parts is very firm about the vocal folds and dorsal side of the epiglottis, but loose in the aryepiglottic folds, where much areolar tissue is present. In general, the mucosa is pink in color becoming bright red over the epiglottic tubercle and edges of the epiglottis and fading over the vocal folds, which appear almost white.

Numerous **mucous glands** [glandulæ laryngeæ] occur about the larynx and are aggregated into groups in certain places. One cluster of **anterior glands** is found in front of and on the posterior side of the epiglottis; another, the **middle glands,** is in the ventricular fold, in the triangular fovea of the arytenoid cartilage and clustered about the cuneiform cartilage, while a third set, the **posterior glands,** is disposed about the transverse arytenoid muscle. Many glands pour their secretion into the appendix of the laryngeal ventricle, but there are none on or about the vocal folds. **Lymph-nodules** of the larynx occur in the mucosa of the ventricle and on the posterior surface of the epiglottis.

Position and relations.—The larynx opens above into the pharynx by the aditus laryngis and in this region is connected with the hyoid bone. Below, its cavity leads into the trachea. Its position in the neck is indicated on the surface by the laryngeal prominence (Adam's apple). It stands ventral to the fourth, fifth, and sixth cervical vertebræ; from these it is separated by the prevertebral muscles and fascia and the laryngeal portion of the pharynx. The integument and cervical fascia cover the larynx ventrally in the middle line, while toward the side are the sternohyoid, sternothyroid, and thyrohyoid muscles. The lateral lobe of the thyroid gland and the inferior constrictor of the pharynx are in relation to it laterally, while further removed are the great vessels and nerves of the neck.

Peculiarities of age and sex. Position.—The larynx is placed high in the neck in fetal and infantile life and descends in later life. In a six-months fetus the organ is two vertebræ higher than in the adult. (Symington.) The descent of the larynx has been attributed to the vertical growth of the facial part of the skull, but this cause is questioned by Cunningham, who points out the high position of the larynx in the anthropoid apes, where the facial growth is more striking than in man; it appears also that the larynx follows the thoracic viscera in their subsidence, which, according to Mehnert, continues until old age. At birth the interval between the hyoid bone and thyroid cartilage is relatively very small and increases but little during early life.

Growth and form (cf. p. 51).—The larynx of the newborn is relatively large and in contour more rounded than that of the adult. The organ continues to grow until the third year, when a resting period begins, lasting until about twelve years of age, during which time there appears to be no difference between the larynx of the male and that of the female. At puberty, while no marked change is observable in the larynx of the female, rapid growth, accompanied by modification of form of the larynx is initiated in the male. The laryngeal cavity is enlarged, the ventrodorsal diameter markedly increased; the whole framework becomes stronger; the thyroid cartilage especially increases greatly in its dimensions, giving rise to the laryngeal

prominence; the vocal folds are lengthened and thickened, the voice changing in quality and pitch. These changes are, for the most part, effected in about two years, but complete development is not attained before twenty to twenty-five years of age. Castration is known to influence the development of the larynx, for in the eunuch it has been found to resemble that of a young woman. The changes in the structure of the cartilages have already been described.

Dimensions.—In the male the distance from the upper edge of the epiglottis to the lower margin of the cricoid is 70 mm.; in the female, 48 mm. The transverse diameter is 40 mm. in the male, 35 mm. in the female. The greatest sagittal diameter is 40 mm. in the male, 37, mm. in the female. The *vocal folds* in the male measure relaxed about 15 mm., in the female but 11 mm.; when stretched, about 20 mm. and 15 mm., respectively.

The length of the *rima glottidis* in the quiescent state is on the average 23 mm. in the male; 17 mm. in the female. In the male the *pars intermembranacea* measures 15.5 mm., the *pars intercartilaginea*, 7.5 mm. In the female these are 11.5 mm. and 5.5 mm., respectively. The rima may be lengthened by stretching of the vocal folds to 27.5 mm. in the male and 20 mm. in the female. (Moura.) In the male the width of the rima glottidis is 6–8 mm. in its widest part, but may be increased nearly to 12 mm.

Vessels and nerves (figs. 1060, 1065).—The *arteries* supplying the larynx are the superior and inferior laryngeal, which accompany the internal and inferior laryngeal nerves, respectively, and the cricothyroid arteries (see pp. 615, 639). The superior and inferior laryngeal *veins* join the superior and inferior thyroid veins, respectively. The *lymph* vascular system is well developed throughout the larynx generally, but in the vocal folds where the mucosa is thin and tightly bound down the vessels are scarce and small in size (see p. 787).

The *nerves* of the larynx are the superior and inferior laryngeal branches of the vagus and also certain branches of the sympathetic. Taste-buds occur and are abundant in the mucosa of the posterior surface of the epiglottis. The innervation of the muscles has already been indicated, and the description of the course and relations of these nerves will be found in the chapter on the PERIPHERAL NERVOUS SYSTEM. It should be mentioned here, however, that the idea of sharply limited territories of innervation, not only for the mucosa, but for the muscles as well, has been brought into question by the researches of Semon and Horsley, Exner, and others, which show that the distribution and functions of the laryngeal nerves are extremely complex.

The development of the larynx.—The larynx is developed partly from the lower portion of the embryonic pharynx and partly from the upper portion of the trachea (see p. 51). The cricoid cartilage represents the uppermost tracheal cartilage, while the thyroid is formed by the fusion of four cartilages representing the ventral portions of the cartilages of the fourth and fifth branchial arches. The laryngeal muscles are derived from the musculature of these arches and consequently their nerve-supply is from the vagus. Whether or not the arytenoid and epiglottic cartilages are also derivatives of the branchial arches is uncertain, although it seems probable that they are.

THE TRACHEA AND BRONCHI

The tubular **trachea** (figs. 1035, 1052, 1069), or windpipe, extends from the larynx downward through the neck and into the thorax to end by dividing into two branches, the **right** and **left bronchi** [bronchus (dexter et sinister)], which lead to the lungs. These tubes are simple transmitters of the respiratory air. Their walls are, for the most part, stiff and elastic, consisting in large part of cartilage. While the general form of these tubes is cylindrical, a rounded contour is presented by their walls only in front and at the sides, the posterior surface being flat. The inner surface of the walls of the tubes presents a succession of slight annular projections caused by the cartilaginous rings which enter into their structure (fig. 1066). The caliber of the trachea varies at different levels, a cast of the lumen being in general spindle-shaped. Its sectional area is less than the combined sectional areas of the two bronchi. When the **bifurcation** of the trachea [bifurcatio tracheæ] is viewed by looking down into its cavity, a sagittally directed keel, the *carina tracheæ* (fig. 1070), is seen between the openings which lead into the bronchi.

Position and relations (figs. 1052, 1069, 1073).—The trachea lies in the median plane, extending from the level of the sixth cervical vertebra caudalward and dorsalward, receding from the surface in following the curve of the vertebral column, and deviating a little to the right, reaches the level of the fourth or fifth thoracic vertebra, where it divides. Its caudal end is fixed so that with elevation and descent of the larynx the tube is stretched and contracted, changes in length which also result from extension and flexion of the head and neck. The mobility of the trachea is favored by its loose investment of connective tissue.

About half of the trachea lies in the neck, but the extent varies with the length of the neck, the position of the head and with age; the trachea holds a lower position in adult life than in childhood and a still lower one in old age when the bifurcation may be as low as the sixth or seventh thoracic vertebra. Ventrally and closely connected with the trachea is the isthmus of the thyroid gland, covering usually the second, third and fourth cartilages; ventral to this the cervical fascia and integument. More caudally, the trachea is related ventrally to the inferior thyroid veins and some tracheal lymph-glands, and sometimes a thyroidea ima artery, and the thymus, especially in children. The innominate artery occasionally crosses the trachea obliquely

in the root of the neck. Dorsal to the trachea, in its whole length, lies the esophagus, which in this part of its course inclines to the left. On either side are the great vessels and nerves of the neck, and the lobes of the thyroid gland. The inferior laryngeal nerve lies in the angle between the esophagus and trachea.

Within the thorax the trachea lies in the mediastinum, enveloped in loose areolar tissue and fixed through strong fibrous connections with the central tendon of the diaphragm. The innominate artery and the left common carotid are at first ventral and then lateral as they ascend, while the left innominate vein and the remains of the thymus are further ventralward.

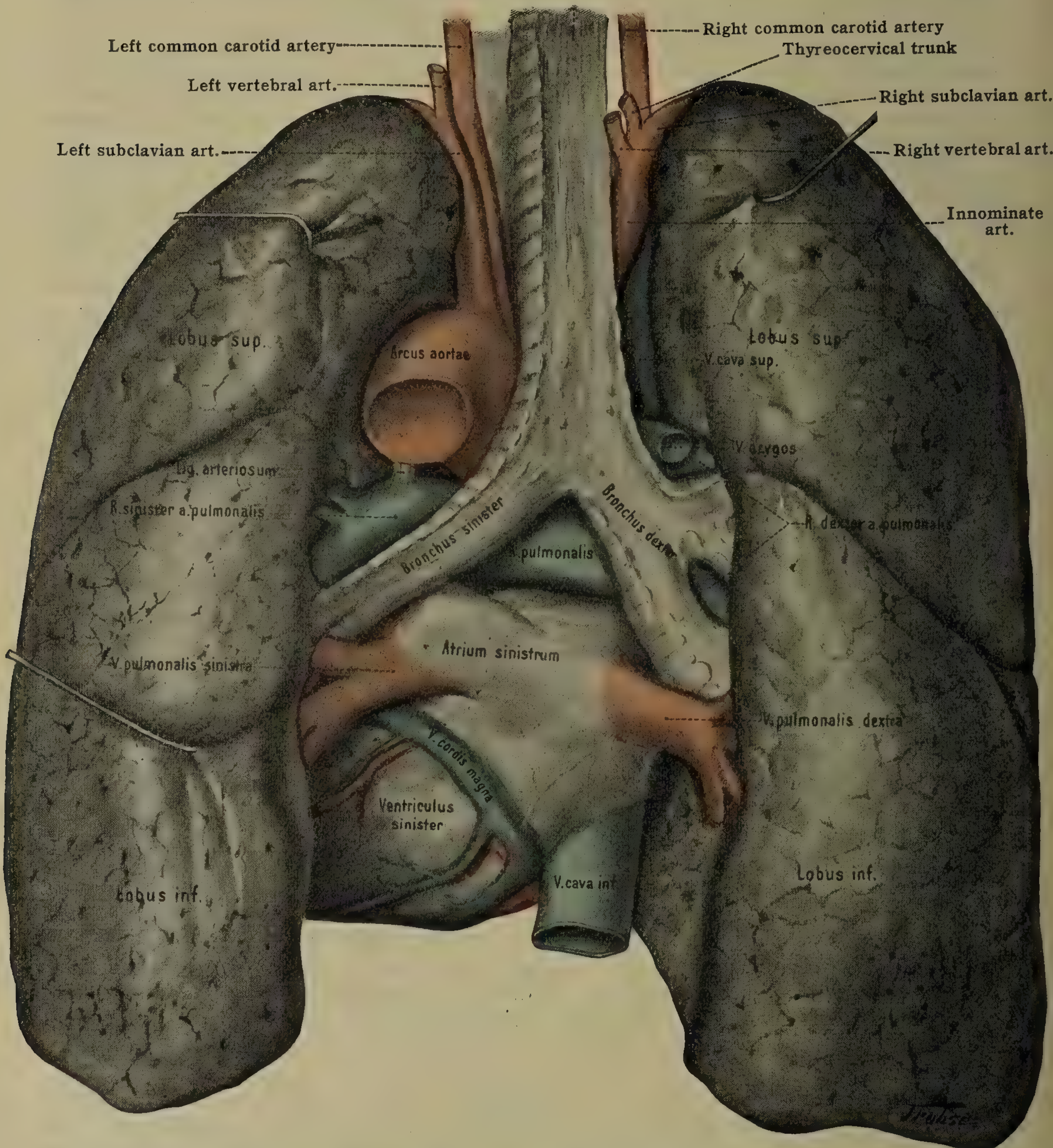


FIG. 1069.—TRACHEA AND BRONCHI IN THEIR RELATIONS TO THE GREAT VESSELS AS SEEN FROM BEHIND. (Rauber-Kopsch.)

The arotic arch is in contact with the ventral surface of the trachea near the bifurcation. On the right side are the vagus nerve, the arch of the vena azygos, the superior vena cava, and the mediastinal pleura; on the left, the arch of the aorta, the left subclavian artery, and the inferior laryngeal nerve. A large group of **bronchial lymph-glands** [lymphoglandulæ bronchiales] lies caudal to the angle of bifurcation. The esophagus is dorsal and to the left.

Clinical aspects.—In doing a tracheotomy the operator must have in mind the important relations of the larynx and the cervical portion of the trachea, especially the large vessels and nerves lateral to the midsagittal plane of the trachea and the esophagus dorsally. A high tracheotomy above the isthmus of the thyroid gland should be abandoned. In its place a tracheotomy should be made as low as possible and the incision should never be made through the first ring of the trachea; the 3rd, 4th, and 5th tracheal rings should be incised. It is a rule now that the cricoid should never be cut because stenosis is apt to follow the wearing of a cannula

in this high position; moreover, it is dangerously near the vocal folds. While it is generally safe to make an incision in the midline and in the long axis of the trachea from the laryngeal prominence to the suprasternal notch, this safety line ends when the suprasternal notch is reached, due to the fact that large blood-vessels course from side to side in this neighborhood. Usually large veins, especially if in aberrant positions, and an occasional thyroidea ima artery may be in the line of a median sagittal incision. Such vessels must, of course, be ligated if encountered.

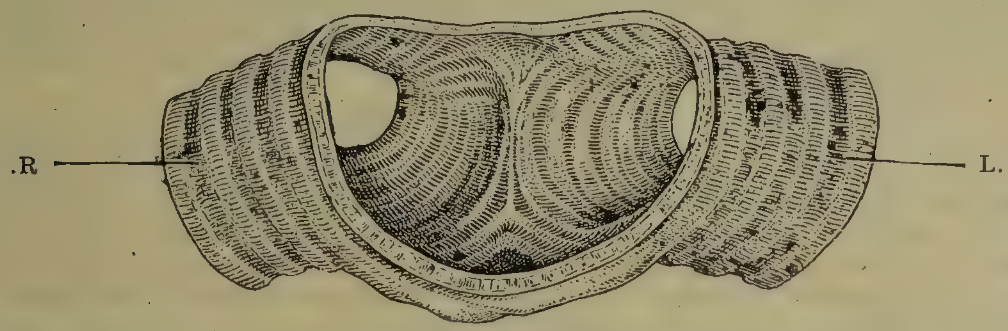


FIG. 1070.—BIFURCATION OF THE TRACHEA SHOWING THE TRACHEAL KEEL. R. L., right and left bronchi. (Heller and von Schroetter, from Poirier and Charpy.)

The **bronchi** take an oblique course to the hilus of the lung, where they branch. The right bronchus is nearer to the vertical in its course than is the left; it is also shorter and broader. These conditions explain the more frequent entrance of foreign bodies into the right than into the left bronchus. The asymmetrical course of the two bronchi is probably genetically associated with the position of the heart and aorta.

The azygos vein arches over the right bronchus, the vagus passes dorsally, and the right branch of the pulmonary artery crosses ventrally below the level of the first (eparterial) branch of the bronchus. The aorta arches over the left bronchus and gains its dorsal surface along with the esophagus; the left branch of the pulmonary artery passes at first ventrad and then cephalad to the bronchus.

Dimensions.—On account of their elasticity considerable difficulty is met with in obtaining accurate measurements of the air-tubes. The length of the trachea is given at 95–122 mm.; its transverse diameter 20–27 mm.; the sagittal diameter 16–20 mm. The right bronchus has a length of 25–34 mm.; the left, 41–47 mm. The transverse diameter of the right is 18 mm.; of the left 16 mm. The angle of bifurcation of the trachea varies from 56° to 90°, the mean being 70.4°; a wide angle corresponding to the breadth of the thorax of man. The right bronchus makes an angle of 24.8° with the median plane; the left, 45.6°.

According to Tillaux the length of that portion of the trachea between the superior edge of the sternum and the cricoid cartilage varies with age and sex as follows:

Adult male,	from 4.5 to 8.5 cm.	average, 6.5 cm.
Adult female,	from 5 to 7.5 cm.	average, 6.4 cm.
Boys 2½ to 10 years,	from 2.7 to 6.5 cm.	average, 4.4 cm.
Girls 3½ to 10½ years,	from 4 to 6.5 cm.	average, 5.1 cm.

The diameter of the lumen of the trachea when distended to a cylindrical form has been measured by Sée as follows: newborn, 4.12 to 5.6 mm.; infant 2 years, 7.5 to 8 mm.; infant 4 to 7 years, 8 to 10.5 mm.; over 20 years, male, 16 to 22.5 mm.; over 20 years, female, 13 to 16 mm.

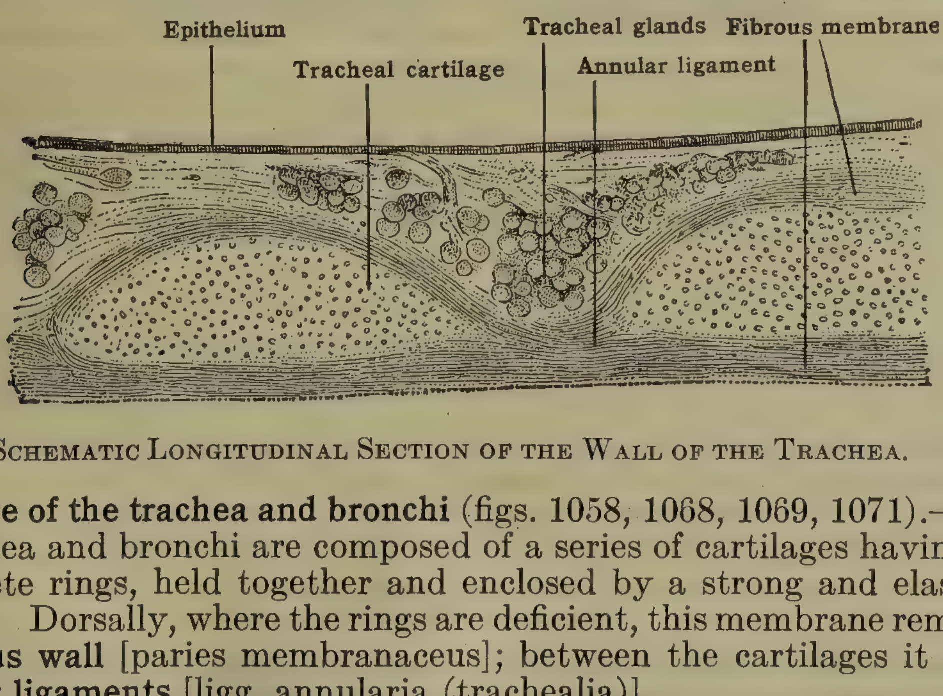


FIG. 1071.—SCHEMATIC LONGITUDINAL SECTION OF THE WALL OF THE TRACHEA. (Gegenbaur.)

Structure of the trachea and bronchi (figs. 1058, 1068, 1069, 1071).—The walls of the trachea and bronchi are composed of a series of cartilages having the form of incomplete rings, held together and enclosed by a strong and elastic fibrous membrane. Dorsally, where the rings are deficient, this membrane remains as the **membranous wall** [paries membranaceus]; between the cartilages it constitutes the **annular ligaments** [ligg. annularia (trachealia)].

A **tracheal cartilage** [cartilago trachealis] comprises a little more than two-thirds of a circle. Its ends are rounded, its outer surface flat, while the inner surface is convex from above downward; the upper and lower margins are nearly parallel. The cartilages are from sixteen to twenty in number. The first is usually broader than the type, and is connected by the cricotracheal ligament with the cricoid cartilage. Sometimes these two cartilages are in part continuous. The last cartilage is adapted to the bifurcation of the trachea and presents at the middle of its lower margin a hook-like process. This turns backward between the origins of the bronchi, and in the majority of cases gives a cartilaginous basis to the tracheal carina. Some of the tracheal cartilages vary from the type by bifurcating at one end. The cartilages keep the lumen of the trachea patent for the free passage of the air. Calcification occurs as with the laryngeal cartilages, but much later in life.

A **mucous coat** [tunica mucosa], soft and pinkish-white in color, covers the inner surface of the trachea (fig. 1071); posteriorly it is thrown into longitudinal folds. Mucous **tracheal glands** [gl. tracheales] are present in the elastic **submucous coat** [tela submucosa] between the cartilages and at the dorsum of the trachea. A thin layer of transversely disposed smooth muscle-fibers, stretching between the ends of the cartilages in the dorsal wall, constitutes the **muscular coat** [tunica muscularis]. Contraction of this *trachealis muscle,* as it is more properly named, causes the ends of the tracheal cartilages to be approximated and the lumen of the windpipe to be diminished.

The structure of the walls of the bronchi is similar to that of the trachea. The right bronchus possesses six to eight cartilages; the left, nine to twelve.

An inconstant *bronchoesophageal* muscle may connect the back of the left bronchus with the gullet.

Vessels and nerves.—The *arteries* supplying these air-tubes come from the inferior thyroid and from the internal mammary by its anterior mediastinal or bronchial branches. *Venous radicles* come together in the annular ligaments and join lateral veins on either side, which empty the blood into the plexuses of the neighboring thyroid veins.

Lymph-vessels are abundant, and are disposed in two sets, one in the mucosa, another in the submucosa. They drain into the tracheal, bronchial and esophageal lymph-glands. The lymphatics of the tracheal submucosa establish a direct pathway of infection to the lung by anastomosing with periarterial and peribronchial lymphatics at the bifurcation of the trachea (Winternitz). *Nerves* are provided by the vagus direct, by the inferior laryngeal, and by the sympathetic.

THE THORACIC CAVITY

Thoracic cavity [cavum thoracis] is the term used to denote the space included by the walls of the thorax and occupied by the thoracic viscera. These are, on each side, the lung, the pleura with its cavity, and in the middle the thymus gland or its remains, the pericardium and heart, great vessels, nerves, trachea, thoracic duct and esophagus, all closely associated and surrounded by connective tissue, forming a dividing wall, the mediastinal septum, standing between the right and left sides of the thoracic space. (See figs. 1085 and 1086.)

The **limits** of the thoracic space are given by the skeletal parts of the thorax together with the ligaments involved in the articulations and the muscles and membranes interposed between the bones. The arched diaphragm forms the inferior limit; and the barrier presented by the scalene muscles and the cervical fascia makes the superior boundary, which, it is to be observed, lies above the plane of the superior aperture of the thorax and therefore in the base of the neck (fig. 1072). These boundaries are approached by the extension of the pleural cavities; yet there intervenes the parietal layer of the pleural sac which is connected with the thoracic walls by loose connective tissue, the **endothoracic fascia.**

The **form** of the thoracic space departs from the external contour of the thorax chiefly through the projection into it of the ridge made by the succession of the thoracic vertebral centra, and by the presence on either side of the latter of the broad, deep pulmonary sulcus. On account of these features a transverse section of the thoracic space is somewhat heart-shaped, however, much compressed ventrodorsally (fig. 1078).

The arch of the diaphragm on the right side rises to the level of the spinous process of the seventh thoracic vertebra dorsally and the fourth intercostal space ventrally; on the left, to the level of the eighth thoracic spinous process dorsally and the fifth interspace ventrally. At its circumference the diaphragm is in contact to a variable extent above its origin with the inner surfaces of the costal arches. In the lower part of this zone a connection exists between the muscle and the thoracic wall through a continuation of the endothoracic fascia; in the upper part, the phrenicocostal sinus (see p. 1334) intervenes. The level reached by this deepest part of the pleural cavity is lower than the summit of the peritoneal cavity, so they overlap to a considerable extent.

THE PLEURÆ

The **pleuræ** (figs. 1072, 1078) are the paired, closed serous sacs which invest nearly the whole surface of the lungs, forming the **pulmonary pleuræ,** and in large

measure line the inner surface of the thoracic walls, forming the **parietal pleuræ.** Strictly speaking, however, the *endothoracic fascia* lines the thoracic cavity, and the pleuræ together with other structures are contents of the thoracic cavity. The right and left pleural sacs are completely separated one from the other by a sagittal partition, the *mediastinal septum* (see p. 1335). The walls of the sacs enclose paired spaces or cavities known as the **pleural cavities,** which in the normal state are merely potential or capillary spaces containing a small amount of serous fluid for lubrication of the apposed surfaces of the pulmonary and parietal pleuræ.

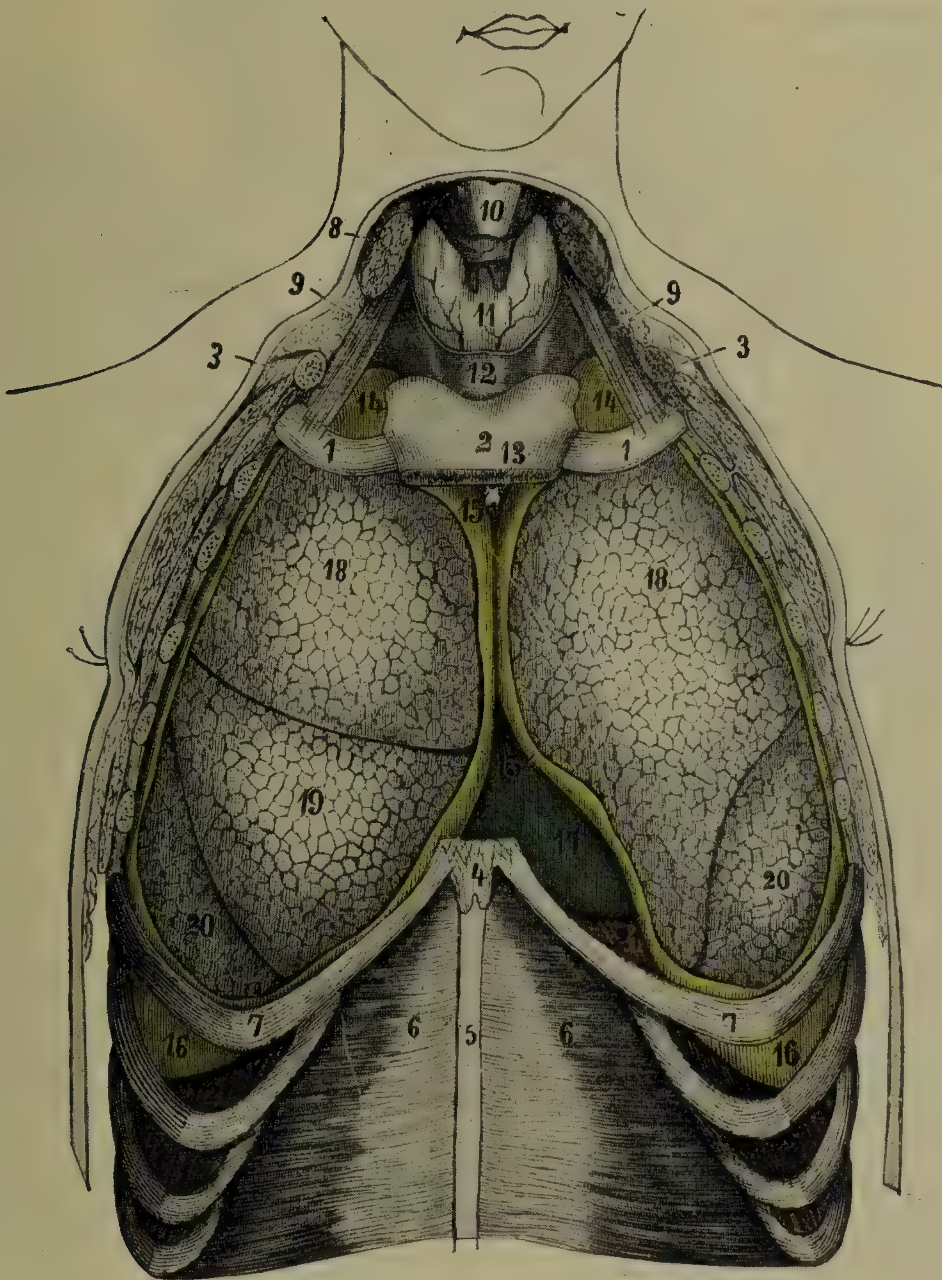


Fig. 1072.—Pleural Cavities Opened From in Front.

1, first rib; 2, manubrium sterni; 3, acromial extremity of clavicle; 4, xiphoid process; 5, linea alba; 6, m. transversus abdominis; 7, seventh rib; 8, sternocleidomastoid m.; 9, anterior scalene m.; 10, larynx; 11, thyroid gland; 12, deep layer of cervical fascia in front of the trachea; 13, superior mediastinum; 14, pleural cupola; 15, mediastinal pleura (costomediastinal sinus); 16, lower margin of costal pleura (phrenicostal sinus); 17, pericardium; 18, superior lobe of lung; 19, middle lobe of right lung; 20, inferior lobe of lung; 21, diaphragm. (Rauber-Kopsch.)

The right and left pleural cavities, as the pleural sacs, are absolutely independent of each other, are lined by mesothelium, and present a smooth glistening appearance.

The **pulmonary pleura** covers the outer surface of the lung, with which it is inseparably connected. It follows all irregularities of the lung surface and dips into the fissures of the lung so as to separate the lobes. At the hilus the pulmonary pleura passes from the mediastinal surface of the lung (forming the *mesopneumonium* NK) to cover the root above, in front, and behind, then continues medialward as the mediastinal portion of the parietal pleura, forming caudal to (below) the root of the lung a double layer of mediastinal pleura which is directed caudalward and medialward as the **pulmonary ligament** (fig. 1079).

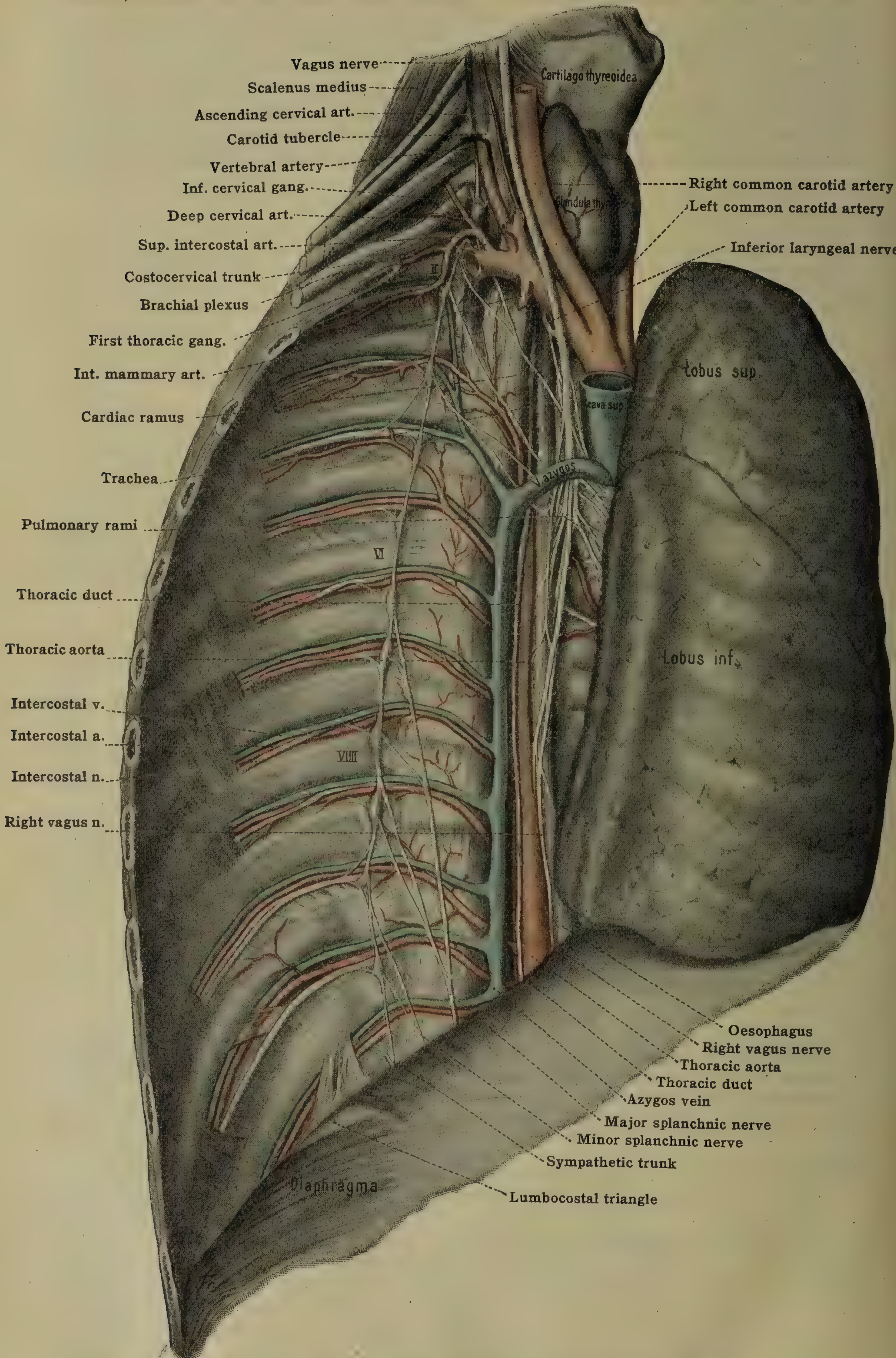
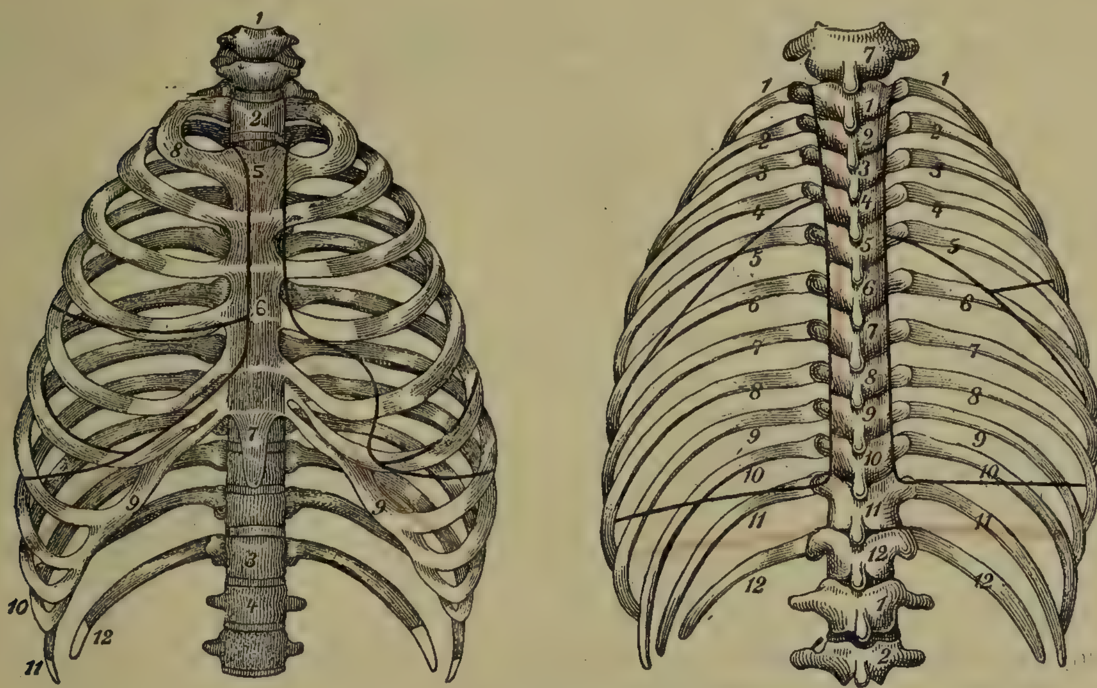


Fig. 1073.—Right Lateral Surface of the Mediastinum and the Inner Surface of the Posterior Thoracic Wall after the Removal of the Parietal Pleura and the Displacement of the Right Lung to the Left. (Rauber-Kopsch.)

The portion of the lung occupied by the hilus and the very limited space of the lung surface between the layers of the pulmonary ligament caudal to the hilus have no pleural investment.

The **parietal pleura** of each side is divided, according to the regions of the chest with which it is associated, into the *costal, diaphragmatic,* and *mediastinal pleuræ;* moreover, the parietal pleura extends into the root of the neck, forming the *cervical pleura* [*cupula pleuræ*]. It must be kept in mind that the subdivision of the parietal pleura as indicated is more or less arbitrary and that the several divisions are directly continuous with each other.

The **costal pleura** lines the thoracic wall, to which it is loosely bound by the *endothoracic fascia;* dorsally where the pleura is reflected from the ribs to the vertebral column, it is more firmly attached. It covers incompletely the deep surface of the sternum and extends laterally upon the inner surfaces of the ribs and intercostal muscles. Dorsally beyond the angles of the ribs it passes over the anterior rami of the thoracic nerves and intercostal vessels, the heads of the ribs, and the sympathetic trunk to the vertebral column; here it becomes continuous with the mediastinal pleura. Above (cranialward), the costal pleura reaches beyond the superior aperture of the thorax into the root of the neck, and in the form of a dome, the **cupola** of the pleura, is adapted to the apex of the lung. It is supported by processes of the deep cervical fascia, and by a fibrous aponeurosis known as *Sibson's fascia,* coming from the scalenus minimus muscle and connected with the inner margin of the first rib. In relation to the pleural cupola are those structures grouped about the lung apex: the brachial plexus, subclavian artery, anterior scalene muscle, and the subclavian vein, and, on the left side, in addition, the thoracic duct. The highest point dorsally of the cervical pleural dome reaches the neck of the first rib; ventrally from 3 to 6 cm. above the sternal end of the first rib, and from 1 to 4 cm. above the clavicle. Below (caudalward), the costal pleura is continuous with the **diaphrag-**



FIGS. 1074 AND 1075.—BOUNDARIES OF THE PLEURÆ AND LUNGS.

Lines of pleural reflection *red,* boundaries of the lungs and pulmonary lobes *black.*

1, sixth cervical vertebra; 2, first thoracic vertebra; 3, twelfth thoracic vertebra; 4, first lumbar vertebra; 5, manubrium sterni; 6, body of sternum; 7, xiphoid process; 8, first rib; 9, cartilage of seventh rib; 10, 11, 12, tenth, eleventh and twelfth ribs. (Rauber-Kopsch.)

matic pleura [pleura diaphragmatica], which is bound closely by a very sparse endothoracic fascia to the thoracic surface of the diaphragm and covers it, excepting the pericardial area and where the diaphragm and thoracic wall are in contact.

The **mediastinal pleuræ** are reflected from the costal pleuræ on the deep surface of the sternum, at the right and left sides of the mediastinum as the **laminæ mediastinales,** covering the pericardium [pleura pericardiaca], to which they are closely adherent, and also the other structures of the mediastinum, with which the two layers are less firmly connected. Above (cephalad to) the lung root each mediastinal pleura stretches directly from the sternum to the vertebral column; at the level of the root it is reflected laterally to the pulmonary pleura covering the root ventrally and dorsally, while caudal to the root the mediastinal pleura forms a double layer—the *pulmonary ligament.* The right mediastinal lamina covers (fig. 1073) the right innominate vein, the superior vena cava, the vena azygos, the trachea, the innominate artery, the right vagus and phrenic nerves, and the esophagus. The left lamina lies against the left innominate vein, the arch of the aorta, the left subclavian artery, the thoracic aorta, the left phrenic and vagus nerves, and the esophagus. About the base of the heart-sac are a number of **adipose folds** [plicæ adiposæ] projecting from the pleura, the surfaces of which present some villous processes, the **pleural villi** [villi pleurales]; the latter also occur on the pulmonary pleura along the inferior margin of the lung.

The **pulmonary ligament** (plica mediastinopulmonalis NK) is a double layer of mediastinal pleura consisting of ventral and dorsal lamellæ prolonged caudally from the pleural layers covering the ventral and dorsal aspects of the lung root along the medial or mediastinal surface of the lung to the diaphragm. The pulmonary ligament is triangular in shape, widest just below the lung root and narrowing as the diaphragm is approached. It is directed medialward from the lung in the frontal or coronal plane, the ventral lamella continuing sternalward as the pericardial portion of the mediastinal pleura. The deep lamella of the ligament turns dorsally and after a short course as mediastinal pleura, continues as costal pleura. Along the medial surface of the lung the pulmonary ligament is reflected on to the lungs to continue as pulmonary or visceral pleura. Near the diaphragm the pulmonary ligament ends in a free falciform border. Together with the root of the lung the pulmonary ligament helps to hold the lung in position (fig. 1079).

The **lines of pleural reflection** are of practical importance (figs. 1074–1076, 1078, 1081–1086). Dorsally, the costal pleura simply turns forward in a gentle curve to become the mediastinal pleura, but ventrally and caudally the membrane is folded upon itself, leaving intervening capillary spaces, the **sinuses** of the pleura. Such a space is present where the costal pleura is reflected upon the diaphragm, the **sinus phrenicocostalis,** the fold of the pleura occupying the upper part of the angle between the thoracic wall and diaphragm, the endothoracic fascia filling the lower part. The inferior margin of the lung with its covering of visceral pleura enters this sinus a variable distance in inspiration. The line of the costodiaphragmatic reflection begins in front on the sixth costal cartilage, which it follows, descending obliquely to cross the seventh interspace in the mid-clavicular line. The greatest depth reached in the axillary line is at the tenth rib or interspace. The line of reflection then continues around the thorax ascending slightly to the twelfth costovertebral joint. The line of reflection behind is sometimes found as low as the level of the transverse process of the first lumbar vertebra.

The lines of reflection of the costal pleura backward to the mediastinal pleura behind the sternum begin opposite the sternoclavicular joints, descend obliquely medialward to the level of the second costal cartilage, whence they run near together or in contact, but to the left of the median line, to the level of the fourth cartilage. The reflection on the *right* side continues behind the sternum as far as the sixth rib cartilage, there turning laterally into the costodiaphragmatic reflection. The line on the *left* side, in the region of the cardiac notch (from the fourth to the sixth cartilages), is a little to the left of the sternal margin. From this position of the line of reflection it happens that there is left uncovered by pleura a small area of the peri-

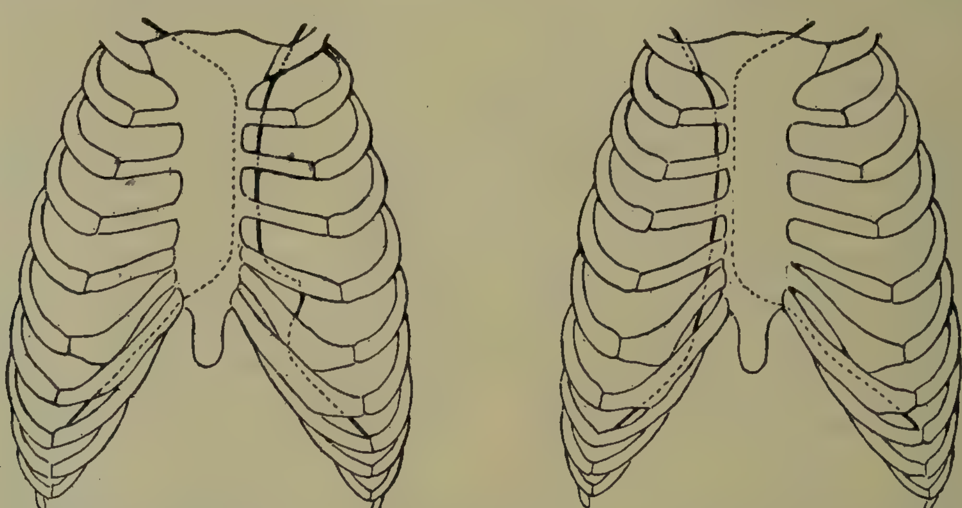


FIG. 1076.—SCHEMATIC DRAWING TO REPRESENT THE MAXIMUM OF FLUCTUATION IN THE POSITION OF THE ANTERIOR LINES OF PLEURAL REFLECTION. (Tanja.)

cardium which is in contact immediately with the chest-wall. A reduplication of the pleura takes place along the anterior line of reflection, and into the **sinus costomediastinalis** so formed the thin anterior margin of the lung advances in inspiration. That part of the left costomediastinal sinus which is in front of the pericardium is not completely filled by the margin of the lung (fig. 1083). Although the positions of the lines of reflection of the mediastinal pleuræ here described are those usually encountered, it should be noted that they are subject to variation. The extremes of variation of the anterior lines, as determined by Tanja, are indicated in fig. 1076.

Clinical aspects.—The *deepest part of the pleural sac* is where the reflection crosses the tenth rib or tenth space in the midaxillary line. From this it ascends slightly as it curves back to the spine (Cunningham). *The relations of the pleura to the last rib* are of much importance to the surgeon in operations on the kidney. In the case of a twelfth rib of ordinary length, the pleural reflection crosses it at the lateral border of the sacrospinalis; when a rudimentary last rib does not reach the lateral border of this muscle, an incision carried upward into the angle between the eleventh rib and the sacrospinalis will open the pleural sac. (Melsome.)

For *tapping the pleura* there are two chief sites:—(1) The sixth or seventh space in front of the posterior fold of the axilla. (2) The eighth space behind, in the line of the angle of the scapula. For the *incision of an empyema* the first site is usually chosen. The overlying soft parts are not thick, the interspace is wide enough, drainage is sufficient (especially if part of the seventh or eighth rib be resected), and this site is free from the objection that the angle of the scapula overlaps the seventh and eighth ribs, unless the arm is raised.

Blood-vessels.—The vascular networks of the pulmonary pleura are derived from the bronchial artery and probably to some extent from the pulmonary artery which, in the dog, is the only source of blood-supply. The venous radicles arising from the network enter the lung.

(See p. 1344.) The parietal pleura is supplied by **arteries** from several sources: internal mammary, intercostals, phrenics, mediastinal, and bronchial. The **veins** correspond to the arteries. The **lymphatics** of the pulmonary pleura form rich networks without definite relations to the lobules of the lung. They accompany the radicles of the pulmonary veins and drain into the bronchial lymph-glands. In the parietal pleura lymph-vessels are present most abundantly over the interspaces; they empty into the sternal and intercostal nodes. (See p. 793.) The **nerves** supplied to the pulmonary pleura are branches from the pulmonary plexus; to the parietal pleura, from the intercostals, vagus, phrenic, and sympathetic.

THE THORACIC MEDIASTINUM

The thoracic **mediastinum** (NK) or **mediastinal septum** [septum mediastinale] is a sagittal partition of asymmetrical contour extending from the superior (cephalic) aperture of the thorax to the diaphragm, between the thoracic vertebræ dorsally and the deep surface of the sternum ventrally (figs. 1073, 1078). Its right and left surfaces are formed by the related mediastinal portions of the

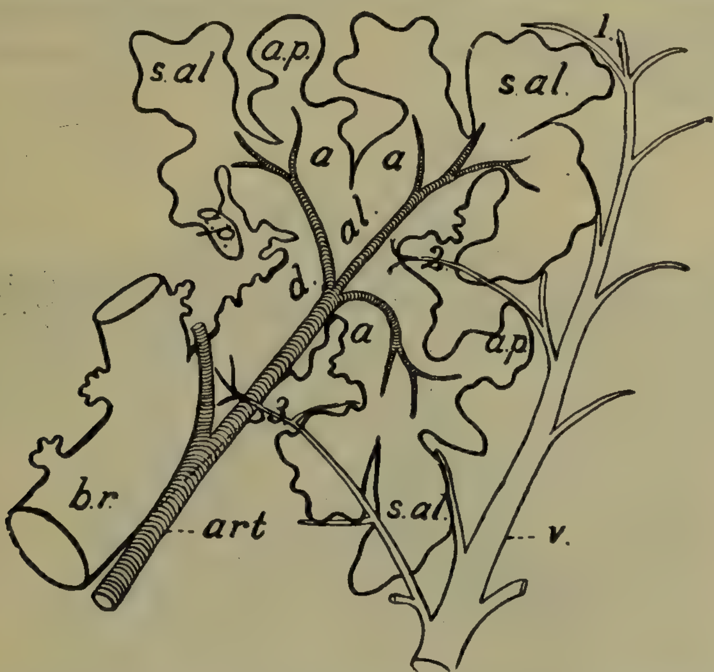


Fig. 1077.—Schematic Section of a Lobule of the Lung showing the Relation of the Blood-vessels to the Air-spaces. (After Miller, from the 'Reference Handbook of the Medical Sciences.')

b.r. Respiratory bronchiole. *d.al.* Alveolar duct; a second alveolar duct is shown cut off. *a,a.* Atria. *s.al.* Alveolar saccule. *a.p.* Alveolus. *art.* Pulmonary artery with its branches to the atria and saccules. *v.* Pulmonary vein with its tributaries from the pleura (1), the alveolar duct (2), and the place where the respiratory bronchiole divides into the two alveolar ducts (3).

parietal pleuræ. The mediastinum includes the heart and pericardium and many other structures which occupy the interpleural space of the thoracic cavity, surrounded and supported by loose connective tissue.

The designation of those portions of the thoracic mediastinal partition located ventral and dorsal to the plane of the pericardium as *ventral* and *dorsal mediastinal cavities* (BNA), respectively, is not appropriate since there are no cavities in these positions, but merely spaces occupied by component structures of the mediastinal septum.

The customary subdivision of the thoracic mediastinum or interpleural space into *superior*, *anterior*, *middle* and *posterior mediastina* is more or less arbitrary, but is useful for descriptive purposes. In a general way the superior mediastinum occupies the space between the pericardium and the superior aperture of the thorax, the middle mediastinum is coextensive with the pericardium, and the anterior and posterior mediastina occupy positions ventral and dorsal, respectively, to the pericardium.

The **superior mediastinum** (pars cranialis NK) (fig. 1078) is bounded caudally by a plane passing from the disk between the fourth and fifth thoracic vertebræ to the juncture of the manubrium with the body of the sternum; limited cephalically by the thoracic aperture; ventrally by the manubrium sterni and the caudal ends of the sternohyoid and sternothyroid muscles; dorsally by the first four thoracic vertebræ and the thoracic extension of the longus colli muscles; and laterally by the mediastinal pleuræ. The superior mediastinum consists of a number of structures supported by connective tissue: a portion of the thymus gland, lymph-nodes, the innominate veins, the superior vena cava, the arch of the aorta and large vessels issuing therefrom, the trachea, the esophagus, the thoracic duct, the vagi, phrenic, left inferior (recurrent) laryngeal and cardiac nerves, and portion of the roots of the lungs.

The **anterior mediastinum** (pars ventralis NK) (figs. 1072, 1078) is extremely shallow, lying between the pericardium dorsally and the body of the sternum, the left fifth, sixth and portion of the seventh costal cartilages and the triangularis sterni muscle ventrally. As may be inferred from the description of the reflections of the parietal pleuræ, the ventral mediastinal space is narrow cephalically, due to the close approximation in the midline of the right and left mediastinal pleuræ. This takes place on the ventral aspect of the pericardium from the sternal angle to the fourth costal cartilages. Owing to the receding of the left mediastinal pleura from the midplane and from its fellow, the ventral mediastinum is of considerable but variable breadth in its lower or caudal half. The components of the ventral mediastinum are the caudal portion of the thymus, a few lymph-nodes, lymph-vessels, adipose and areolar tissue, and small branches from the internal mammary blood-vessels.

The **middle mediastinum** is the expanded central portion of the caudal segment of the mediastinal septum. It is, generally speaking, coextensive with the pericardium and in addition to the latter consists of the heart, the ascending aorta, the trunk of the pulmonary artery, the cardiac end of the superior vena cava, the arch of the azygos vein, the phrenic nerves and accompanying vessels, the bronchial lymph-nodes, and a large portion of the roots of the lungs.

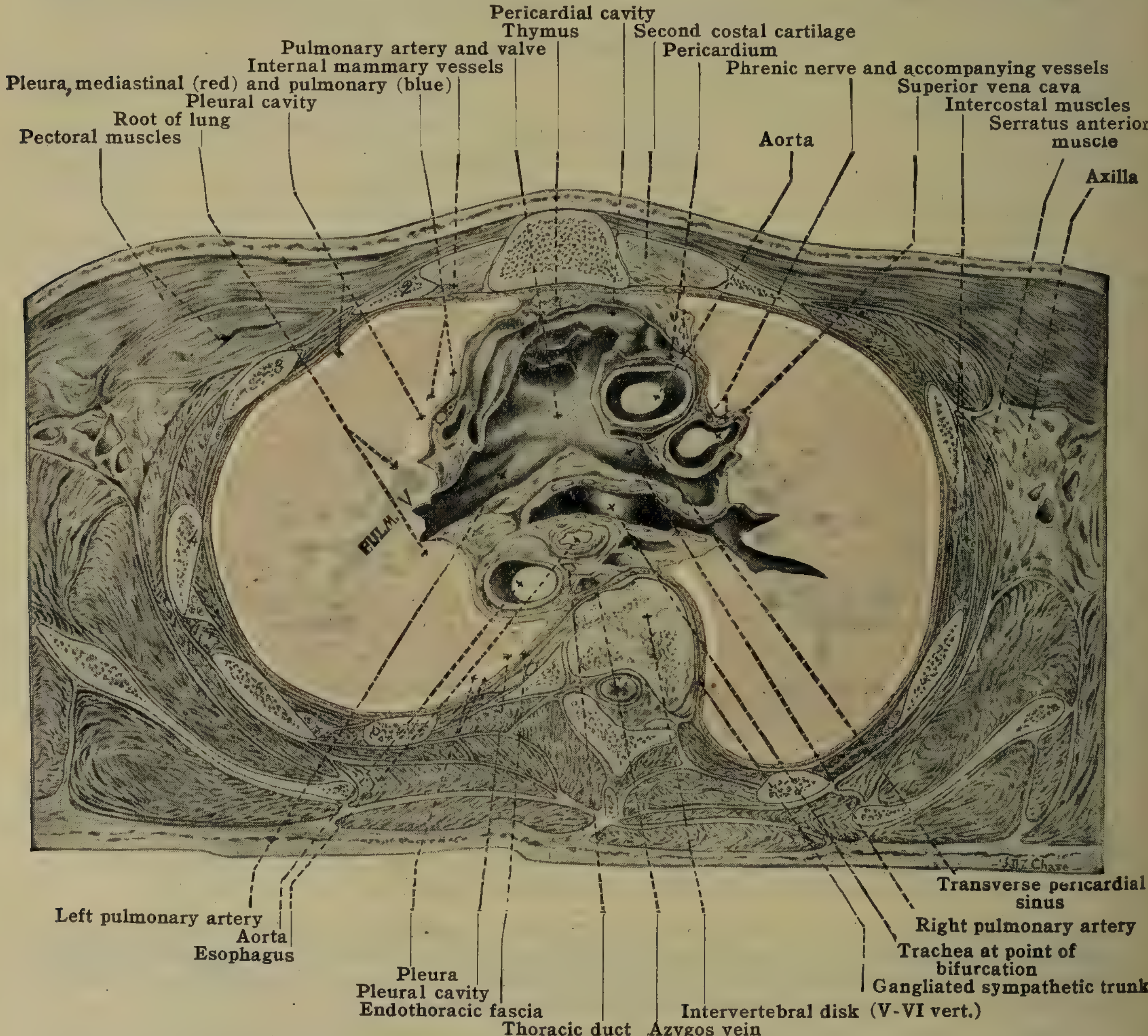


FIG. 1078.—HORIZONTAL SECTION OF THE THORAX THROUGH THE ROOTS OF THE LUNGS.

The **posterior mediastinum** (pars dorsalis NK) (fig. 1078) occupies the interval bounded by the lower eight thoracic vertebræ dorsally; the pericardium and the roots of the lungs ventrally; the mediastinal pleuræ laterally. It extends from the fourth thoracic vertebra to the diaphragm. It may be thought of as a caudal extension of the more dorsal portion of the superior mediastinum, many of the component structures of the latter being prolonged into the dorsal mediastinum on their way to the abdominal cavity. The dorsal mediastinum includes the esophagus, the descending thoracic aorta and its right intercostal branches, the azygos and hemiazygos veins and tributaries, the thoracic duct, the vagi and splanchnic nerves, and the dorsal mediastinal lymph-nodes; all surrounded and supported by connective tissue.

THE LUNGS

The **lungs** [pulmones], the essential organs of respiration, are constructed in such a way as to permit the blood to come into close relation with the air (fig. 1077). In plan of structure the lung has been compared with a gland, since it is composed of a tree-like system of tubes terminating in expanded spaces. Closely

associated with the system of tubes are certain blood-vessels, some nutritive, but most of them respiratory in character.

The lungs are two in number, and lie one on either side of the thoracic cavity, separated by the mediastinal partition (figs. 1035, 1078). Serous membranes covering the latter, right and left, are parts of two closed sacs, the **pleuræ**, each of which is reflected about a lung and the neighboring chest-wall after the manner of serous membranes in general. The spaces enclosed within the sac-walls are the **pleural cavities**, genetically subdivisions of the cœlom. It must be kept clearly in mind that the lungs are not contained within the pleural cavities (see p. 1331), the latter being potential cavities containing a small amount of serous fluid.

Form of the lungs (figs. 1078, 1079).—Each lung is pyramidal or conical in form, with the **base** [basis pulmonis] caudal and resting on the diaphragm, and with **apex** [apex pulmonis] cephalic, in the root of the neck. Three surfaces, costal, mediastinal, and diaphragmatic are described. The broad convex **costal surface** [facies costalis] is directed against the thoracic wall ventrally, laterally and dorsally, and is marked by grooves corresponding to the ribs. The **media-**

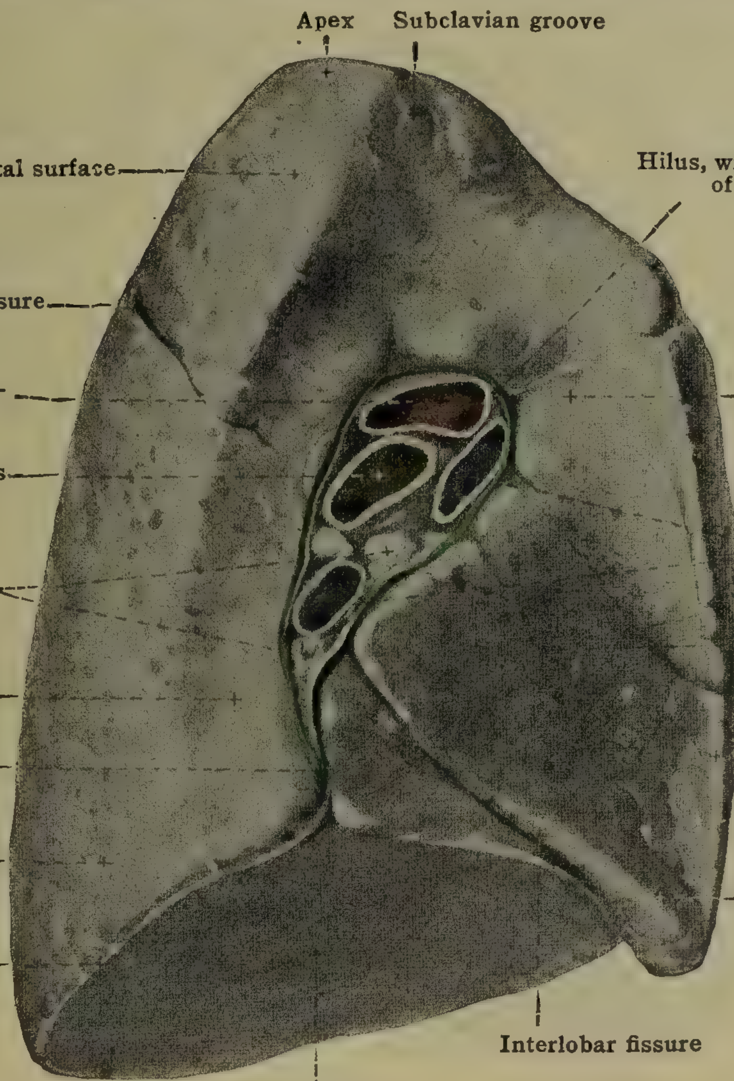


Fig. 1079.—Left Lung, viewed from the Mediastinal Surface. (Spalteholz.)

stinal surface [facies mediastinalis] is concave and presents a contour adapted to structures of the mediastinum (fig. 1079). A special concavity on this surface, known as the **cardiac fossa**, corresponds to the prominence of the heart and is deeper in the left lung than in the right. Above and behind the cardiac fossa is a depression, the **hilus** of the lung [hilus pulmonis], where the bronchus, pulmonary vessels, lymphatics and nerves, together constituting the **root** of the lung [radix pulmonis], enter and leave. Near the dorsal edge of the mediastinal surface is a groove, which ascends and turns forward over the hilus. The groove of the left lung is adapted to the cylindrical surface of the aorta; that of the right, the vena azygos. A well-marked **subclavian sulcus** extends upward on this surface to the apex, corresponding on the right side to the lower part of the trachea and right subclavian artery, on the left to the left subclavian artery alone. Further forward is a groove adapted in the right lung to the superior cava; in the

left to the left innominate vein. The lung with its visceral pleura is not in actual contact with these several structures, but is separated from them by the pleural cavity and the mediastinal pleura. The mediastinal surface passes gradually into the costal surface dorsally, there being no proper dorsal edge. Where the mediastinal and costal surfaces meet ventrally, a sharp **ventral margin** [margo anterior] exists (figs. 1078, 1079). In the right lung this runs down in a gentle curve to turn lateralward in the inferior margin. In the left lung the anterior margin is cut into by a wide **cardiac notch** [incisura cardiaca] (impressio cardiaca NK), which is occupied by the heart within the pericardium as these structures are pressed toward the ventral thoracic wall (fig. 1083). The cardiac notch is separated from the inferior margin by a little tongue of lung substance, the pulmonary **lingula** [lingula pulmonis].

The **base** of the lung (fig. 1079) presents the **diaphragmatic surface** [facies diaphragmatica], concave and oblique in adaptation to the dome of the diaphragm. It is limited by a sharp **inferior margin** [margo inferior] (m. diaphragmaticus NK), which follows the curves of the mediastinal and costal surfaces, and fits into the angle between the diaphragm and thoracic wall.

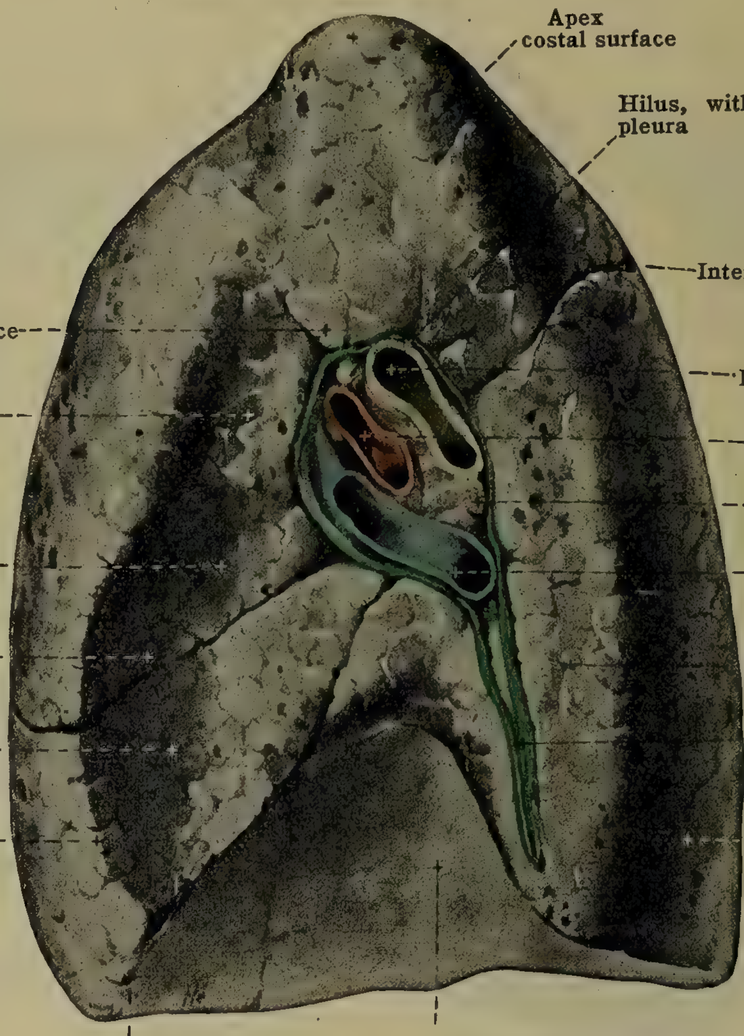


Fig. 1080.—Right Lung, viewed from the Mediastinal Surface. (Spalteholz.)

The **apex** of the lung [apex pulmonis] (figs. 1079, 1083–1086) is rounded and points upward with an inclination ventrally and medially, accommodating itself to the structures within and about the superior aperture of the thorax.

The **hilus** and **root** of the lung (fig. 1079), are situated on the mediastinal surface. The hilus presents in the left lung a raquette-shaped outline, has an average height of about 8.8 cm. (Luschka) and extends over both lobes. The hilus of the right lung (fig. 1080), rather four-sided in outline and shorter than that of the left, is related to the three lobes. The entering structures, constituting the **root** of the lung (figs. 1069, 1073, 1078–1080), include the bronchus, pulmonary artery and veins, bronchial vessels, lymphatic vessels and nodes, and pulmonary nerves. These are bound together by connective tissue and invested by the pleura. The bronchus is in the dorsal and cephalic part of the root on the right, but caudal to the pulmonary artery on the left; the pulmonary vessels lie ventrally, the veins caudal to the arteries.

The **surface** of the lung is marked off in polygonal areas of different sizes (secondary lobules) by lines containing pigment. The pigmentation is especially deep on the lateral surface along the furrows corresponding to the ribs.

Fissures and lobes of the lungs.—A deep **interlobar fissure** [incisura interlobaris] (figs. 1079, 1084), reaching through the lung substance nearly to the hilus, divides each organ into a smaller **superior lobe** [lobus superior] and a larger **inferior lobe** [lobus inferior]. The interlobar fissure runs caudally and ventrally, beginning a short distance below the apex, and reaching the base near the anterior margin in the left lung, somewhat further back in the right lung. From the obliquity of the plane of the fissure it will be noticed that the inferior lobe reaches dorsally to within a short distance of the apex, and includes the greater part of the back and base of the lung, while the superior lobe takes in the anterior margin

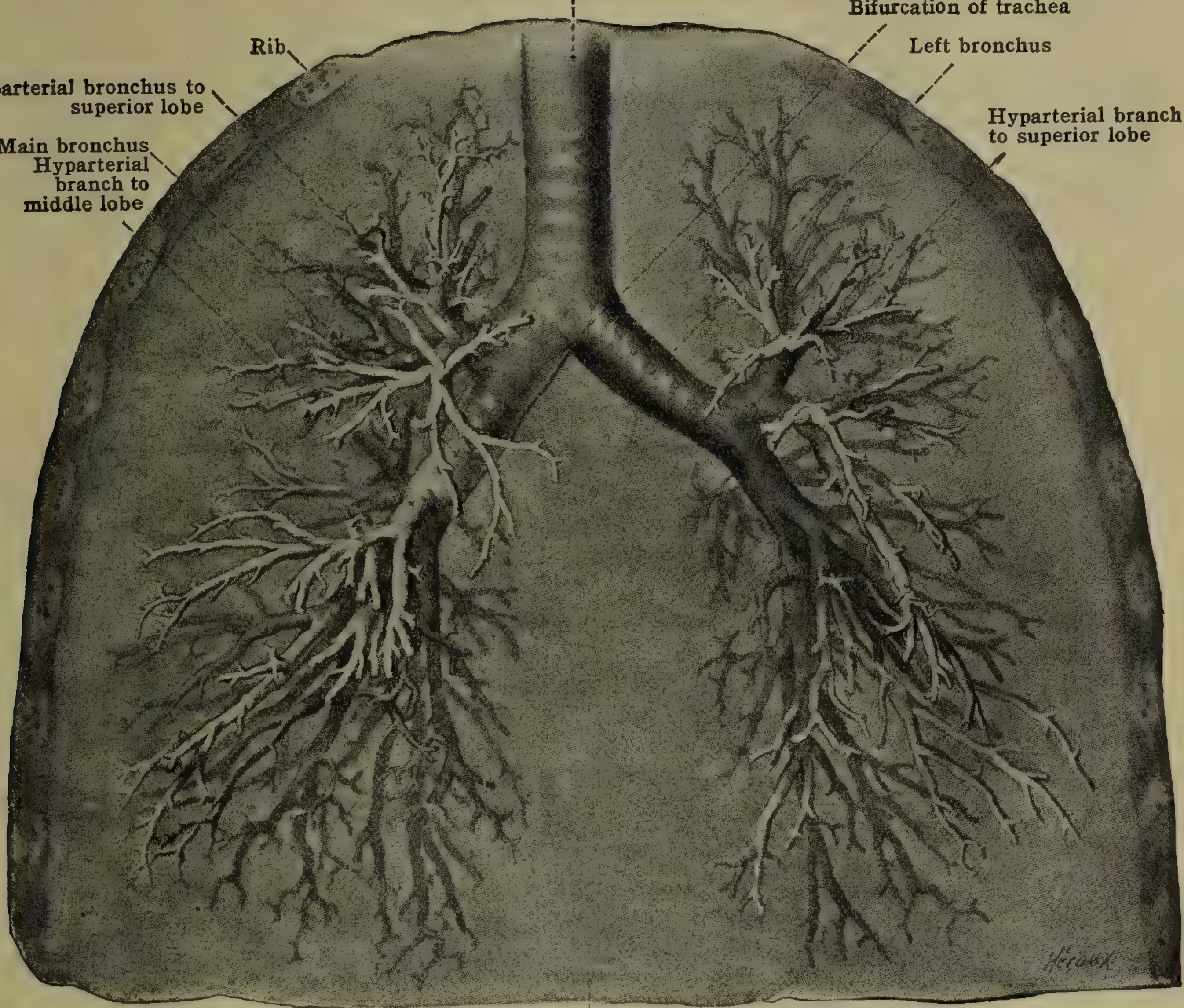


FIG. 1081.—CAST OF THE AIR-TUBES AND THEIR BRANCHES, VIEWED FROM IN FRONT. (Spalteholz.)

and apex. The presence of a **middle lobe** [lobus medius] disturbs the symmetry of the right lung (fig. 1085). This results from a deep, nearly horizontal **secondary fissure** cutting through the lung somewhat below its middle, and extending along the plane of the fourth rib between the anterior margin of the lung and the main interlobar fissure, which it reaches at about the level of the midaxillary line.

Besides possessing the individual peculiarities mentioned, the two lungs further differ from each other in general form and weight, the right lung being considerably broader and heavier than the left. The difference in length maintained by some anatomists, even if it prove constant, must be slight and of little practical importance. These differences seem to follow the asymmetry of the vault of the diaphragm and the position of the heart.

Topography of the lungs.—The **apices** of the lungs extend upward as high as the first thoracic vertebra, a level considerably higher than the superior margin of the sternum (figs. 1083–1086). The subclavian vein and artery and the brachial plexus, together with the anterior scalene muscle, control to a certain degree the height reached. There seems to be no constant difference between the levels attained by the apices of the two lungs. The extent to which the apex rises above the clavicle is rarely more than 3.5 cm. (Merkel), and will, of course, vary with

individual differences in the position and form of this bone. The average is not over 2.5 cm. (1 in.).

The base of each lung, resting on the diaphragm, is separated by that thin partition from the underlying abdominal viscera: thus beneath the base of the right lung is the right lobe of the liver, while under the left lung are the left lobe of the liver, the fundus of the stomach, and the spleen. The position of the apex changes very little in respiration, and the same holds true for the dorsal bulky part of the lung. In deep inspiration the thin inferior (caudal) and anterior (ventral) margins of the lung migrate into and partially obliterate the phrenicocostal and the costomediastinal sinuses of the pleura, respectively. The dorsal part of the lung rests against the side of the vertebral column in the deep hollow of the angles of the ribs, and reaches below to the level of the eleventh costovertebral joint (fig. 1084).

The **ventral margins** (fig. 1083) descend in curves from behind the sternoclavicular joints, and run near together a little to the left of the median line. At the level of the sixth costosternal junction the anterior margin of the right lung turns lateralward to follow the sixth costal cartilage. The anterior margin of the left lung turns lateralward along the fourth costal cartilage as far as the parasternal line, descending in a curve to the lingula and thus forming the cardiac incisure. The **inferior margins** (figs. 1083, 1084, 1085, 1086) of the two lungs are practically alike in their topography. Each extends in a curve convex downward, behind the sixth costal cartilage in its entire length, crosses the costochondral junction of the sixth rib to the superior margin of the eighth rib in the axillary line, and so to the ninth or tenth rib in the scapular line, whence they run horizontally medialward to the eleventh costovertebral joint. These relations are the mean between the conditions observed in the cadaver and as found by physical examination of the living. In old age the inferior margins of the lungs reach a level one or two intercostal spaces lower than is the case in adult life (Mehnert).

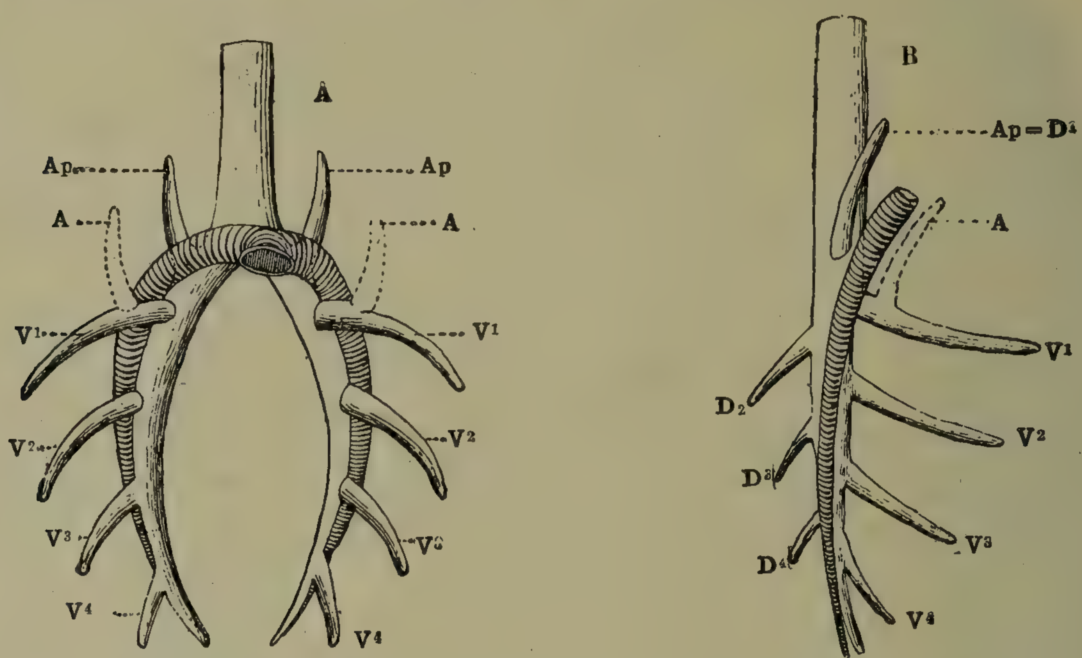


FIG. 1082.—SCHEME OF THE BRONCHIAL TREE ACCORDING TO NARATH. A. Anterior view. B. Right lateral view. (Poirier and Charpy.)

A. Apical bronchus, collateral of the first ventral and susceptible of becoming eparterial, Ap. in migrating to the bronchial trunk.

The chief or **interlobar fissure** (fig. 1084) begins dorsally about 6 cm. below the apex of the lung at the level of the head of the third rib. With the arm hanging at the side, a line drawn across the back from the third thoracic spine to the root of the scapular spine would indicate the course of the upper part of this fissure. (Merkel.) Thence it passes caudalward and around the chest to the end of the sixth rib in the midclavicular (mammillary) line. Merkel points out the use of the root of the scapular spine as a landmark for finding the limits of the lobes dorsally: with the arm hanging at the side all above this spot is superior lobe; all below it the inferior. The **secondary fissure** of the right lung begins at the main interlobar fissure in the midaxillary line, about the level of the fourth rib or fourth interspace, and passes nearly horizontally to the anterior margin of the lung at the level of the fourth rib.

The **roots** of the lungs are placed opposite the fifth, sixth, and seventh thoracic vertebræ. The right root lies dorsal to the superior vena cava and under the arch of the azygos vein; the left root is beneath the aortic arch and ventral to the thoracic aorta. The phrenic nerve passes ventrad to each root, the vagus dorsad. The pulmonary plexuses occupy ventral and dorsal positions. The pulmonary ligament of the pleura extends from the caudal edge of the root (see figs. 1079, 1080).

Branching of the bronchial tubes (figs. 1069, 1081).—Each bronchus, from its origin at the bifurcation of the trachea, takes an oblique course to the hilus, and then continues in the lung as a main tube, extending toward the posterior part of the base. These stem-bronchi are curved, probably in adaptation to the heart, the right like the letter C and the left like an S. Throughout their course the stem-bronchi give off in monopodic fashion collateral branches, the **bronchial**

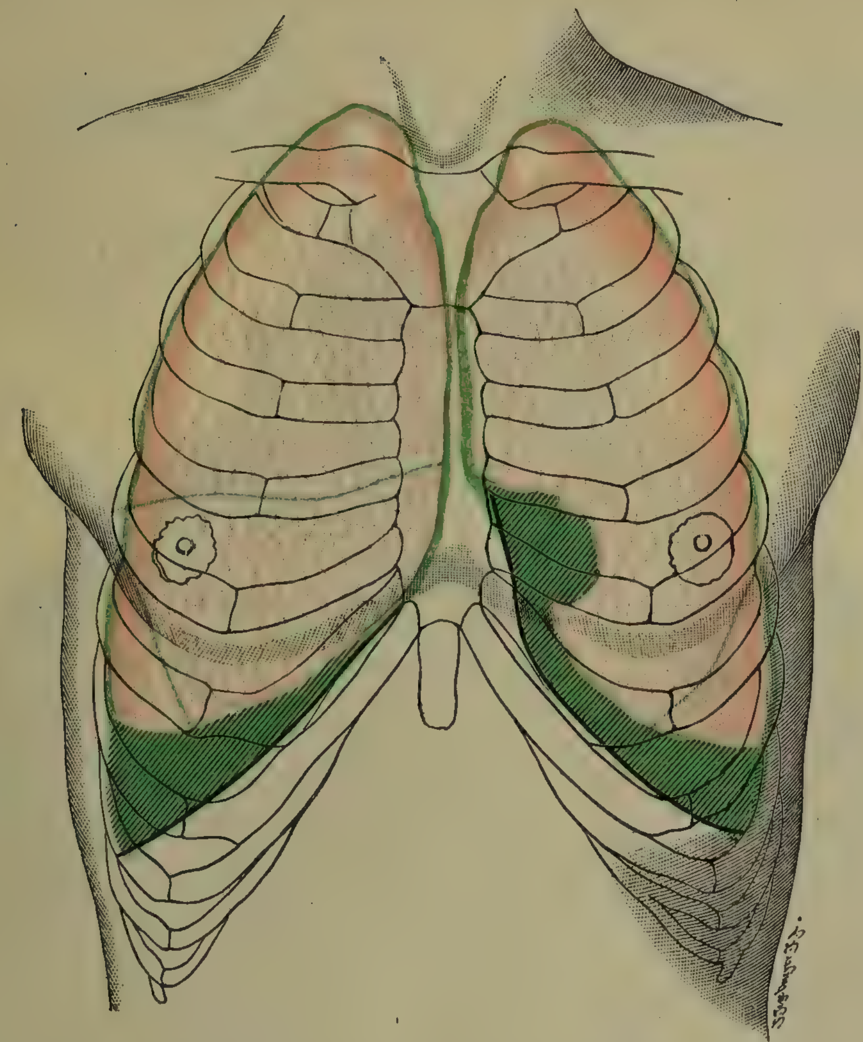


FIG. 1083.—VENTRAL TOPOGRAPHY OF THE LUNGS AND PLEURA. (After Merkel.) The parietal pleura is in green, visceral pleura and lungs in red, lung fissures in blue.

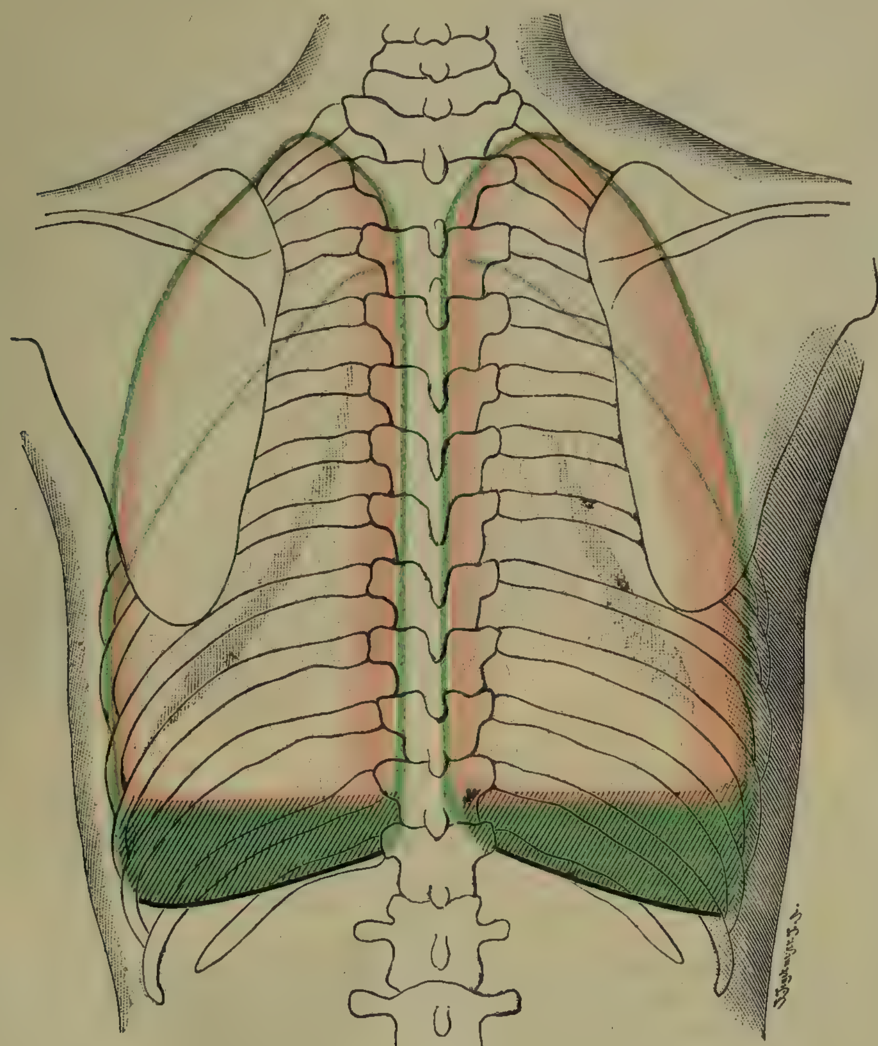


FIG. 1084.—DORSAL TOPOGRAPHY OF THE LUNGS AND PLEURA. (After Merkel.) The parietal pleura is in green, visceral pleura and lungs in red, lung fissures in blue.

rami [rami bronchiales], and these, branching in a similar way, reach all parts of the lung.

The first bronchial ramus of the right stem-bronchus arises above the place where the latter is crossed by the pulmonary artery and is named the **eparterial bronchial ramus** [ramus bron-

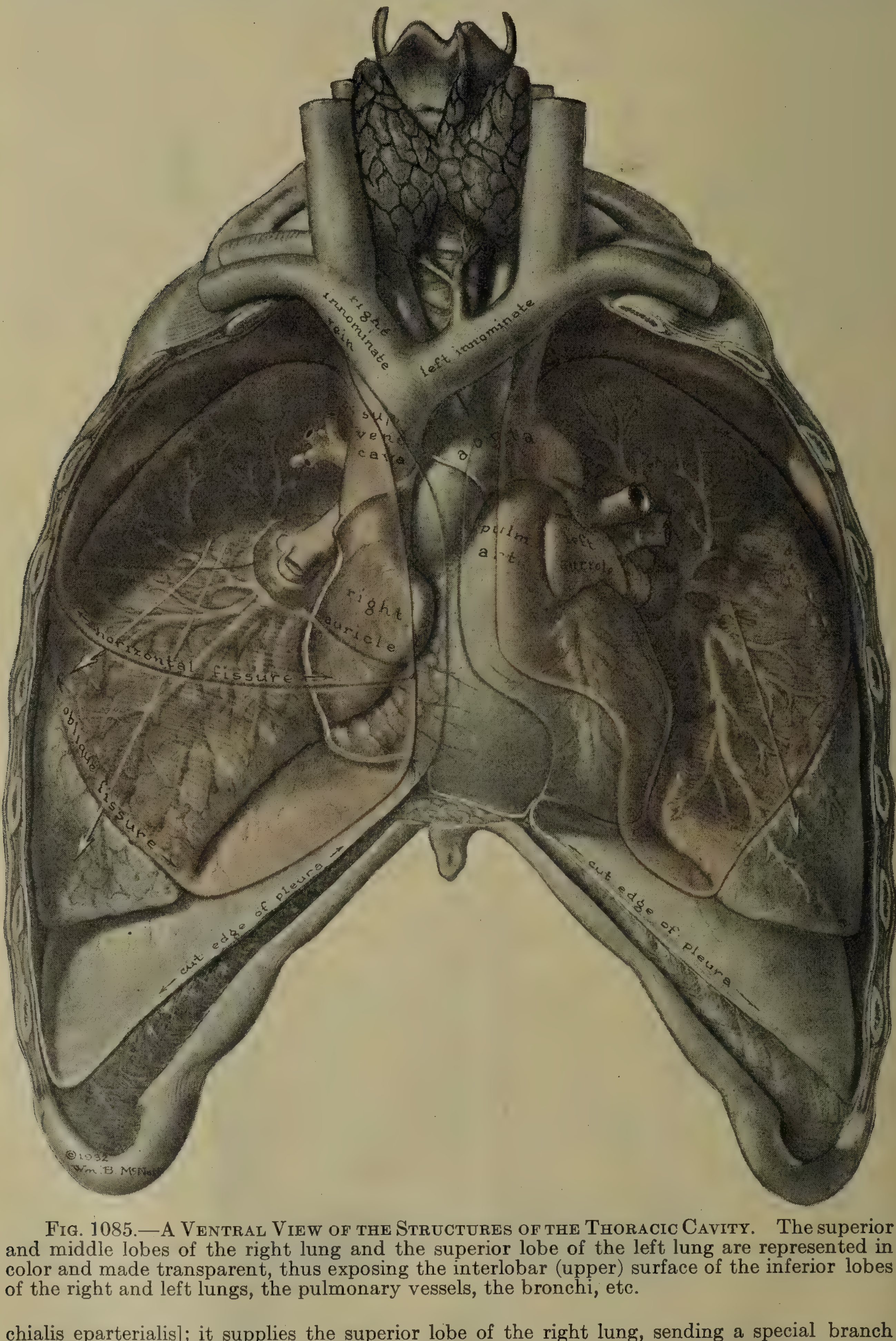


FIG. 1085.—A VENTRAL VIEW OF THE STRUCTURES OF THE THORACIC CAVITY. The superior and middle lobes of the right lung and the superior lobe of the left lung are represented in color and made transparent, thus exposing the interlobar (upper) surface of the inferior lobes of the right and left lungs, the pulmonary vessels, the bronchi, etc.

chialis eparterialis]; it supplies the superior lobe of the right lung, sending a special branch to the apex. All other bronchial rami, whether in the right or left lung, take origin from the stem-bronchi below the level of the crossing of the pulmonary artery and are called **hyparterial bronchial rami** [rami bronchiales hyparteriales]. The second bronchial branch of the right lung goes to supply the middle lobe, while several bronchial branches enter the inferior lobe. On the left side, the first bronchial branch arises below the crossing of the pulmonary artery, and

goes to supply the superior lobe, providing it with an apical ramus. The other branches are given to the inferior lobe.

Aeby suggested and first used the terms eparterial and hyparterial in reference to the bronchial branches as related to the pulmonary artery. He believed that the relationship was of great morphological significance. Narath subsequently opposed this view, and Huntington in extensive studies of the bronchial tree in mammals came to the conclusion that the designation 'eparterial' connotes a faulty morphological conception and that except for purposes of topography the distinction between eparterial and hyparterial bronchi should be abandoned.

Structure of the bronchial rami.—The larger bronchial rami contain in their walls both C-shaped and irregular plates of cartilage, the latter gradually replacing the former as the branches become smaller. The membranous wall is lost and plates of cartilage are disposed on all sides. The mucosa, with ciliated epithelium, is thrown into longitudinal folds covering

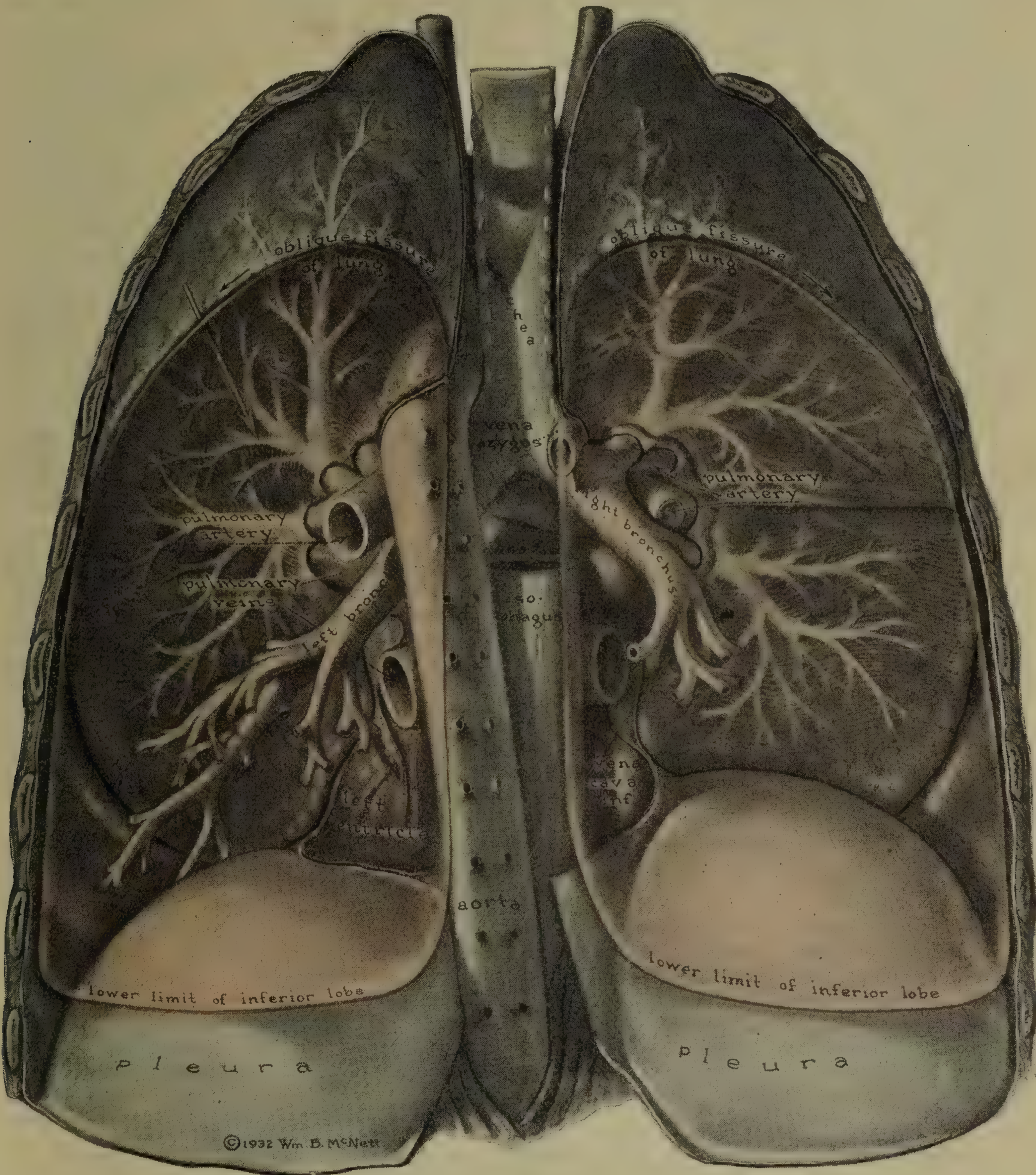


FIG. 1086.—A DORSAL VIEW OF THE STRUCTURES OF THE THORACIC CAVITY. The inferior lobes of the right and left lungs are represented in color and made transparent, thus exposing the interlobar (lower) surface of the superior lobe of the right and the left lungs, the pulmonary vessels, the bronchi, etc.

bundles of elastic fibers of the membrana propria. Next to the latter is a continuous layer of smooth muscle-fibers circularly arranged. Macklin has shown that there is an alternate lengthening and shortening of the trunk and branches of the bronchial tree in inspiration and expiration, respectively, and that these movements are fundamental in the process of respiration. His work shows the importance in clinical practice of comparative X-ray negatives showing full expiration and full inspiration. Mucous secreting **bronchial glands** [gll. bronchiales] are present as far as tubes of 1 mm. diameter; here the cartilages also disappear.

To W. S. Miller is due the credit of having greatly increased our knowledge of the finer structure of the lung and for having presented the conception of the primary lung lobule now generally accepted by anatomists. Some of the chief results of Miller's work are embodied in the following descriptions pertaining to the termination of the air-tubes and to the blood and lymph vascular systems of the lungs and pleura.

Through further branching of the bronchial rami a great number of very fine **bronchioles** [bronchioli] are reached, whose walls possess a weak muscle layer and are lined by mucosa having an epithelium of flattened non-ciliated cells. These, subdividing, give rise to the **respiratory bronchioles** [bronchioli respiratorii], the walls of which are beset with alveoli (fig. 1077). From the respiratory bronchioles arise the **alveolar ducts** [ductuli alveolares], or terminal bronchi, each of which leads to a group of air-spaces, called *atria*, each of which again communicates with a second series of air-spaces, the *air-sacs* (alveolar sacs or infundibula), whose walls are pouched out to form numerous **pulmonary alveoli** [alveoli pulmonum].

A terminal bronchus with its air-spaces and blood-vessels, lymphatics and nerves, together form a **pulmonary lobule** [lobulus pulmonum], the unit of lung structure.

The physical properties of the lungs.—The average *dimensions* in the adult male are as follows: Height of the lung is given at 25–27 cm., the greatest sagittal diameter at 16–17 cm., and the greatest transverse measurement as 10 cm. for the right and 7 cm. for the left. The *volume* of the lungs when well expanded is 6500 c.c. (Merkel.) The *weight* of the lungs can be found only approximately on account of the presence of blood and mucus. In the adult male the weight of both lungs is given as 1300 gm.; female, 1023 gm. The weight of the right lung compared with the left is as 11 is to 10. Ried and Hutchinson found the weight of the lungs compared with that of the body as 1:37 (male), 1:43 (female); in the fetus at term, 1:70. After respiration has been established, the lung, if placed in water, will float. Its *specific gravity* is between 0.345 and 0.746. (Rauber.) The fetal lung contains no air and is heavier than water. Its specific gravity is 1.045 to 1.056. (Krause.) Lung tissue, free of air, with vessels moderately filled, has likewise a specific gravity of 1.045 to 1.056. (Vierordt.)

The color of the lung results from the presence of blood, pigment, and the air in the alveoli. It varies, therefore, as these constituents are all or in part present and with differences in their proportions. Thus the general color is red in the fetus, pink in the infant, and gray mottled with black in the adult. The dark color is traceable to the carbonaceous matter carried into the lungs from the atmosphere.

In **consistence** the lung is soft and spongy, and when compressed between the fingers, emits a crackling sound. Among the physical properties, the **elasticity** of the lung is quite remarkable. Under ordinary conditions the pressure of the air in the lung keeps the alveoli and the organ as a whole distended, but when the pleura has been opened and the air pressure equalized without and within, the lung collapses.

Vessels and nerves of the lungs.—The **bronchial arteries** (see p. 660), belonging to the systemic system, carry blood for the nourishment of the lungs. They arise from the aorta or from an intercostal artery, two for the left lung and one for the right, and, entering at the hilus, reach the dorsal wall of the main bronchus. The bronchial arteries accompany the bronchi, whose walls they supply, as far as the distal ends of the alveolar ducts, beyond which they do not go. These vessels also supply the lymph-nodes of the hilus, the walls of the large pulmonary vessels, and the connective-tissue septa of the lung. **Bronchial veins** (see p. 736), anterior and posterior, arise from the walls of the first two or three divisions of the bronchi and end in the innominate and the azygos or in one of the intercostal veins; those arising from the walls of the smaller tubes, including the alveolar ducts, join the pulmonary veins. The **pulmonary artery** (see p. 605), entering the hilus in a plane anterior to the bronchus (fig. 1078), turns to the posterior aspect of the main-stem, following its branches and their subdivisions of the lobules. Entering the lobule, the last branch of the vessel gives off as many twigs as there are atria (fig. 1077), and these twigs end in dense capillary nets in the walls of the alveoli. Here the venous blood brought by the pulmonary artery, separated from the air in the alveolus only by a thin septum, is changed to arterial blood in the respiratory process. According to Miller, anastomosis between the branches of the pulmonary artery is exceptional. Anastomosis between the bronchial and pulmonary arteries has been claimed, but the connection apparently existing between these vessels is through the radicles of the bronchial veins which join the pulmonary veins. The pulmonary venous radicles begin at the capillary networks and drain the arterial blood into the pulmonary veins, which run between adjacent lobules and which receive also blood coming from the capillary network of the pulmonary pleura and from the capillary network of the bronchi (fig. 1077). Thus it will be seen that while the pulmonary vein carries mainly arterial blood, it carries also some venous blood. The **pulmonary veins** (see p. 606) follow the bronchial tree on the side opposite the arteries to the hilus, where, having converged to two large trunks located in the root of the lung below the plane of the artery, they pass to the left atrium. The pulmonary veins have no valves.

Lymphatics.—Miller has found the lymphatic vessels forming a closed tube system in the walls of the bronchi, in the pleura, and along the branches of the pulmonary artery and veins. Within the lung numerous **pulmonary lymph-glands** [lymphoglandulæ pulmonales] are found chiefly at the places of branching of the larger bronchi [lymphoglandulæ bronchiales]. Scattered along the latter, as well as associated with the branches of the pulmonary artery and vein, are found nodules of lymphoid tissue. Deposits of carbonaceous matter in the lymphoid structures of the lung are present, except in early infancy; the amount increases with age.

Nerves.—Parasympathetic (via vagus) and sympathetic contribute to form the pulmonary plexuses in front and behind the root of the lung, from which branches go to accompany bronchial arteries; a smaller number accompany the air-tubes (see p. 1123).

Variations.—Congenital absence of one or both lungs has been observed. Variations in the lobes are not uncommon—four for the right and three for the left lung have been recorded. An *infracardiac lobe*, as found in certain mammals, sometimes occurs; an infracardiac bronchus is, however, constant in man. More or less complete fusion of the middle and upper lobes of the right lung is not rare. The lungs may be symmetrical, with two lobes each, the apical bronchus

of the right springing from the first ventral bronchus, as is normal for the left lung (Waldeyer, Narath); or the lungs may have three lobes each, the apical bronchus of the left arising from the main bronchus. The apical bronchus of the right lung may arise from the trachea, an origin that is normal in the hog and other artiodactyls. A *lobus cavæ*, extending behind the terminal end of the inferior vena cava can be demonstrated in many cases if care is taken in making the exposure. An *azygos lobe* appears to be present more frequently than was hitherto reported. It occurs in the upper part of the right lung, where a deep groove occupied by the major azygos vein isolates a portion of the upper lobe of the lung. This condition appears to affect the physical signs in the region (Mackmull).

Development of the lungs and trachea.—The first indication of the trachea and lungs appears in embryos of the third week as a trough-like groove in the ventral wall of the upper part of the esophagus, communicating above with the pharynx. Later the groove becomes constricted off from the esophagus, the constriction extending from below upward, so that a tube is formed which opens into the pharynx above. For further details, see DEVELOPMENTAL ANATOMY, p. 51.

References for respiratory system. A. **External nose and nasal cavity.** Kallius, in von Bardeleben's Handbuch; Zuckerhandl, Normale u. path. Anatomie d. Nasenhöhle, Bd. 1, Wien, 1893; Schaeffer, The Nose and Olfactory Organ, Phila., 1920; (*Development*) His, Archiv f. Anat. u. Phys., 1892; Killian, Arch. f. Laryngol., Bd. 4, 1896; Schaffer, Jour. Morphol., vol. 21, 1910; (*Conchæ*) Peter, Arch. f. mikr. Anat., Bd. 60, 1902; (*Paranasal sinuses*) Bartels, Zeitschr. f. Morph. u. Anthrop., Bd. 8; Turner, Accessory Sinuses of the Nose, Edinburgh, 1901, Schaeffer, The Paranasal Sinuses, in the Nose and Olfactory Organ, *loc. cit.*; Davis, Nasal Accessory Sinuses, Phila., 1914; (*Anthropology*) Hoyer, Morph. Arbeiten, vol. 4, 1894. B. **Larynx.** Gerlach, Anat. Hefte, H. 56; (*Development*) Lisser, Amer. Jour. Anat., vol. 12; (*Ossification*) Scheier, Arch. f. mikr. Anat., Bd. 59. C. **Lungs.** (*Structure; vascular supply*) Miller, Arch. f. Anat. u. Entw., 1900, Amer. Rev. Tuberculosis, vols. 2 and 3, 1919; Amer. Jour. Anat., vol. 7; Schultze, Sitzb. Akad. Wiss., Berlin, 1906; Winternitz et al, Bul. Johns Hopkins Hosp., 1920; (*Development*) Aeby, Der Bronchialbraum der Säugethiere und des Menschen, 1880; Narath, Der Bronchialbaum der Säugethiere und des Menschen, 1892, 1901; Flint, Amer. Jour. Anat., vol. 6; Huntington, Amer. Jour. Anat., vol. 27, 1920; (*Topographical*) Mehnert, Topogr. Altersveränderungen d. Atmungsapparatus, Jena, 1901; Mackmull, The relation of anatomical variations to physical diagnosis: Amer. Review of Tuberc. vol. 22, no. 3, 1930; Macklin, A note on the elastic membrane of the bronchial tree of mammals, Anat. Rec., vol. 24, no. 2, pp. 119–135; X-ray studies on bronchial movements, Amer. Jour. Anat., vol. 35, no. 2, 1925; D. **Pleura.** Ruge, Morph. Jahrb. Bd. 41, 1910.

SECTION XII

UROGENITAL SYSTEM

By FRANKLIN P. JOHNSON, Ph.D., M.D.

ASSISTANT PROFESSOR OF CLINICAL UROLOGY, UNIVERSITY OF OREGON; FORMERLY PROFESSOR OF ANATOMY, UNIVERSITY OF MISSOURI

The **urogenital system** [apparatus urogenitalis] includes (A) the **urinary organs** [organa uropoëtica] and (B) the **reproductive organs** [organa genitalia].

A. URINARY ORGANS

THE organs forming the urinary apparatus (organa urinalia NK) are the **kidneys**, by means of which the urine is produced; the **ureters**, which convey the urine to the bladder; the **bladder**, which serves as a reservoir for the urine and from which, by a single duct, the **urethra**, the urine is carried to the exterior. A general view of the urinary organs is shown in fig. 1087.

THE KIDNEYS

The **kidneys** [renes] are paired organs situated in the posterior part of the abdomen, on either side of the vertebral column and behind the peritoneum. The right kidney is lower than the left in approximately two-thirds of all cases, a circumstance which has been attributed to the presence of the liver on the right side. Each kidney is somewhat bean-shaped (fig. 1088) and is tilted in such a way that the *ventral* or *visceral surface* [facies anterior] looks obliquely ventrally and laterally, while the *dorsal* or *parietal surface* [facies posterior], usually less convex, looks dorsally and somewhat medially (fig. 1090). The *upper extremity* [extremitas superior] is usually larger than the *lower extremity* [extremitas inferior], and is about 1 cm. nearer the vertebral column. The *lateral border* [margo lateralis] is narrow and convex while the *medial border* [margo medialis], which is directed medially and ventrally, is concave, and presents in its middle third a slit-like aperture, the **hilus.** This is the orifice of a cavity called the **sinus** (fig. 1093), which is about 2.5 cm. in depth and is occupied mainly by the **renal pelvis,** the interval between this and the actual kidney substance containing adipose tissue, and the renal vessels and nerves. Except for the sinus the kidneys are solid organs, moderately elastic, and because of their high degree of vascularity, of a dark reddish brown color.

Size.—The length of the kidney in the male averages 10–12 cm., its breadth about 5 to 6 cm. and its thickness 3 to 4 cm.; its average weight in a state of physiological distention is 168 gms. (Kelley and Burnham). The dimensions of the female kidney are slightly smaller and its weight one-eighth less. In the child the organ is relatively large, its weight compared with that of the entire body being about 1:140 at birth; its permanent relation, which is about 1:170 being usually attained at the end of the tenth year.

Investment and fixation.—The surface of the kidney is covered by a thin but strong *fibrous capsule* [tunica fibrosa] (fig. 1090). The capsule divides in the region of the hilus into two layers, one of which turns inward at the hilus to line the walls of the sinus. The other forms a sheath covering the vessels and nerves before they pass into the hilus. It may readily be peeled off from a healthy kidney, except at the bottom of the sinus, where it is adherent to the blood-vessels entering the kidney substance and to the terminal portions of the pelvis. External to the capsule is a quantity of fat tissue, the **adipose capsule** [capsula adiposa], which forms a complete investment for the organ and is prolonged through the hilus into the sinus.

The *peritoneum*, which covers the ventral surface of the adipose capsule, has usually been regarded as the principal means of fixation of the kidney, but in reality this is accomplished by means of a special **renal fascia** (fig. 1090), developed from the subperitoneal areolar tissue (Gerota).

Renal fascia.—Lateral to the kidney there occurs between the transversalis fascia and the peritoneum a subperitoneal fascia, which, as it approaches the convex border of the kidney, divides into two layers, one of which passes in front of and the other behind the kidney, enclos-

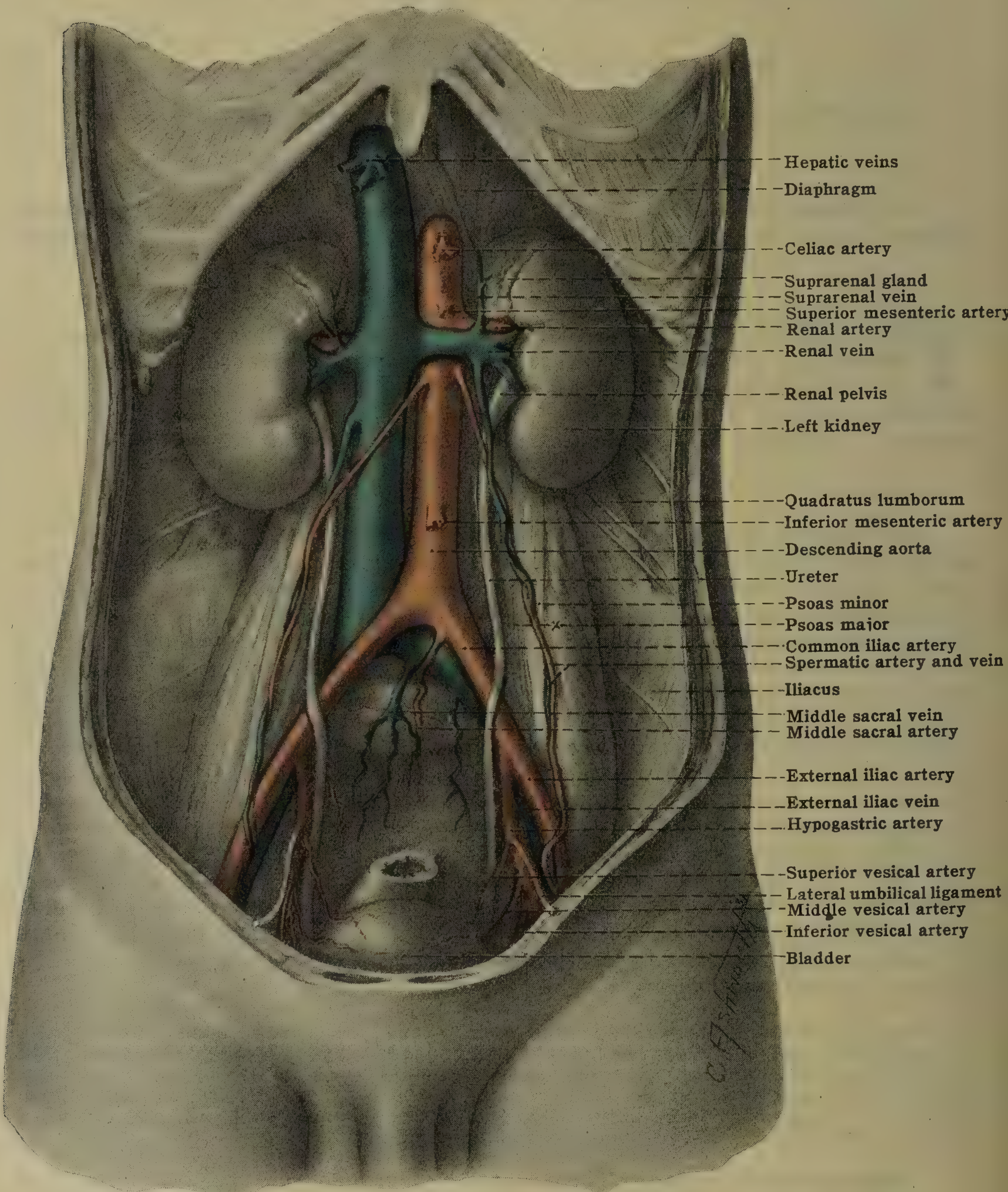


FIG. 1087.—KIDNEYS, URETERS, ETC. IN SITU.

ing the adipose capsule. Traced medially, the anterior layer of the renal fascia passes in front of the renal vessels, and, over the aorta, becomes continuous with the corresponding layer of the opposite side; upward, it passes over the suprarenal gland and at the upper border of that organ becomes continuous with the posterior layer; and downward, it is lost in the adipose tissue intervening between the iliac fascia and muscle. The posterior layer, which is the thicker of the two, passes medially behind the renal vessels and is lost in the connective tissue in front of the vertebral column, and like the anterior layer is lost below in the iliac region. Between the posterior layer and the quadratus lumborum is a mass of adipose tissue, the so-called

'*pararenal adipose body,*' which is to be clearly distinguished from the adipose capsule, frequently called the *perirenal fat*. Both layers of the renal fascia are united to the fibrous capsule of the kidney by strands of connective tissue which traverse the adipose capsule.

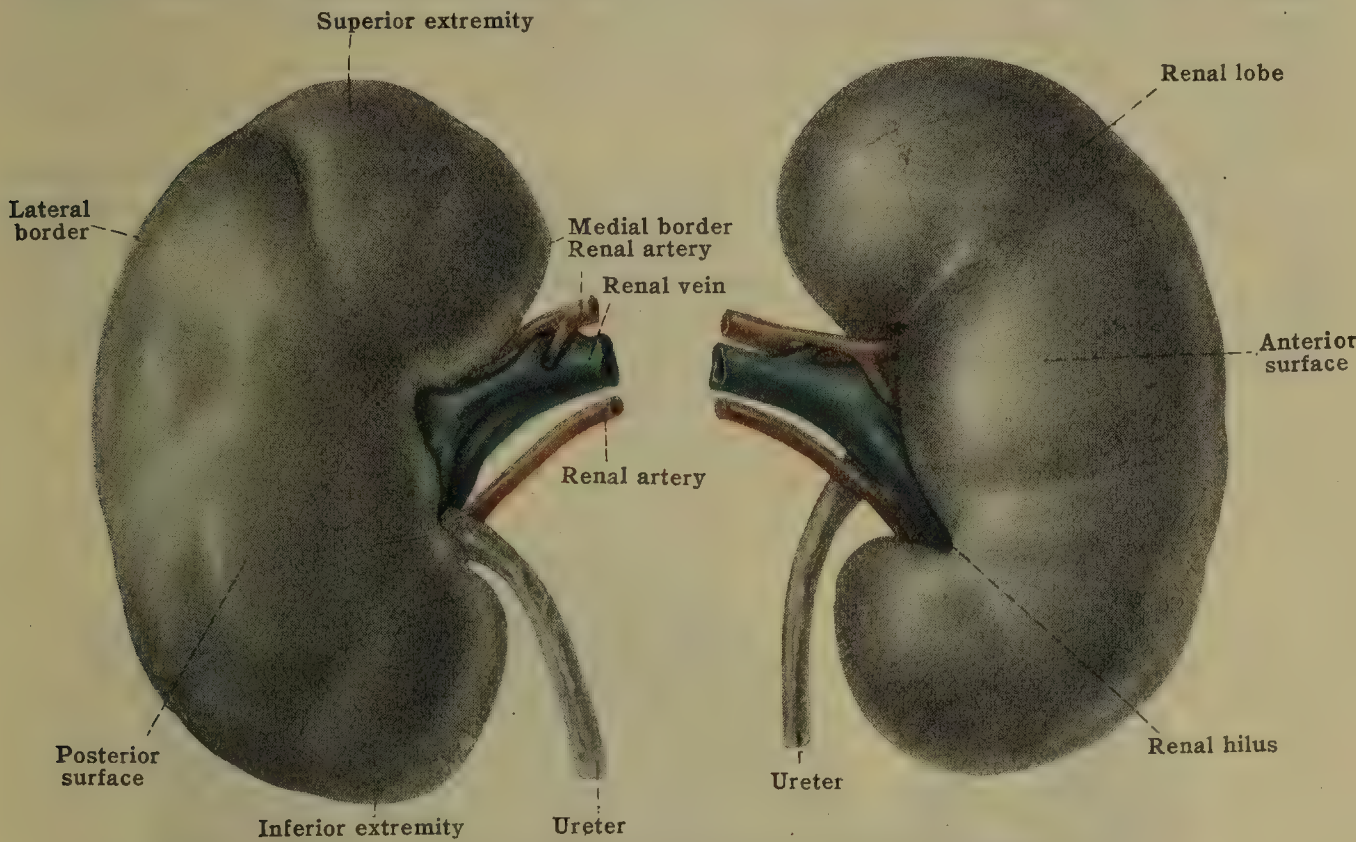


FIG. 1088.—LEFT KIDNEY, REAR AND FRONT VIEWS.

Position and relations (figs. 1032, 1087).—The kidney is said to lie in the lumbar region. It is however, intersected by the horizontal and vertical planes which separate the hypochondriac, lumbar, epigastric and umbilical regions from each other, and hence belongs to all these segments of the abdominal space (see fig. 1032). Its vertical extent may be said to correspond to the last thoracic and upper

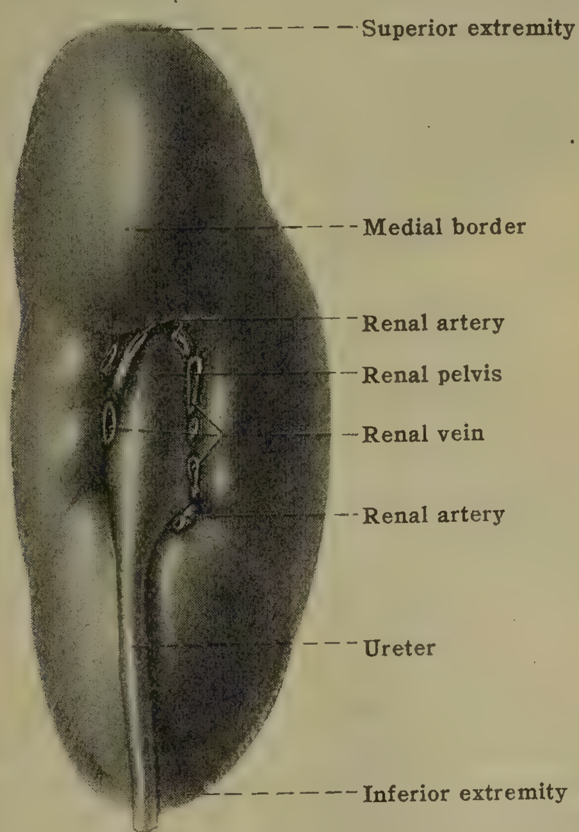


FIG. 1089.—LEFT KIDNEY, MEDIAL VIEW.

two or three lumbar vertebræ, the right lying in most cases from 8 to 12 mm. (⅓ to ½ in.) lower than the left; but exceptions to this rule are not infrequent.

The **posterior surface** (fig. 1092) rests against the posterior abdominal wall overlying the eleventh and twelfth ribs and the tips of the transverse processes of the first, second and occasionally the third lumbar vertebræ. There is con-

siderable variation in the relation of the kidneys to ribs and vertebræ. In women they are usually one-half vertebra lower; moreover they are normally lower on inspiration than on expiration, and while standing than when lying down. In the male the left kidney may reach the lower border of the tenth rib while the right seldom goes above the eleventh rib. In the female the left kidney usually reaches slightly above the eleventh rib while the right barely reaches its lower border.

The posterior surface of the kidney is in relation to the following abdominal structures: its upper portion rests upon the *diaphragm* and because of its higher position the left kidney enters into this relationship more extensively than the right. The *diaphragmatic area* may be divided into two portions, a medial which rests against the crus of diaphragm and a lateral which is related to the muscular portion of this structure. Between the two is a triangular area in which

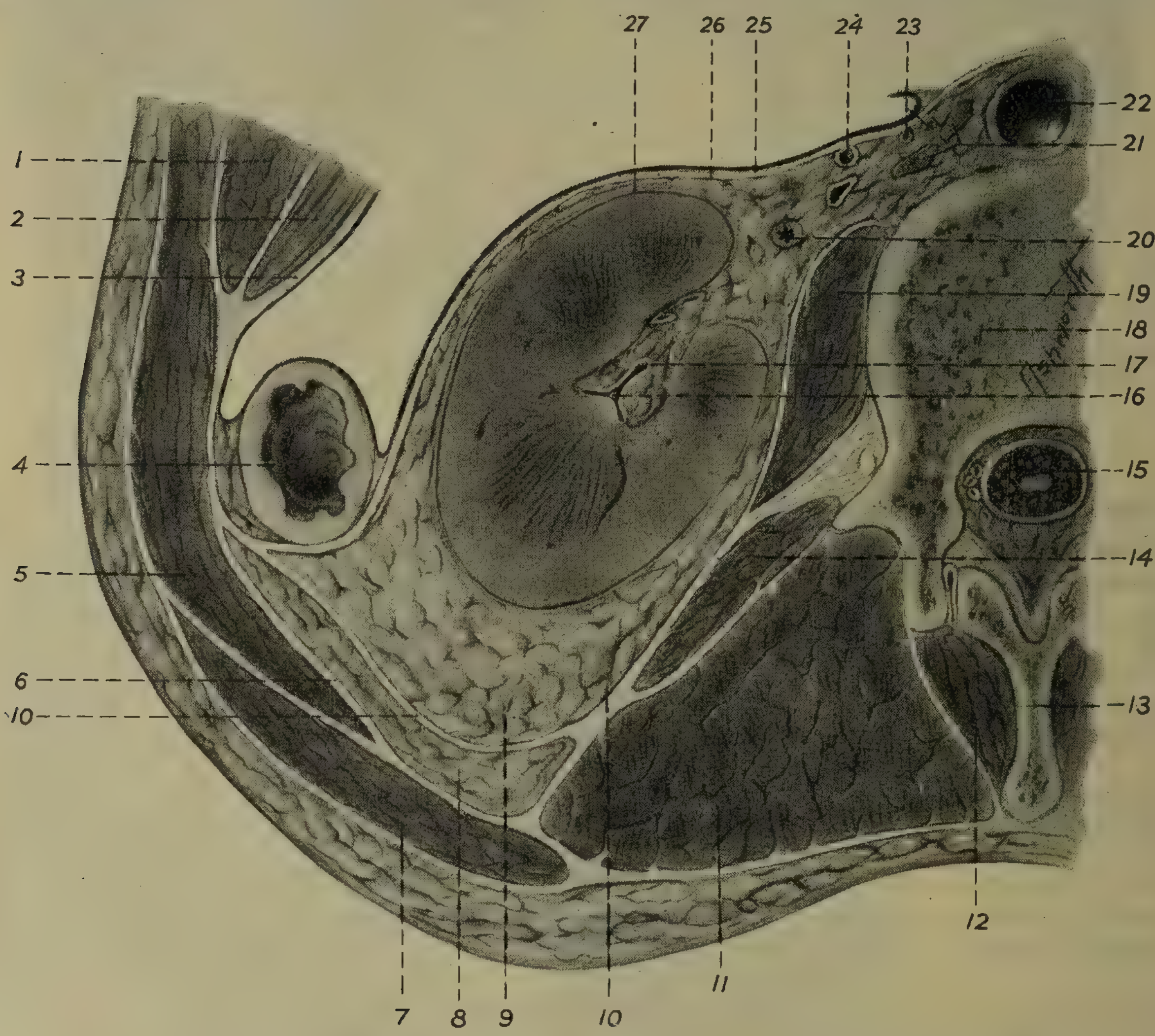


Fig. 1090.—Cross-section Showing Relations of Renal Fasciæ.

1, Internal oblique muscle. 2, Transverses abdominis. 3, Transversalis fascia. 4, Descending colon. 5, External oblique. 6, Iliac fascia. 7, Latissimus dorsi. 8, Retroperitoneal (pararenal) fat. 9, Adipose capsule (perirenal fat). 10, Posterior renal fascia. 11, Iliocostalis lumborum and longissimus dorsi. 12. Multifidus muscle. 13, Spinous process, 2nd lumbar vertebra. 14, Quadratus lumborum. 15, Cauda equina. 16, Minor calyx. 17, Major calyx. 18, Body of 3rd lumbar vertebra. 19, Psoas major. 20, Ureter, 21. Lymph glands. 22, Aorta. 23, Spermatic artery and vein. 24, Inferior mesenteric artery. 25, Peritoneum. 26, Anterior renal fascia. 27, Fibrous capsule of kidney.

the pleura is in direct contact with the kidney. This relationship is of importance to the surgeon as the pleural cavity can be easily ruptured into at this point. If the remainder of the posterior surface is divided into three longitudinal areas, these areas from within outward correspond to the positions of the *psoas major*, the *quadratus lumborum*, and the tendon of the *transversus abdominis* muscles respectively. The last thoracic, iliohypogastric, and ilioinguinal nerves, and the anterior division of the subcostal and first lumbar vessels, all of which run obliquely downward and laterally in front of the psoas major and quadratus lumborum muscles, also lie in relationship to this surface of the kidney.

The anterior surface (fig. 1091) of each kidney in early embryonic life is completely covered by peritoneum which separates it from the neighboring viscera. With the growth of the abdominal organs, the ascending and descending colons,

the duodenum and the pancreas become retroperitoneal organs, and come into direct relationship with one or the other of the kidneys, thus separating portions of them from actual contact with the peritoneum. Thus, in the case of the *right kidney* (figs. 1032, 1091), the portion of the anterior surface immediately adjacent

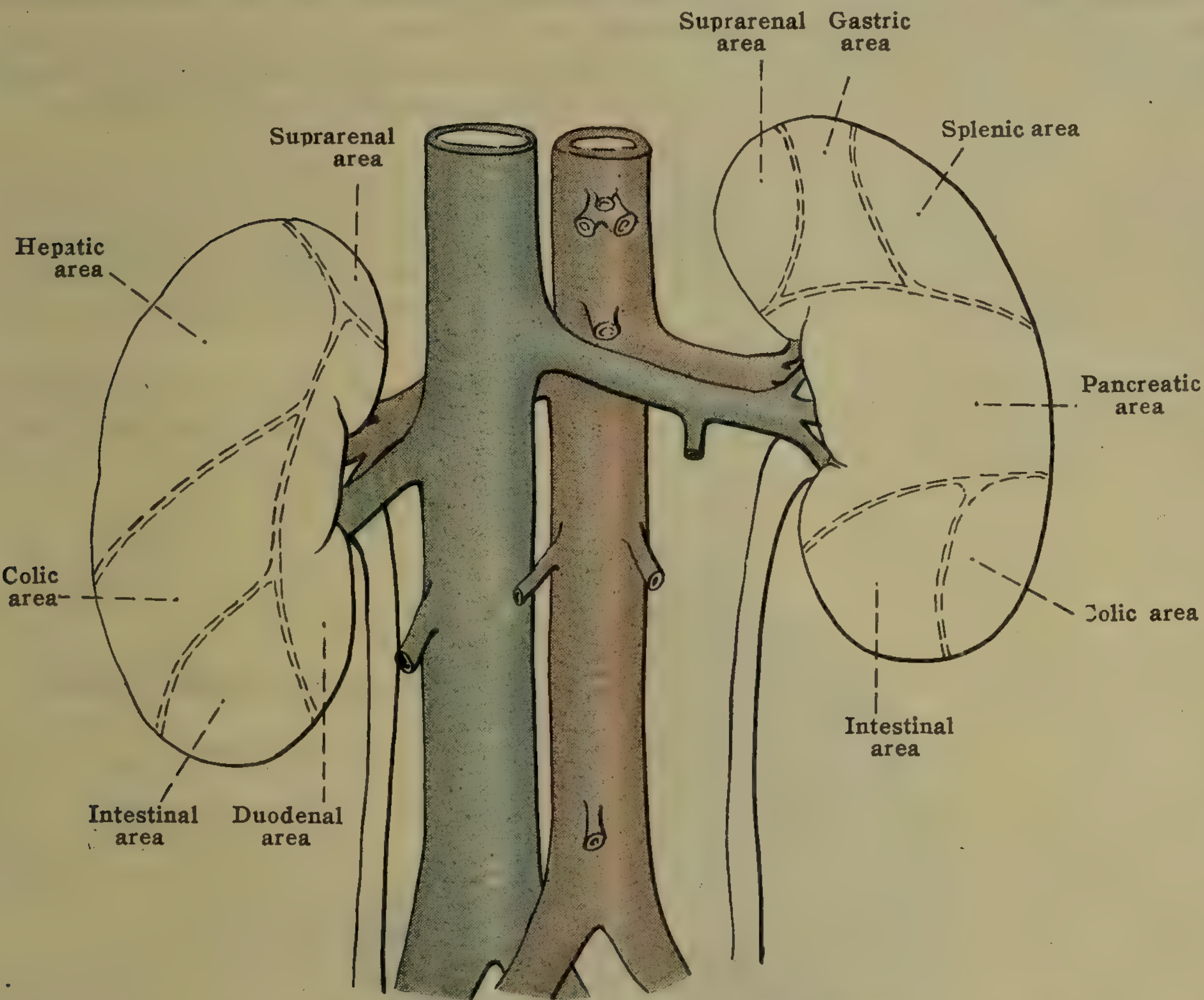


Fig. 1091.—Diagram Showing Anterior Relations of Kidneys.

to the medial border has the descending portion of the duodenum in direct contact with it; similarly the ascending colon and right colic flexure make non-peritoneal contacts with the kidney, fig. 1091. Almost the entire upper half, however, and a small portion of the lower pole are covered directly by peritoneum,

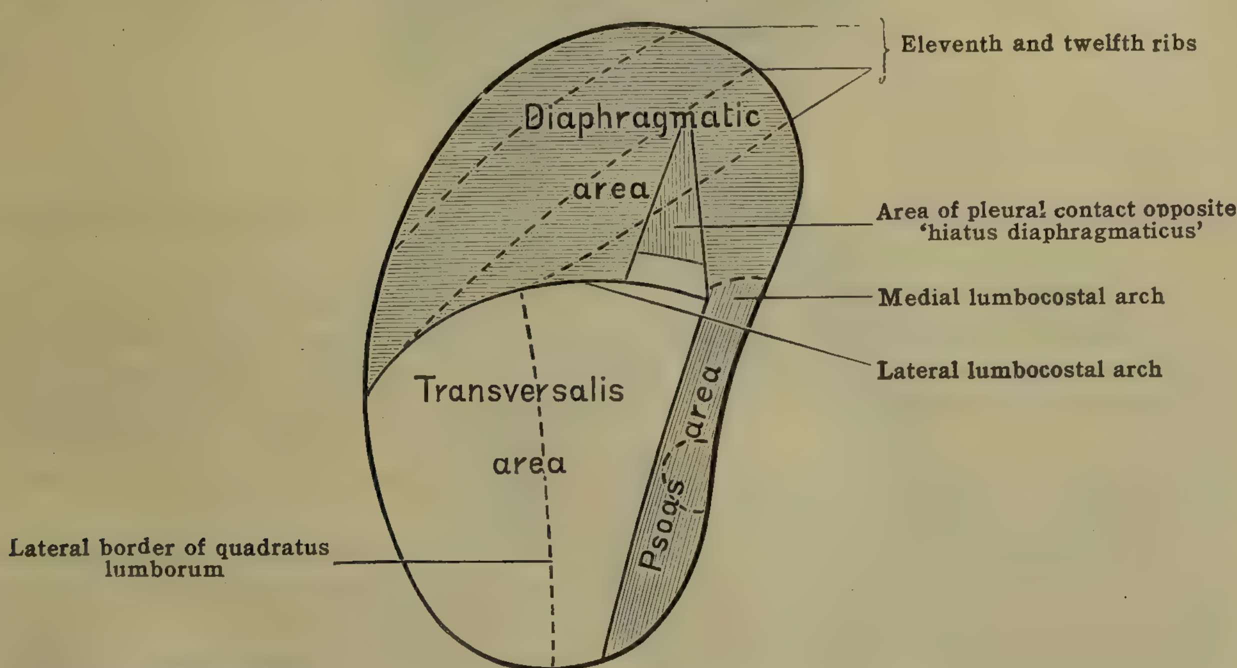


Fig. 1092.—Diagram of Relations of Posterior Surface of Left Kidney.

the upper peritoneal area having an indirect relation with the lower surface of the liver, upon which it produces the 'renal impression.'

The anterior surface of the *left kidney* presents a similar situation (figs. 670, 1091). It is in direct contact with the pancreas throughout a broad transverse

area situated a little above the middle of the organ, and the splenic artery pursues its tortuous course along the upper border of this 'pancreatic area,' while the corresponding vein is interposed between the pancreas and the surface of the kidney. Below the pancreas, the lateral portion of the kidney is in direct contact with the descending colon and the left colic (splenic) flexure, but the remainder of the lower extremity and a small upper area of the kidney is directly covered by peritoneum. The upper peritoneal area has, as an indirect relation, the posterior surface of the stomach medially, and the spleen laterally (figs. 670, 1091).

Just as there may be variation in the position of the kidneys, so too there may be considerable variation in the extent to which they are in relation to the various structures mentioned above. And this is especially true as regards their relations to the colons; for if the kidneys were lower than usual they might lie entirely beneath the line of attachment of the transverse mesocolon and thus have no direct relations with either colon, or, on the other hand, either the ascending or descending colon, or both, may be provided with a mesentery, whereby they would be removed from direct contact with the kidney.

The **medial border** of the right kidney approaches the vena cava inferior closely, especially above; that of the left is separated from the aorta by an interval of about 2.5 cm.

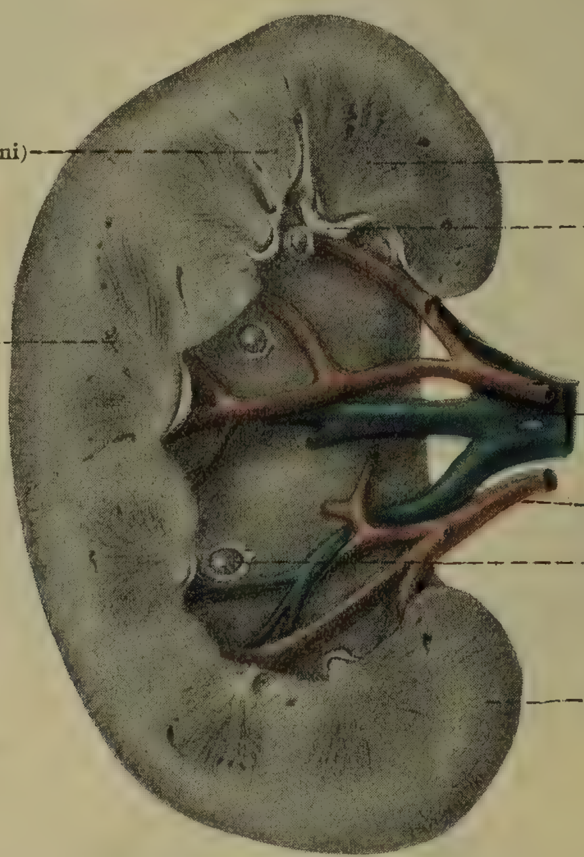


Fig. 1093.—Dissection of Anterior Half of Right Kidney, Showing Structures in the Renal Sinus.

The **lateral border** of each kidney lies 8.5–10.0 cm. lateral to the spines of the lumbar vertebræ, a distance that brings them lateral to the lateral edge of the sacrospinalis muscle and even beyond the lateral edge of the quadratus lumborum, so that this border of the kidney may be readily approached through the posterior wall of the body. The upper portion of the lateral border rests upon the muscular portion of the diaphragm while the lower portion is in contact with the tendon of the transversus abdominis muscle.

The **superior extremity** of each kidney is partially crowned by the suprarenal gland (see fig. 1087) which also encroaches upon the anterior surface and medial border of the kidney and is fixed to it by fibers derived from the subperitoneal tissue. The remainder of the upper extremity lies in direct contact with the diaphragm.

The **inferior extremity** of the right kidney lies in contact with the hepatic flexure of the colon and the duodenum while the left is related to the transverse colon and jejunum.

The **renal sinus** (fig. 1093) is the cavity of the kidney which opens on the medial border by means of an aperture known as the *hilus*. Its three dimensions

are roughly proportionate to those of the kidney itself. It contains the *renal pelvis* and its *calyces*, an irregular sac-like structure which collects the urine from all portions of the kidney. It also contains the branches of the renal artery and veins, nerves, a small amount of adipose tissue etc., which lie between the renal pelvis and walls of the sinus. These vessels and nerves enter the renal parenchyma directly from the sinus. The shape of the sinus is properly appreciated only when the kidney is split longitudinally and when the renal pelvis and

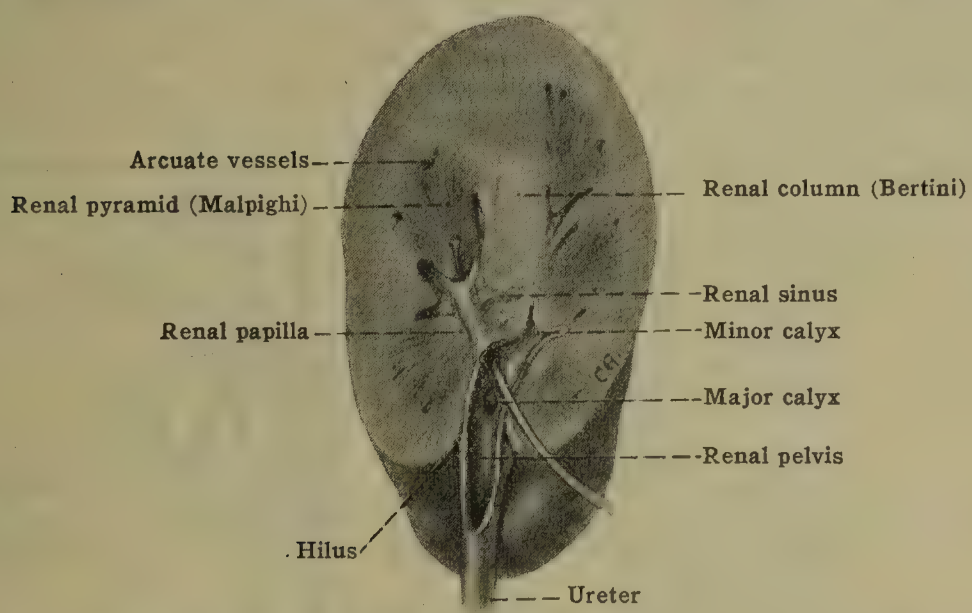


Fig. 1094.—Cross-section of Kidney, Showing Relations of Renal Pelvis.

vessels are dissected (fig. 1093). The walls of the sinus are then seen to be studded with small conical protuberances, the *renal papillæ.* These are usually 6 to 8 in number but as few as 4 and as many as 18 have been recorded.

The **renal pelvis** (figs. 1094) is a small reservoir which collects, and in which is mixed, the urine from all parts of the kidney. It is funnel-shaped, the broad portion lying within the renal sinus while the apical portion passes out through the hilus to unite with the ureter. Within the sinus the pelvis usually splits into two main divisions, the *major calyces* which pass toward the upper and lower

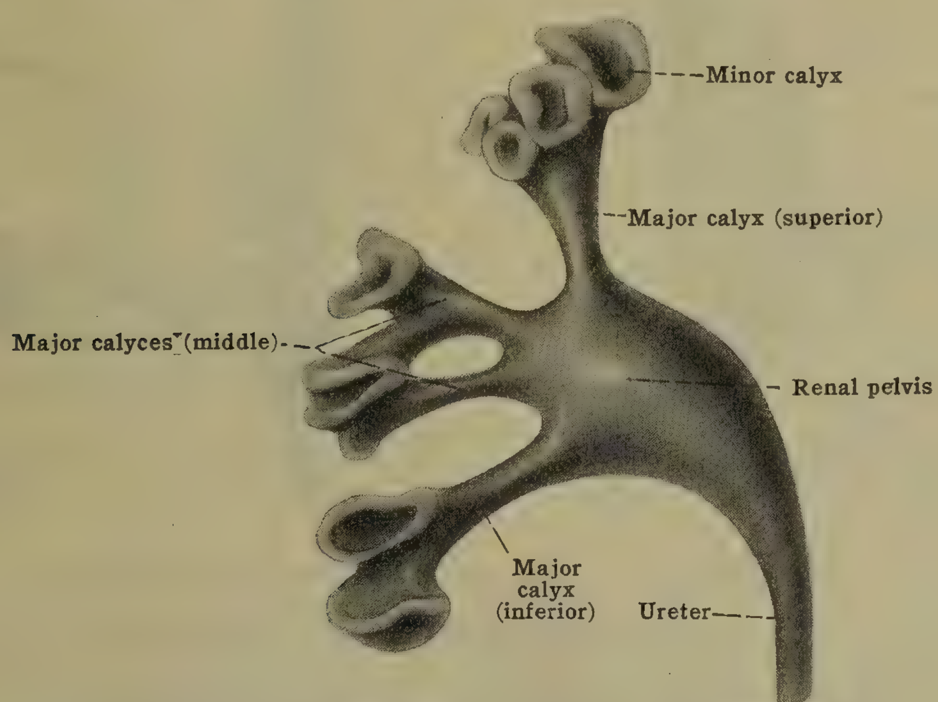


Fig. 1095.—Cast of Renal Pelvis. (After Hauch.)

portions of the kidney. Occasionally one or more additional major calyces may be present (fig. 1095). The major calyces divide into the *minor calyces*, each of which terminates in relation to one, two, or sometimes three *renal papillæ;* the number of calyces is, therefore, usually fewer than the papillæ. The papillæ, protruding into the ends of the calyces, give to the latter a characteristic cup-shaped appearance. At the summits of the papillæ are a number of small openings,

the apertures of the *papillary ducts* of the kidney, through which the urine enters the calyces.

Not only is there considerable variation in the number of renal calyces and the shape of the renal pelvis, but there is also a marked variation in position of the pelvis. Thus a pelvis may lie almost entirely within the sinus, an *intrarenal pelvis,* or its main portion may be a dilated sac and lie outside the kidney proper, an *extrarenal pelvis.*

Structure.—A section through the kidney shows its substance to be composed of an external **cortex** [substantia corticalis] and an internal **medulla** [substantia medullaris] (fig. 1094). The medulla consists of a variable number (eight to eighteen) of conical segments termed **renal pyramids** [pyramides renales (Malpighii)], the apices of which project into the bottom of the sinus and are received into the various minor calyces of the pelvis, while their bases are turned toward the surface, but are separated from it and from each other by the cortex.

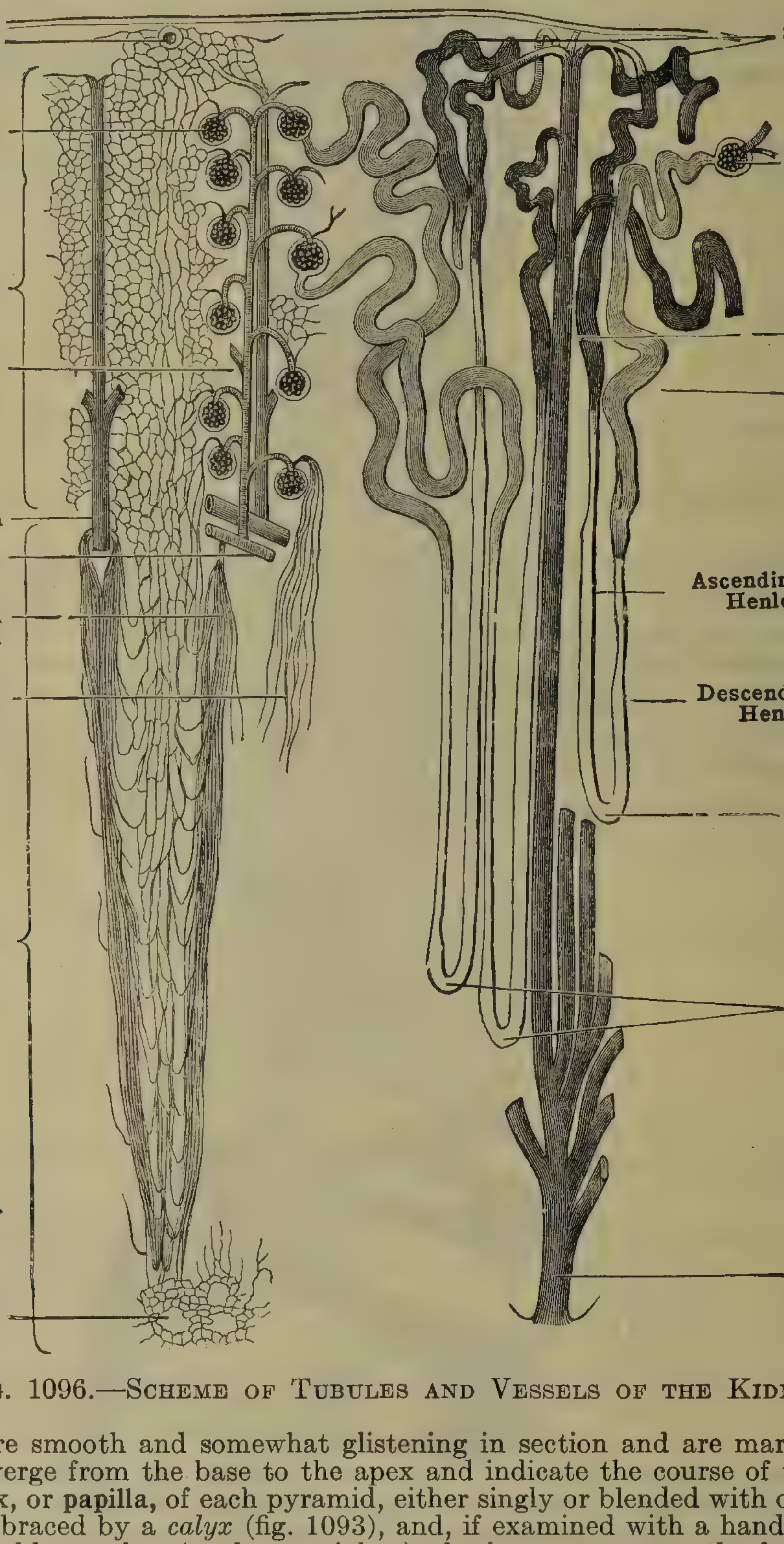


FIG. 1096.—SCHEME OF TUBULES AND VESSELS OF THE KIDNEY.

The pyramids are smooth and somewhat glistening in section and are marked with delicate striæ which converge from the base to the apex and indicate the course of the renal tubules. The blunted apex, or **papilla,** of each pyramid, either singly or blended with one or even two of its fellows, is embraced by a *calyx* (fig. 1093), and, if examined with a hand-lens, will be seen to present a variable number (twelve to eighty) of minute apertures, the **foramina papillaria,** which represent the terminations of as many **papillary ducts** (of Bellini) through which the urine passes into the renal pelvis.

The **cortex** may be regarded as composed of two portions, (1) a peripheral layer, the cortex proper, which is about 12 mm. in thickness and extends from the fibrous tunic to the bases of the pyramids, and (2) processes termed **renal columns** [columnæ renales (Bertini)] which dip inward between the pyramids to reach the bottom of the sinus (fig. 1094). In section the cortex is somewhat granular in aspect, and when examined closely shows a differentiation into a number of imperfectly separated portions termed *cortical lobules* [lobuli corticales].

Each of these is composed of a *convoluted portion* [pars convoluta], surrounding an axial *radiate portion* [pars radiata (processus Ferreini)]. The latter consists of a group of tubules which extend from the cortex into the base of one of the medullary pyramids, whence it is also termed a medullary ray; and each medullary pyramid is formed from the rays of a number of cortical lobules, these structures, therefore, greatly exceeding the pyramids in number.

Renal tubules (fig. 1096).—The structure described above is the result of the arrangement of the renal tubules, which constitute the essential units of the kidney. Each of these commences in a spherical **glomerular capsule,** one wall is invaginated by a small *glomerulus* of blood-vessels, the combination of glomerulus and capsule forming what is termed **a renal (Malpighian) corpuscle.** These corpuscles are situated in the convoluted parts of the cortical lobules, and from each of them there arises by a narrow neck a tubule, which quickly becomes wide and convoluted, this portion being termed the first (proximal) **convoluted tubule.** This enters the radiate part of the cortical lobules, where it narrows again and descends as a straight tubule, the **descending limb of Henle's loop,** into the subjacent medullary pyramid, and, turning upon itself, forming the **loop of Henle,** ascends to the cortex as the **ascending limb of Henle's loop,** where it again becomes wide and contorted, forming the second (distal) **convoluted tubule.** This returns to the convoluted portion of the cortical lobule, and, becoming narrower, opens with other similar tubules into a straight or **collecting tubule,** which passes into the radiate part of the cortical lobule, then descends into the subjacent medullary pyramid where it unites with other collecting tubules, and finally opens into the renal plevis at the summit of a papilla.

The tubules are lined with epithelium throughout, the cells being flat in the capsule, irregularly cubical and imbricated in the convoluted tubules, flattened in the descending limb of Henle's loop, changing to cuboidal in the loop. The epithelium is cubical in the ascending limb of Henle's loop and in the smaller collecting tubules but becomes columnar in the larger collecting tubules and ducts of Bellini.

The renal pelvis with its calyces has a structure quite similar to that of the ureter. From within outward there is the (1) *mucosa* consisting of an epithelium of several layers of cells, 'transitional' in type, and a tunica propria especially rich in elastic fibers; (2) *muscularis*, consisting of two layers of longitudinally placed smooth muscle fibers between which is a circular layer of fibers, the former being incomplete and indistinct, while the latter is well developed; (3) a *fibrous coat* which is joined to the adipose tissue surrounding these structures.

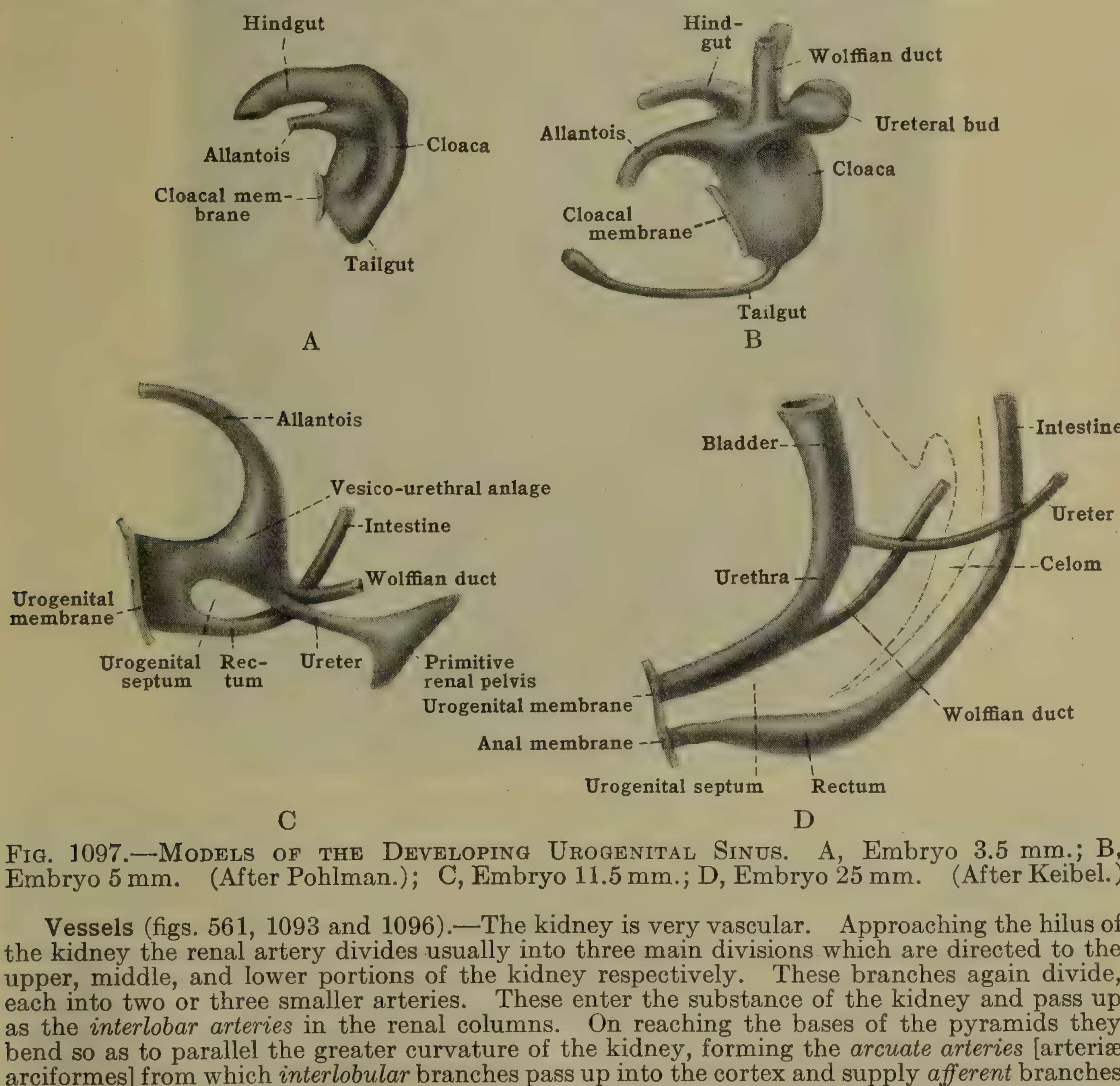


FIG. 1097.—MODELS OF THE DEVELOPING UROGENITAL SINUS. A, Embryo 3.5 mm.; B, Embryo 5 mm. (After Pohlman.); C, Embryo 11.5 mm.; D, Embryo 25 mm. (After Keibel.)

Vessels (figs. 561, 1093 and 1096).—The kidney is very vascular. Approaching the hilus of the kidney the renal artery divides usually into three main divisions which are directed to the upper, middle, and lower portions of the kidney respectively. These branches again divide, each into two or three smaller arteries. These enter the substance of the kidney and pass up as the *interlobar arteries* in the renal columns. On reaching the bases of the pyramids they bend so as to parallel the greater curvature of the kidney, forming the *arcuate arteries* [arteriæ arciformes] from which *interlobular* branches pass up into the cortex and supply *afferent* branches to the glomeruli. *Efferent* stems which issue from the glomeruli break up into capillaries which supply the tubules contained in the cortex. From the arcuate arteries numerous branches, the *arteriolæ rectæ*, pass down into the pyramids, supplying the tubules of which these are composed. *Veins* corresponding to the arteriolæ rectæ and to the interlobular, arcuate and inter-

lobar arteries drain into the renal veins. Beneath the fibrous capsule of the kidney, when viewed from the surface, are veins arranged in star-like groups, the *stellate veins* [venæ stellatæ], which open into the interlobular veins and also communicate with the veins of the adipose capsule. The renal *lymphatics* are divided into two sets, capsular and parenchymatous. The former drain directly through the capsule of the kidney while the latter tend to follow the main blood vessels and pass out through the hilus. Both terminate in the upper lumbar nodes.

Nerves.—The nerves form a rich plexus accompanying the vessels, and are derived from the sympathetic and vagus through the renal plexuses. They supply the renal tubules and the musculature of the blood vessels, as well as the musculature of the calyces and renal pelvis.

Development.—For the development and fate of the *pronephros* and *mesonephros*, which precede the permanent kidney, see Section I, p. 53.

The *metanephros*, or permanent kidney, first appears in embryos of about 5 to 6 mm. in length as a hollow bud-like outgrowth from the lower end of the Wolffian duct, the *ureteral bud* (fig. 1097). It soon elongates, the distal end becoming expanded to form the *primitive pelvis.* This is early surrounded by a condensation of mesenchymatous tissue, the *metanephric blastema.* As the primitive pelvis grows it divides into other tubules each carrying with it a portion of the

Fig. 1098.—Pyelogram of Normal Kidneys.

metanephrogenic tissue. These tubules become the adult collecting tubules by undergoing a series of some 16 divisions before reaching maturity. From the metanephric blastema the renal corpuscles and the remaining portions of the uriniferous tubules are formed and these unite directly with the collecting tubules.

The ureteral bud, arising from the Wolffian duct, at first grows directly backward toward the vertebral column. As it reaches this it turns upward for a short distance, and early (9.5–13 mm) reaches its definitive position in relation to the vertebral column, at a time when the ureter is relatively short. As further growth of the body takes place largely by an elongation of the lumbar region, the ureter must greatly increase in length in order to reach between its two fixed points, namely, the kidney above and the bladder below. The so-called 'migration' of the kidney is, therefore, largely apparent. In addition to this 'movement' of the kidney there is a very definite rotation about its vertical axis; whereas the pelvis of the kidney in early stages is directed anteriorly, in the adult it is directed medially, a medial rotation of approximately 90 degrees thus taking place.

Variations.—As is the case with other organs of the body the kidneys present variations in size, shape and position, all of which may be considered within the normal realm. In many

instances these variations are directly proportional to the size of the individual or to a characteristic build, while in others there seems to be no demonstrable reason for the variation. With regard to *size,* the kidneys are in general proportional to the size of the body, though there are numerous exceptions to this rule. Normal variations in *shape* may produce an 'elongated kidney,' or the hilus may be more marked than in the usual kidney. Again an elongated kidney may in reality be a 'double kidney,' each with its own renal pelvis and ureter (fig. 1099). In such cases there is usually no apparent division of the renal parenchyma as detected by surface markings. In many kidneys there may be distinct surface *fissures,* marking the kidneys into more or less definite *lobules.* When these are particularly well marked they are spoken of as fetal lobulations for the condition is one which is constant in the fetal stages. Similar lobulations of the adult kidney are found normally in certain of the adult mammals, particularly the ruminants.

Changes in the position of the kidneys from that previously described as normal are commonly found. Slight changes of position, from 1 to 2.5 cm., cannot be regarded as anomalous or pathological. Under normal conditions (as above noted) the kidney descends slightly with each inspiration and ascends again with expiration. Moreover a normal drop of approximately 1 to 2 cm. may be noted in many individuals in changing from the recumbent to the standing position. But in addition to these minor changes in position there frequently occur changes of

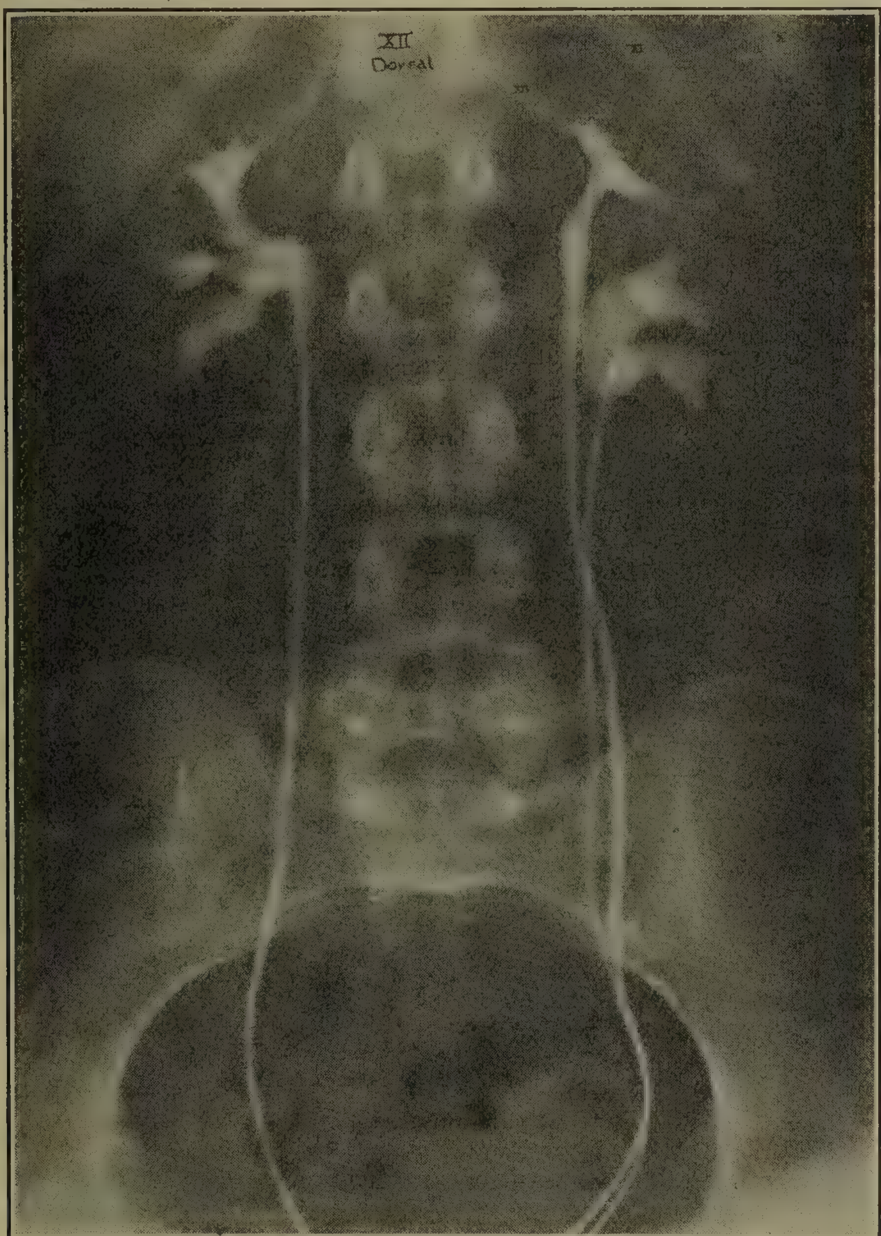


FIG. 1099.—PYELOGRAM SHOWING DOUBLE URETER.

far greater magnitude so that the kidney may be found at any level between its normal positoin to one deep within the pelvis. Such changes are classified as *congenital* or *acquired.* The former is briefly described below under congenital anomalies, while the latter is described as *movable kidney* or *nephroptosis.* (See Clinical Considerations.)

Congenital anomalies.—Congenital anomalies of the kidneys may affect their number, form, position, structure, and vascular supply. Anomalies of *number* may give rise to either absence of a kidney or to supernumerary kidneys. Congenital absence of one kidney, known also as *single kidney,* is rare, statistics showing its occurrence on the average being 1 in 2400 cases. The condition is brought about by either a failure of one of the ureteral buds to form (true agenesis), or by its early degeneration. In the latter case there is usually found some remnant of the kidney or ureter.

Supernumerary kidney is likewise a very rare anomaly. It consists of an extra kidney found on either side below the normal one, and either attached to it (*fused*) or entirely separate from it (*free*). Associated with the condition there is, necessarily, the anomaly of double ureter.

Embryologically its explanation lies in the fact that there is either a supernumerary ureteral bud, or a longitudinal splitting of the single normal one. The condition of double kidney, in which there may be only an elongation of the kidney to mark the anomaly as seen from the surface, differs from the foregoing only in degree.

Anomalies of form are usually the result of the fusion of portions of the two kidneys, and are frequently associated with doubling of either one or both kidneys. The most frequent type of this anomaly is known as *horseshoe kidney*, in which there is usually a fusion of the lower poles of the right and left kidneys across the midline of the body (fig. 1101). More rarely the upper poles are fused together. The degree of fusion may vary markedly; it may be either fibrous or parenchymatous. The fused portion usually lies in front of the aorta and vena cava, but may lie behind these vessels. The anomaly is in many cases so profound that it has usually associated with it marked anomalies of the ureters and renal pelvis, as well as in the renal arteries and veins. Horseshoe kidney occurs according to various autopsy statistics in approximately 1 out of every 1000 cases. Other forms of fusion anomalies have been described as *disc kidneys, sigmoid kidneys, lump kidneys*, etc. They are, however, rare anomalies and but few have been reported in the literature.

Anomalies of position.—These include only those congenital forms in which there is a marked change in the position of one or both kidneys. As noted above the kidneys normally undergo an apparent ascent from the pelvis to the upper abdomen during their development. It is a failure of this normal 'migration' which accounts for these anomalies. In such cases the kidneys may be found within the true pelvis. Their ureters are short and deformed, the vas-

FIG. 1100.—PYELOGRAM SHOWING NEPHROPTOSIS.

cular supply coming from the lower aorta or common or internal iliac vessels. Kidneys of this type are spoken of as *ectopic kidneys* and the condition is known as *ectopia* or *dystopia.* In *simple dystopia* the ectopic kidney lies on its own side of the body, but in *crossed dystopia* the kidney swings over to the opposite side so that both kidneys lie on the same side of the body. In such cases the ureter of the crossed kidney crosses the midline of the body and enters the bladder normally. Both simple and crossed dystopia may be associated with fusion; the former giving rise to the horseshoe kidneys, sigmoid kidneys, etc., the latter to the so-called *elongated unilateral kidney* and to various other fusion anomalies.

Among **anomalies of structure** by far the most important is known as *polycystic kidney.* The condition consists of enlarged kidneys, the parenchyma of which is largely displaced by numerous cysts of varying size. Many of these cysts are connected with the tubules of the kidneys. Between them are found small areas containing normally functioning renal glomeruli and tubules. The exact nature of polycystic kidney is not definitely known. The condition has been described as a congenital anomaly, as due to occlusion of the tubules with cyst formations, and as a new growth, yet none of these views adequately explains the condition.

CLINICAL CONSIDERATIONS

Among the renal diagnostic methods palpation and X-ray studies are of importance. *Palpation* of the kidneys in the living subject is not possible in obese or extremely muscular

individuals, but in those of lighter build the lower poles of the kidneys can be palpated through the abdominal wall. The lower extremities can be felt to descend with forced inspiration and to recede with expiration. Minor changes in position and size are usually not detectable but those of any clinical significance can readily be made out. In order properly to palpate the kidney in the living, one hand should be placed in the loin behind the kidney to press it forward while the other hand feels down upon it from the front.

Visualization of the outlines of the kidneys by the X-ray is not always possible. In certain cases they stand out distinctly but in others their outline is either faint or imperceptible. The most satisfactory X-ray studies of the kidneys are known as *pyelograms* (figs. 1098, 1099 and 1100) and are made as follows: By means of a cystoscope which is introduced into the bladder, small hollow catheters are directed into the ureteral orifices and passed through the ureters to the kidneys. Urine can be collected from the two kidneys separately for individual study. The kidney pelvis is then injected with sodium iodide and an X-ray exposure made. Such a 'pyelogram' shows only the cavities of the ureters, pelvis and calyces of the kidney, but from them changes in the position and size of the kidney as well as its gross structure are brought to light.

Nephroptosis or *movable kidney* (fig. 1100) is a condition which is almost always acquired during life and is to be clearly distinguished from the above-described cases of congenital anomalies of position. It is a condition which is quite common, but one which is not easily recognizable in the cadaver. It occurs ten times more frequently in the female than in the male, some degree of the condition being present in one of every 4 or 5 women. The degree of mobility may vary from an up-and-down movement of a few centimeters to a condition in which the kidney moves freely about in the abdomen and even into the pelvis. Severe cases are called 'wandering' or 'floating' kidneys. Various factors have been attributed to the cause of the

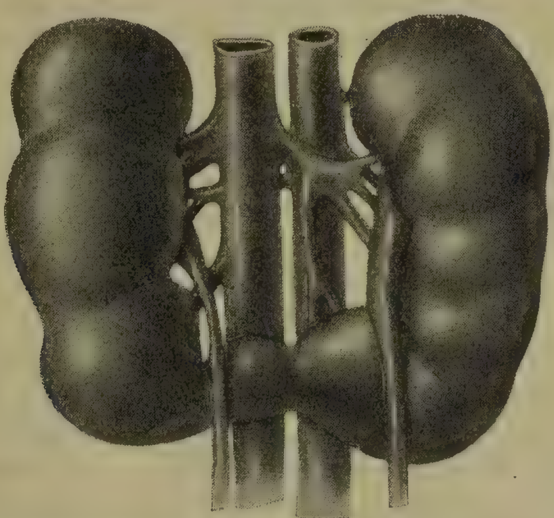


FIG. 1101.—HORSESHOE KIDNEY VIEWED FROM IN FRONT.

condition, among which may be mentioned, peculiar body form, trauma, tight lacing, rapid absorption of perirenal fat, pregnancy and childbirth, and enlargement of the kidneys from tumors, hydronephrosis, stones, etc. All of these causes presuppose a weakening in the various ligaments, etc. which hold the kidney in place. This support is gained through the following anatomical structures: the peritoneum, with its duodeno-renal and hepato-renal ligaments; the renal fascia (Gerota); the fatty capsule; the renal pedicle; the attachment to the suprarenal and pancreatic glands. Intra-abdominal pressure, maintained by the tonicity and strength of the abdominal muscles, is also an important factor in holding the kidneys in their normal position.

Conditions of the kidneys which are amenable to surgical treatment include suppuration, either within the kidney (pyonephrosis) or without the kidney (perinephritic abscess); kidney stones; renal tumors; unilateral hydronephrosis; unilateral tuberculosis; etc. Depending upon the condition for which the operation is done, nephrotomy, nephrostomy, or nephrectomy is performed. In *nephrotomy*, the surgical approach to the kidney may be either transperitoneal or extraperitoneal. Of these the former, by which the kidney is reached through an anterior abdominal incision, is always avoided if possible. The extraperitoneal approach may be by a longitudinal incision over the kidney through the back or by an oblique incision through the side. As the latter incision is now almost universally employed, it alone will be described. The patient is placed on the table with the affected part up, while the loin of the under side is propped up with sand bags or by means of the mechanical elevator of a specially designed table. The effect of this is curving the spine and body with the convexity upward, putting the muscles of the lateral abdominal wall under tension, and increasing the distance between the pelvic brim and the ribs. With the body erect this distance varies from 2 to 6.5 cm. while in the flexed position it may reach from 6 to 10.5 cm. This 'costo-iliac space' is again greatly increased as soon as the muscles of the region are severed. Furthermore, flexion of the spine tends to push the kidney nearer to the operative field. In making the oblique lumbar incision two points are located; the upper at the outer border of the sacrospinalis muscle and about 1 cm. below the last rib, the lower 2.5 cm. above the anterior superior iliac spine. The incision extends downward and medially and curves slightly forward to parallel the iliac crest, its extent being dependent upon the amount of exposure required. The skin and fasciæ are incised and the muscles exposed. The apex of the triangle of Petit comes into view as it lies between the fibers of the latissimus dorsi posteriorly and the external oblique anteriorly. The lumbar fascia covers this area while beneath it lie the fatty capsule and kidney. The incision through the muscles includes some of the fibers of the latissimus dorsi while the fibers of the external oblique are split longitudinally. The fibers of the internal oblique are cut across transversely while those of the transversalis are cut obliquely. The iliohypogastric and ilio-

inguinal nerves course approximately parallel to this incision, usually lying behind it, but are sometimes exposed and injured unless care is taken to avoid them. The lumbar fascia is next incised and the pararenal fat protrudes through the opening. An opening is made through this fat by blunt dissection and the perirenal capsule (Gerota) is next encountered. This is likewise incised and by dissection of the perirenal fat beneath it, the kidney is reached. In the drainage of a perirenal abscess usually pus is encountered beneath the fascial planes, but if not, search for a walled-off abscess must be made by careful exploration.

In operations upon the kidney and in nephrectomy the kidney must be freed from its bed and pulled upward into the wound. This can be safely done without danger to the suprarenal glands, the pancreas, liver, colon, etc., if the operator keeps within the capsule of Gerota, close to the kidney. Freeing of the kidney is done by blunt dissection, care being taken to ligate any anomalous vessels which occasionally reach the kidney at points away from the hilus. In this maneuver first one extremity is freed, then the other, and the dissection continued until the renal pedicle is reached. In practically all operations on the kidney it is necessary to locate the *ureter*. This is done at a point opposite the lower pole of the kidney and when once found is easy to trace to the renal pelvis. Completely freed of its fibrous attachments, the kidney is held in place only by the pedicle containing the arteries and veins and by the ureter. The elasticity of these structures permits bringing the kidney to the surface of the wound and visualization of the whole kidney is made possible. Occasionally it is necessary to resect the distal portion of the twelfth rib in order fully to expose the kidney. Care must be taken to avoid opening the pleura; contrary to an older opinion, however, a tear into the pleura is seldom followed by serious consequences.

In *nephrectomy* the ureter is ligated and cut across. The pedicle is then clamped and sectioned externally to the clamps, and after removal of the kidney the stump of the pedicle is carefully ligated. Fatal hemorrhage can easily follow from the renal arteries or veins through faulty manipulation of the renal pedicle.

In *pyelostomy* for renal stones, the incision in the pelvis should be made from the posterior surface whenever possible so as to avoid the numerous branches of the renal arteries and veins. If the kidney itself is to be opened to remove stones, this should be done by means of a longitudinal incision following the convex outer border but slightly behind the midline; by such an incision the pelvis of the kidney is reached through an area containing only minute blood vessels.

THE URETERS

The **ureter** (fig. 1087) is a slightly flattened tube which extends from the termination of the renal pelvis to the bladder, its course, lying in the subperitoneal tissue. It is about 5 mm. in diameter when distended and it is fairly uniform in size except for three slightly constricted portions. The first of these is located at the uretero-pelvic junction and is known as the 'upper isthmus' (Schwalbe). The second ('lower isthmus') occurs where the ureter crosses the pelvic brim while the third, ('intramural') is located at the extreme lower end of the ureter in its passage through the bladder wall. Between these constrictions the ureter has the form of elongated spindles. The length of the ureter averages 28–30 cm. it being slightly longer on the left side on account of the higher position of the left kidney, and slightly longer in the male than in the female. For descriptive purposes the ureter is divided into an upper abdominal portion and a lower pelvic portion.

The **abdominal portion** [pars abdominalis] (fig. 1087) extends from the pelvis of the kidney, where its beginning is usually indefinitely marked, to the pelvic brim. It courses downward and slightly medially and is in relation *posteriorly* with the psoas muscle and its fascia; it crosses the genitofemoral nerve obliquely and passes in front of the common or external iliac artery to enter the true pelvis. As seen in pyelograms (fig. 1098) it lies in front of the transverse processes of the 3rd, 4th, and 5th lumbar vertebræ. *Anteriorly* it is covered by peritoneum and is crossed by the spermatic or ovarian vessels. On the right side it lies behind the descending portion of the duodenum and is crossed by the line of attachment of the mesentery while on the left the attachment of the pelvic mesocolon crosses it. *Medially* it is in relation on the right side with the inferior vena cava and on the left with the aorta, the vein being almost in contact with the right ureter, while the artery is separated from the left ureter by an interval that diminishes from 2.5 cm. above, to 1.5 cm. opposite the bifurcation of the vessel.

The **pelvic portion** [pars pelvina] begins above at the pelvic brim and courses downward, inclining slightly laterally and posteriorly to conform to the curvature of the lateral pelvic wall (fig. 1087). Reaching the pelvic floor it bends anteriorly and medially at about the level of the ischial spine to reach the bladder. In its upper portion it is related *posteriorly* to the sacroiliac articulation; then, lying upon the obturator internus muscle and fascia, it crosses the obliterated hypogastric artery [lig. umbilicale laterale] the obturator vessels, and obturator nerve. Anteriorly its relations differ in the two sexes. *In the male* the lower end of the

ureter is crossed by the ductus deferens, and passes under cover of the free extremity of the seminal vesicle. *In the female,* after emerging from behind the ovary, the ureter passes behind the uterine, superior and middle vesical arteries, and, coursing anteriorly 8 to 12 mm. distant from the cervix and vaginal wall, reaches the bladder.

When the ureters reach the bladder they are about 5 cm. apart. As they pass through the wall of the bladder they retain for the most part their own musculature. Their course through the bladder wall is very oblique, about 2 cm. in extent, and in an antero-medial and downward direction. They open into the bladder by two slit like apertures, the **ureteral orifices** (ostia ureteris NK) (fig. 1104). These are about 2.5 cm. apart in the empty bladder but upon distention of the bladder may be 5 cm. distant from each other.

The urine enters the bladder, not in a continuous stream, but in spurts every 10 to 30 seconds apart, brought about by successive peristaltic waves which begin in the renal pelvis and pass downward throughout the extent of the ureter. As the urine enters the bladder, the slit-like ureteral orifice opens for 2 to 3 seconds and then closes until the succeeding peristaltic wave opens it again. The ureter is not provided with a definite valve. However, in the empty or partially filled bladder the slit-like opening probably has a valve-like action. In the distended bladder, the pressure upon the bladder wall tends to close off the intramural portion of the ureter by flattening it out. In addition the circular fibers of the intramural portion of the ureter

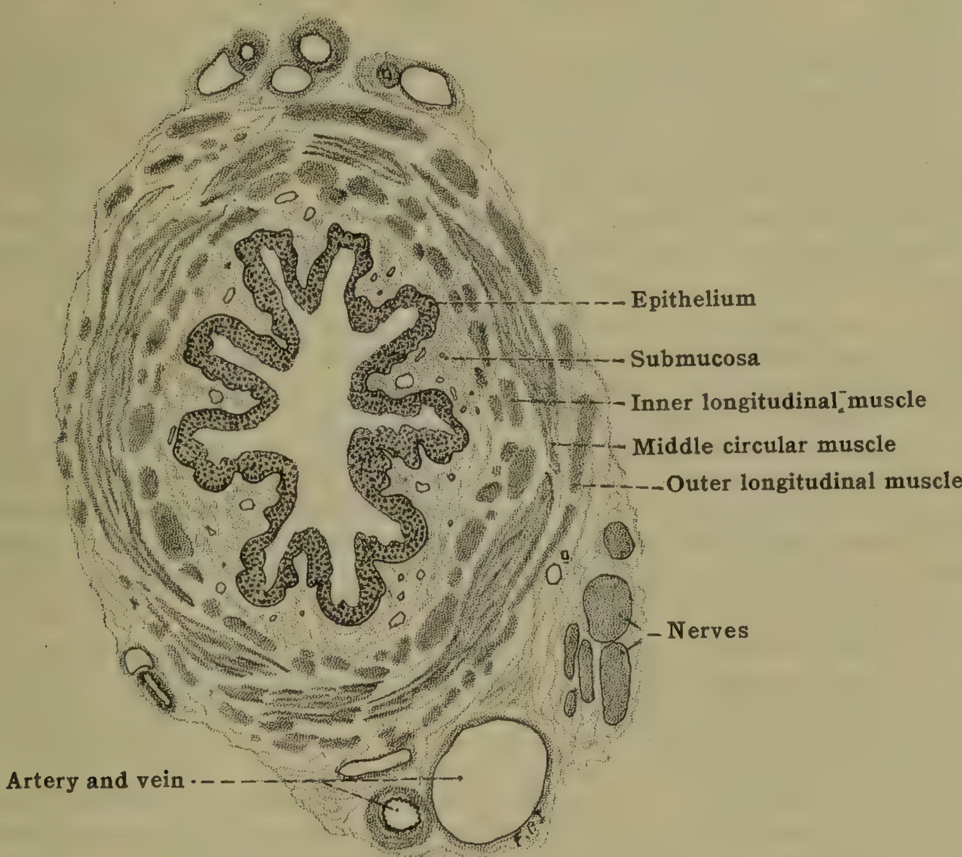


Fig. 1102.—Cross-section of Ureter.

possess a sphincter-like action. When the bladder is distended the valve and sphincter actions above described are not perfect, as it has been amply demonstrated that a reflux of urine may take place under normal conditions.

Structure.—The wall of the ureter is about 1 mm. in thickness, and consists of a mucous membrane, a muscular coat, and an external connective tissue investment (fig. 1102). The mucous membrane is longitudinally plicated, and is lined by transitional epithelium, continuous with that of the papillæ above and with that of the bladder below. Mucous follicles of simple form have been found in the upper part of the tube. The muscularis is about 0.5 mm. in thickness, and consists of three layers, an external, which is rudimentary and composed of scattered bundles of longitudinally directed fibers; a middle, which is a more distinct layer and composed of annular fibers, and an internal, of fibers again longitudinally disposed.

Vessels and nerves.—The *arteries* supplying the pelvis and upper part of the ureter come from the renal; the rest of the abdominal portion of the ureter is supplied by the spermatic (or ovarian), and its pelvic portion receives branches from the middle hemorrhoidal and inferior vesical; the *veins* terminate in the corresponding trunks; and the *lymphatics* pass to the lumbar and hypogastric nodes. The *nerves* are supplied by the spermatic, renal, and hypogastric plexuses.

Development.—For the early development see Section I, p. 53. The ureteral bud, as described above (p. 1356) has its origin from the dorsal surface of the Wolffian duct, a short distance above the point where this duct enters the cloaca. Simultaneously the cloaca undergoes a longitudinal division in the frontal plane, dividing it into the rectum dorsally and the urogenital sinus ventrally (fig. 1097). Above, the allantois joins with the urogenital sinus, the

portion above the Wolffian duct being known as vesico-urethral anlage. There is now an apparent migration of the attached end of the ureteral bud along the Wolffian duct, so that a little later the ureter is found to emerge separately from the vesico-urethral anlage. The migration continues upward until the ureteral orifice reaches its definitive position in the bladder (fig. 1097). It will be noted that the course of the ureter lies lateral to that of the Wolffian duct (fig. 63, B). The migration above described is attributable to the fact that the lower end of the Wolffian duct is rolled into and becomes a part of the vesico-urethral anlage.

Variations.—Under normal conditions the ureter may vary in both length and breadth. Measurements of length, however, are difficult to obtain accurately because of several factors, namely, the lack of a sharp division between the ureter and renal pelvis; the curvature of the pelvic portion; and the inaccessibility of the lower end without disturbing its position and relations. The extensibility of the ureter makes reliable measurements impossible after removal from the body. Such measurements as have been made show it to vary with body height, with sex, and with the individual variations in the positions of the kidneys and bladder.

In diameter the ureter varies from 4 to 6 mm. It is narrower in diameter at the isthmuses and wider at the spindles as described above, but considerable variation exists as regards the presence and position of the constrictions. In the diseased condition of *hydroureter* the diameter may be greatly increased and the course tortuous; in *megalo-ureter* the duct may attain the size and appearance of a distended loop of intestine.

Congenital anomalies are those of number and position, those which affect the size of the ureteral lumen, and those of faulty implantation of the lower end of the ureter.

Anomalies of number.—*Unilateral absence* of the ureter is an accompaniment of the same condition of the kidney. It is usually due to a lack of development but in some instances, where rudiments of a ureter or a ureteral orifice have been found, is unquestionably due to a subsequent degeneration of the ureteral anlage. *Supernumerary* or *double ureter* may be complete or incomplete, unilateral or bilateral (fig. 1099). In the former there are two separate ureters, each with its own renal pelvis. The two ureteral orifices are situated in the bladder upon the ureteral ridge, one above and lateral to the other. An interesting and constant relation exists between the ureters and these orifices: *the ureter from the superior pelvis terminates in the lower orifice, that from the inferior in the superior orifice.* In *incomplete duplication* (bifurcated ureter) the ureter is Y-shaped the duplication being only above the point of bifurcation, which may be located at any point from the hilus to the bladder.

Double ureter is the most frequent of ureteral anomalies, statistical studies showing that it occurs in about 3 per cent of all individuals. It is slightly more frequent in females than in males, is more frequently (4–5 times) unilateral than bilateral, and more often complete than incomplete.

Embryologically two explanations for double ureter have been proposed: (1) that duplication is the result of a fission of the primary pelvis extending downward into the ureter: (2) that it is the result of a supernumerary ureteral bud. The first of these appears to be the more plausible, especially as an explanation for bifurcated ureter, while the second cannot be denied in cases of complete duplication. Whether there are two separate ureteral buds or an early divided single one, both ureters 'migrate' with the rolling in process or absorption of the lower end of the Wolffian duct into the vesico-urethral anlage. The ureter belonging to the inferior pelvis reaches the vesico-urethral anlage first and begins its ascent into the bladder. The other ureter, from the superior pelvis, follows behind the first but never migrates as far lateralward from the vesical orifice. As a consequence the ureteral orifice of the inferior pelvis lies above and lateral to the orifice belonging to the superior pelvis.

Anomalies of position.—Malposition of the ureter is not uncommon and is usually associated with anomalies of the kidneys. In ectopic kidneys, horseshoe, sigmoid, and lump kidneys, there is always a disturbance of the course of the ureters. In cases of crossed dystopia, a condition in which both kidneys lie on the same side of the body, one ureter crosses the midline to enter the bladder at its accustomed site.

Anomalies of the ureteral lumen.—Congenital kinks of the ureter are infrequent and usually occur in connection with ectopic or horseshoe kidneys. They may be due to the ureter kinking over an anomalous vessel. *Valve-like structures,* most frequently found in the upper part of the ureter, are mere duplications of the ureteral mucosa. *Congenital stenoses* are occasionally found in the lower end of the ureter and give rise to cyst-like dilations. An interesting form is found at the ureteral orifice and produces a cyst within the bladder (intra-vesical cyst or ureterocele). With each spurt of urine the cyst fills and balloons out, then gradually collapses between spurts. A common site for *ureteral stenosis* is at the uretero-pelvic junction. Incomplete occlusion at this point, acting over a prolonged period of time results in *congenital hydronephrosis,* and frequently entirely destroys the function of the kidney.

Anomalies of implantation.—In this type of anomaly the ureteral orifice is located in some organ other than the bladder. In many cases the anomalous ending ureter is a supernumerary one. The most common of these comprise terminations in the female urethra and its homologue in the male (that portion of the urethra above the prostatic utricle), in the ejaculatory ducts, seminal vesicles, ductus deferens, prostatic utricle, vestibule, vagina, uterus and uterine tubes. For the explanation of these various implantations there must be assumed a failure of the normal shifting or a shifting to an abnormal position of the ureteral buds in their 'migration' from the Wolffian duct to the bladder.

Clinical Considerations

The ureter is so small and lies so deeply imbedded in the posterior portion of the abdomen that it cannot be palpated through the abdominal wall. By digital examination per rectum in the male and per vaginam in the female the lower end of the ureter can, however, be closely approached. The course, shape and size of the ureter may be easily determined by ureterography, in which opaque ureteral catheters are passed into the ureters through their orifices (fig. 1098).

The normal constrictions of the ureter (see above) are of clinical importance as they frequently arrest the passage of small ureteral stones. Impacted stones are, therefore, most frequently found at the uretero-pelvic junction, at the pelvic brim and at the extreme lower end of the ureter.

The ureter is treated surgically for the removal of an impacted stone (ureterolithotomy) or for any condition which requires nephrectomy (ureterectomy, partial or complete). The approach to the ureter, like that to the kidney, is carried out extra-peritoneally and differs for the abdominal and pelvic portions. The upper half of the abdominal portion of the ureter can be easily reached through the ordinary oblique lumbar incision as is made for the kidney, (p. 1359). The lower half can be satisfactorily exposed only by prolonging the kidney incision downward, care being taken to reflect the peritoneum anteriorly. The incision being made and the inferior extremity of the kidney freed, the fatty capsule is penetrated with the fingers to the mesial side of the kidney until the ureter is reached. As guides for locating the ureter should be mentioned its close fixation to the posterior body wall; its relation to the anterior surface of the psoas muscle; its course along the tips of the transverse processes of the lumbar vertebræ; and its relations to the aorta on the left and the vena cava on the right.

The pelvic portion of the ureter is most satisfactorily reached through an incision parallel to and about 2 cm. above the inguinal ligament. It differs from the incision used for inguinal hernia only in being lateral to it. The fibers of the external oblique are separated, those of the internal oblique and transversalis cut across. The peritoneum and transversalis fascia are not opened but are reflected medially and anteriorly by blunt dissection. In this manner the posterior pelvic wall is exposed without entering the peritoneal cavity. The ureter can be located at the base of the bladder, or at the pelvic brim as it crosses the iliac vessels.

THE URINARY BLADDER

The **urinary bladder** [vesica urinaria] is a hollow viscus, whose form, size, and position vary with the amount of urine which it contains. It receives the urine from the kidneys through the two ureteral orifices and disposes of it through the single internal urethral orifice. The average bladder is capable of holding without overdistention approximately 500 cc. of urine. The adult organ in its empty condition lies at the level of the oblique plane of the pelvic inlet; but when distended it rises into the abdomen (figs. 1105 and 1106).

When distended the bladder is almost spherical in shape but when empty it assumes the form of a tetrahedron, the base of which is directed upward and the apex downward, where it is joined by the urethra. In the child it is somewhat pear-shaped, the stalk being represented by the urachus.

For convenience of description four surfaces may be recognized, which are fairly well marked in the empty bladder, but which are blended together in the spherical form of the bladder when it is distended. The **superior surface** which is covered with peritoneum is convex in the filled bladder but when the bladder is empty and relaxed, it sinks down upon the other surfaces, thus becoming concave, and the cavity of the organ is reduced to a T- or Y-shaped fissure. The two **inferolateral surfaces** rest upon the pelvic diaphragm, and join anteriorly in a rounded border (sometimes termed the anterior surface). The **posterior surface**, sometimes flat and sometimes, especially in old age, convex, forms what is known as the base or **fundus** [fundus vesicæ]. The superior and inferolateral surfaces meet anteriorly and above at the **vertex** of the bladder, from which the **middle umbilical ligament (urachus)** extends to the umbilicus. The portion of the bladder between the vertex and fundus is termed the **body** [corpus vesicæ]. Inferiorly, in the angle formed by the fundus and the inferolateral surfaces is the **internal urethral orifice** [orificium urethræ internum], by which the bladder communicates with the urethra. The portion of the organ immediately surrounding this is sometimes spoken of as the **neck**.

Relations.—The *anterior border* looks downward and forward toward the symphysis pubis (figs. 1103, 1132). It is uncovered by peritoneum, but is separated from the pubic bones by a space known as the retropubic or **prevesical space (cavum Retzii)**, which contains a variable quantity of loose fat continuous with the pelvic and abdominal subperitoneal tissue. The *inferolateral surface* on each side is separated from the levator ani and obturator internus by subperitoneal tissue, which usually bears much fat in its meshes and ensheaths the vesical vessels and nerves. Near the border separating the inferolateral from the superior surface on each side is the obliterated hypogastric artery anteriorly, and (in the male) the ductus deferens posteriorly. The latter passes between the ureter and the wall of the bladder, a little above the level at which the former enters the wall of the bladder, at the angle formed by the superior, inferolateral and posterior surfaces. The *posterior surface* is in direct contact *in the male* (fig. 1103) with the anterior wall of the rectum, also with the ampullæ of the ductus

deferentes and the seminal vesicles. Between the diverging ductus deferentes there is a triangular space (fig. 1111), whose base is formed by the line of reflection of the rectovesical peritoneal excavation and the apex by the meeting of the ejaculatory ducts at the summit of the prostate. It represents the area of direct contact of the posterior wall of the bladder with the rectum. *In the female* the posterior surface is adherent to the cervix of the uterus and the upper part of the anterior wall of the vagina (fig. 1132), and is usually not in contact with peritoneum. The *superior surface* is entirely covered by peritoneum. It

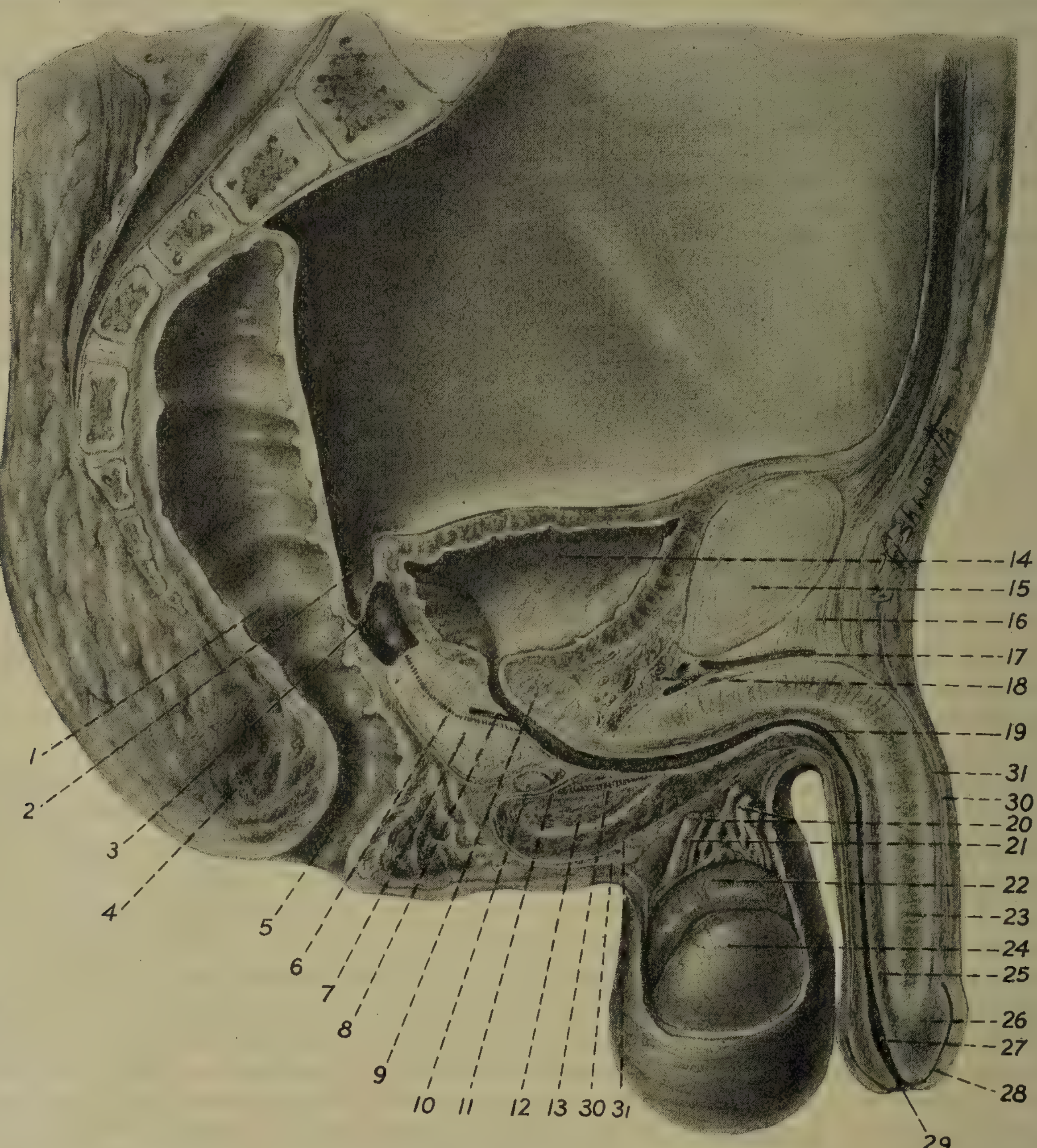


Fig. 1103.—Midsagittal Section of Male Pelvis. (The perineal fasciæ have been exaggerated in distinctness.)

1, Ampulla of rectum. 2, Rectovesical pouch. 3, Ampulla of ductus deferens. 4, Sphincter ani externus. 5, Anal canal. 6, Ejaculatory duct. 7, Prostate. 8, Prostatic utricle. 9, Prostate. 10, Bulbourethral gland. 11, Sphincter of membranous urethra. 12, Bulb of the urethra. 13, Duct of bulbourethral gland. 14, Bladder. 15, Symphysis pubis. 16, Suspensory ligament of penis. 17, Dorsal vein of penis. 18, Urogenital diaphragm. 19, Cavernous urethra. 20, Spermatic artery and vein. 21, Ductus deferens. 22, Epididymis. 23, Septum of penis. 24, Testis. 25, Corpus cavernosum urethrae. 26, Glans plenis. 27, Fossa navicularis. 28, Prepuce. 29, External urethral orifice. 30, Superficial perineal fascia (Colles'). 31, Deep perineal (Buck's) fascia.

looks almost directly upward into the abdominal cavity and has resting upon it coils of the small intestine and sometimes a portion of the sigmoid colon.

As the bladder fills it carries with it the reflection of peritoneum between its upper surface and the anterior abdominal wall. The anterior surface of the bladder is thus brought into relation with the anterior abdominal wall, being separated from it only by the enlarged prevesical space.

The exact position of the bladder in relation to the symphysis pubis varies considerably in different individuals. In the infant, owing to the smaller extent of the pelvic cavity, the bladder lies at a somewhat higher level than in the adult and rises into the abdominal cavity. Indeed

the entire bladder is above the horizontal level of the pubic crests, the urethral orifice being behind the upper margin of the symphysis pubis. As the child learns to walk, however, this position gradually alters and usually by the age of six years the adult relations have been acquired.

The fixation of the bladder.—The reflections of the peritoneum from the superior surface of the bladder to the anterior abdominal wall and the corresponding walls of the pelvis are sometimes described as the superior, lateral and posterior *false ligaments.* Furthermore there extends from the apex of the bladder to the umbilicus a fibrous cord, the *urachus,* the remains of the embryonic allantois; this is described as the *middle umbilical ligament* of the bladder (chorda urachi NK) (fig. 1132). The *lateral umbilical ligaments* are formed by the obliterated hypogastric arteries which carry the fetal blood to the placenta and in the adult are represented by fibrous cords passing along the sides of the bladder and ascending to the umbilicus.

In addition to these structures certain thickenings of the endopelvic fascia, where it comes into relation with the bladder and prostate gland, constitute what are termed the **true ligaments.** Two such thickenings extend from the anterior surface of the capsule of the prostate gland, or from the lower part of the anterior aspect of the bladder in the female, to the pubic bones and constitute what are known as the *middle puboprostatic (pubovesical) ligaments,* with which muscle fibers [m. pubovesicalis] are usually associated. Similarly, thickenings of the fascia extending from the sides of the prostate gland or from the sides of the lower part of the bladder to the lateral walls of the pelvis form the *lateral true ligaments.*

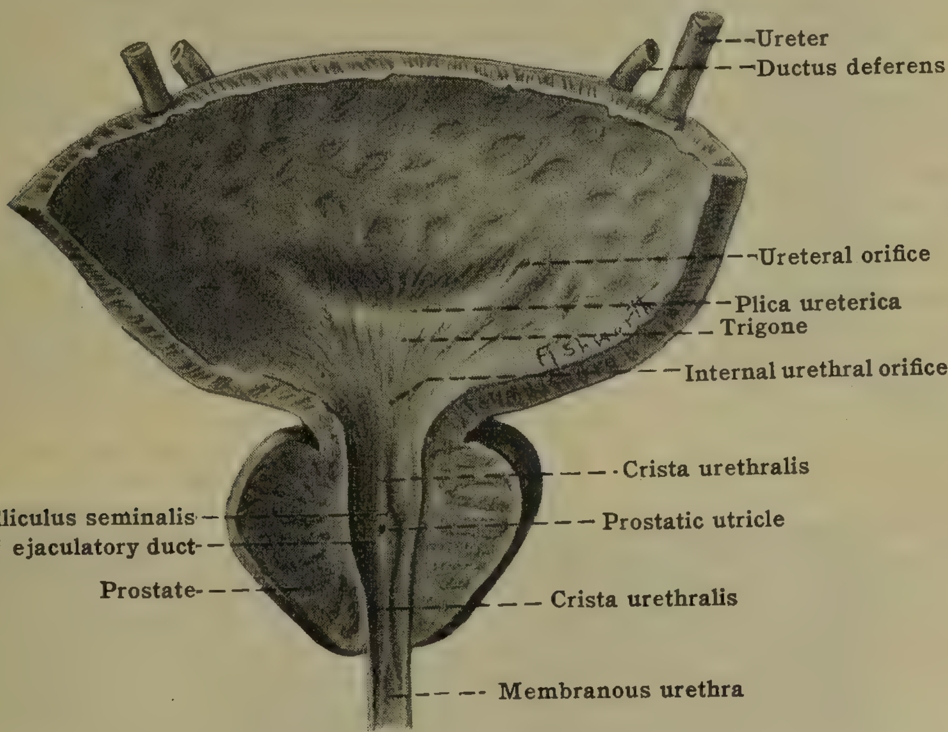


Fig. 1104.—Trigone of Bladder and Floor of Prostatic Urethra.

Muscle fibers [m. rectovesicalis] also occur in the subperitoneal tissue contained within the peritoneal folds (posterior false ligaments) extending from the base of the bladder to the posterior wall of the pelvis and bounding the rectovesical pouch of peritoneum in the male. They correspond to the *mm. rectouterini* of the female.

The internal surface.—The mucous membrane lining the internal surface of the bladder is soft and rose-colored during life, and in the empty bladder is thrown into irregular folds which become effaced by distention. It is modified over a triangular area at the base of the bladder, termed the *trigone* [trigonum vesicæ (Lieutaudi)] (fig. 1104) whose three angles correspond with the orifices of the urethra and of the two ureters. This area is redder in color and free from the plication that characterizes the rest of the mucous membrane. It is bounded posteriorly by a curved transverse ridge, the *plica ureterica,* extending between the orifices of the ureters. Extending toward the urethral orifice, a median longitudinal elevation, the *uvula vesicæ,* has been described. The *internal urethral orifice* is normally situated at the lowest point of the bladder, at the junction of the inferolateral

and posterior surfaces. It is surrounded by a more or less distinct circular elevation, the *urethral annulus*, and is usually on a level with about the center of the symphysis pubis and from 2.0 to 2.5 cm. behind it.

Structure.—The *mucous membrane* of the bladder is lined by an epithelium of the transitional variety, similar to that of the renal pelvis and ureter but somewhat thicker. It rests upon a loose *submucous coat* which is made up of areolar tissue. The greater part of the thickness of the wall is formed, however, of the *muscular coat*, consisting of smooth muscle tissue, the fibers of which are arranged in three more or less distinct layers. The *outer layer* is composed mainly of longitudinal fibers, some of which are continued forward to the pubis from the neck of the bladder to form the mm. pubovesicales and others backward to form the mm. rectovesicales. To this outer layer the term *m. detrusor urinæ* has been applied, but it should be noted that it does not contract independently of the circular layer. The *middle layer* is thicker than the outer and more uniformly developed. It consists of fibers having for the most part a circular direction and is well developed over all the upper portion of the bladder, but becomes thinner in the region corresponding to the trigone. It is here that the *inner layer* is chiefly developed, consisting of fibers, which are situated partly in the submucous tissue and have a general longitudinal direction throughout the region of the trigone. At the neck of the bladder, however, they form a strong circular bundle, which is continued into the prostatic portion of the urethra and forms what is termed the *internal sphincter* of the bladder.

Vessels.—The *arteries* of the bladder are usually three in number, the superior, middle and inferior vesical, all branches of the hypogastric artery; the fundus also receives branches from the middle hemorrhoidal and in the female twigs are also sent to it from the uterine and vaginal arteries. The *veins* form an extensive plexus at the sides of the bladder, from which stems pass to the hypogastric trunk. The *lymphatics* accompany the veins and communicate with the hypogastric nodes, some of those from the fundus passing to nodes situated at the promontory of the sacrum.

Nerves.—The *nerves* are derived partly from the hypogastric sympathetic plexus and partly from the second and third sacral nerves. The fibers from the latter constitute the nervi erigentes, stimulation of which produces contraction of the general musculature and relaxation of the internal sphincter. On each side of the bladder there is formed a sympathetic *vesical plexus*, from which *superior* and *inferior vesical* nerves pass to the corresponding parts of the bladder.

Development.—The early development of the bladder is described in Sec. I, p. 55 and has also been alluded to above in connection with the development of the ureters. It is formed from the upper portion of the vesico-urethral anlage, which early takes on a pyriform shape (fig. 1097). It is joined above by the tube-like allantois which later loses its cavity and becomes a solid fibrous cord, the urachus. The manner in which the lower ends of the Wolffian ducts are absorbed into the bladder and the shifting of the ureteral orifices have already been described. The epithelial lining of the bladder is therefore derived from two of the primary germ layers: (a), a portion surrounding the ureteral orifices and trigone of indeterminable extent of Wolffian duct origin and therefore mesodermal; (b) the remaining portion of cloacal and hindgut origin, and therefore entodermal. The outer coats of the bladder, including the submucosa, muscularis and fibrosa are differentiated from the surrounding mesenchyme.

Variations.—The capacity of the bladder varies considerably in health and markedly in disease. The average bladder will withstand filling to approximately 500 cc. without causing undue distress. However, the sensation to void usually develops before this state of distention is reached, at from 200 to 350 cc. depending upon the individual. This is the bladder's physiological capacity. Size of the adult individual seems not to influence greatly the capacity of the bladder. Habit, however, has a direct bearing upon its size; the individual who acquires the habit of frequently emptying the bladder finds himself unable comfortably to retain the average amount of urine. The capacity of the female bladder is said to be greater than that of the male, but if this statement is true, it is probable that it is due to habit rather than to any inherent qualities of the female bladder or pelvis.

Anomalies.—*Double bladder* is a rare anomaly and but few authentic cases are described in the literature. The splitting may be either in the sagittal or frontal plane. Of the latter type two forms have been described, vesica duplex (complete duplication) and vesica bipartita (incomplete duplication). The anomaly is usually associated with doubling of the ureters and of the urethra, and various other marked malformations.

Patent urachus.—In this condition the allantoic stalk remains as a hollow tube connecting the vertex of the bladder with the umbilicus. It thus gives rise to an umbilical urinary fistula. In the incomplete forms of this anomaly only a portion of the allantois remains patent, giving rise to sinuses or, if closed off at both ends, to urachal cysts. *Exstrophy* of the bladder (ectopia vesicæ) is a profound malformation in which the anterior portion of the bladder, together with the corresponding portion of the anterior abdominal wall is completely lacking. The postero-inferior surface, including the trigone, alone remains and is pushed forward through the defect in the abdominal wall. As seen from in front there is a rounded defect in the integument above the pubes through which appears the bulging inflamed mucosa of the bladder. The ureteral orifices are usually in plain view and are seen to spurt urine intermittently. The integument surrounding the abdominal defect shows much scarring and contracture, and is usually excoriated and inflamed on account of being constantly wet with urine. In *incomplete exstrophy* the urethra is present and passes down from the lower portion of the trigone, behind the symphysis and into the penis or vestibule. In *complete exstrophy* the pubes are ununited by a symphysis and the urethra is reduced to a shallow groove on the lower abdominal surface and on the penis or to the vestibule (epispadias). Embryologically little is known regarding exstrophy. It evidently is due to a developmental defect of the very early stages. (The student is referred to Keibel and Mall's Embryology and to Young's Practice of Urology for further details.)

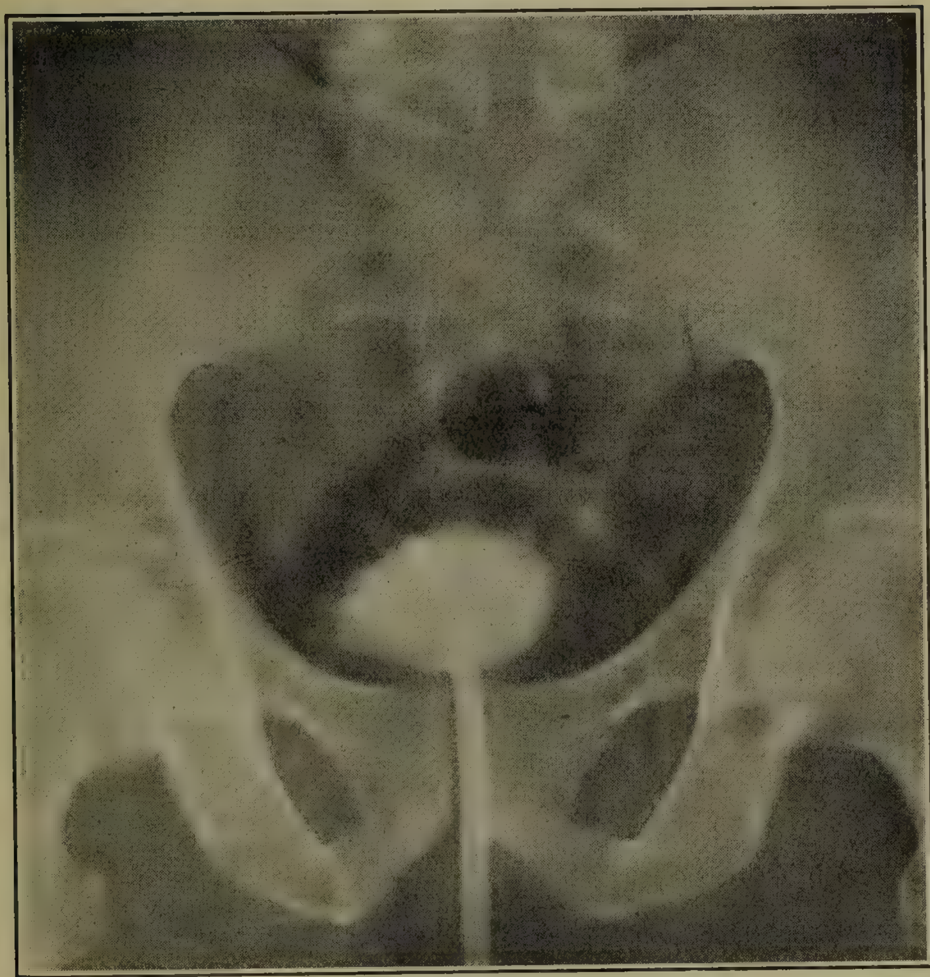


FIG. 1105.—CYSTOGRAM, MALE BLADDER CONTAINING ABOUT 20 C.C. SODIUM IODIDE SOLUTION.

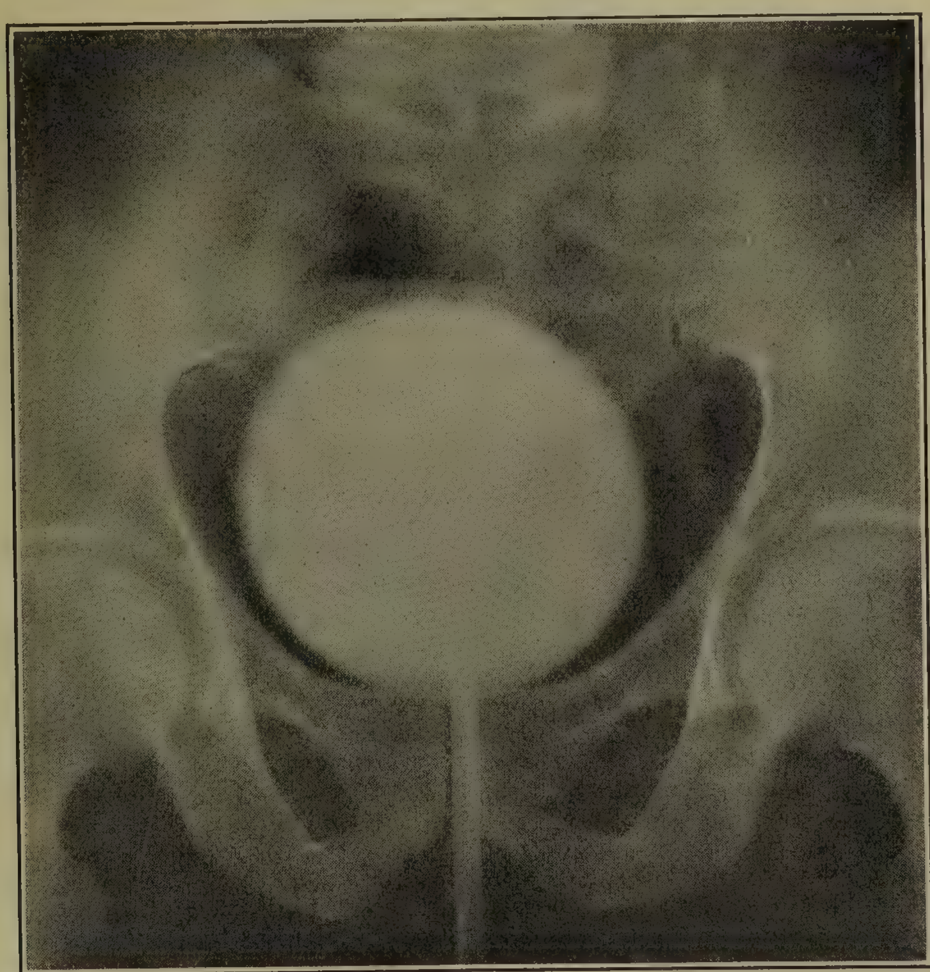


FIG. 1106.—CYSTOGRAM, THE SAME BLADDER SHOWN IN FIG. 1105, FILLED TO 500 C.C. (Normal capacity.)

Clinical Considerations

The act of emptying the bladder (micturition) is normally voluntary and receives its stimulus through the visceral nerve supply which is stimulated by pressure when the bladder becomes distended. In its accomplishment there is a contraction of the smooth muscle of the bladder wall, as well as in the voluntary muscles of the diaphragm, and abdominal walls. At the same time there is a relaxation of the internal vesical sphincter and of the sphincter of the membranous urethra.

In inflammatory conditions the bladder wall becomes more sensitive; the nerve endings are more readily stimulated, and frequency of urination with a decreased bladder capacity results. In marked cases of long standing, as in tuberculosis of the bladder wall, the bladder becomes permanently contracted and its capacity reduced to only a few cubic centimeters. On the other hand, obstructive lesions of the bladder, such as stricture of the urethra or an adenomatous prostate, increase the bladder capacity. Such bladders occasionally may contain as high as 2 to 3 liters and may even extend above the umbilicus.

The contracted bladder lies at the level of the symphysis pubis but cannot be palpated through the anterior abdominal wall. If sufficiently distended, however, it can be felt suprapubicly provided the recti muscles are sufficiently relaxed. The form of the distended bladder can be made out by percussion and occasionally may be seen bulging out the anterior abdominal wall. The inferior surface of the bladder can be felt per rectum in the male and per vaginam in the female. The form of the bladder can also be definitely demonstrated by cystograms (x-rays after the bladder has been filled with sodium iodide solution, figs. 1105 and 1106). The direct observation of the interior of the bladder by means of the cystoscope completes the usual diagnostic procedures.

The more common operations upon the bladder are for the establishment of urinary drainage, for the removal of stones, tumors, diverticula, and obstructions to urination at the internal urethral orifice. In all of these *suprapubic cystostomy* is done through a midsagittal incision above the symphysis pubis. As it is desirable not to open the peritoneal cavity, the bladder, if not already distended, is artificially filled. This raises the line of peritoneal reflection and increases the prevesical space. The median incision begins 1 to 2 cm. above the symphysis and extends upward for 5–10 cm. depending upon the degree of exposure required. The superficial and deep fasciæ are incised down to the anterior sheath of the rectus. This is opened with a similar incision to either one or the other side of the linea alba, the rectus muscle thus exposed is pulled laterally without cutting into its fibers, and the posterior rectus sheath is incised. The prevesical space is thus opened and the peritoneal reflection is usually forced further upward and out of danger. The bladder wall is then cut through by a median incision and after complete emptying its interior can be observed.

B. THE REPRODUCTIVE ORGANS

The reproductive organs include those of the male [organa genitalia virilia] and those of the female [organa genitalia muliebria].

THE MALE REPRODUCTIVE ORGANS

The reproductive organs of the male consist of (1) the **scrotum** containing (2) the two **testes**; the excretory duct system of the testes including (3) the **epididymides,** (4) the **deferent ducts** (O. T. vasa deferentia), (5) the **ejaculatory ducts,** and (6) **seminal vesicles**; (7) the **spermatic cord**; (8) the **penis** which is traversed by (9) the **urethra,** the common outlet for the urine and seminal secretions; (10) the **prostate** and (11) the **bulbourethral glands,** both accessory glands of the reproductive system.

1. The Scrotum

The **scrotum** (figs. 1103 and 1107) is a pouch which is divided by a median *septum* into two compartments, each of which contains a testis and epididymis as well as a small portion of the spermatic cord and ductus deferens. In conformity with the comparative positions of the two testes, the left half of the scrotum reaches a lower level than the right. The scrotal *integument* is pigmented and presents numerous irregular transverse ridges. In the median plane is a constant longitudinal ridge, the *raphe.* Anteriorly this is continuous with the raphe of the ventral surface of the penis while posteriorly it extends into the perineum.

In the adult the integument is furnished with coarse, scattered hairs and its sebaceous and sudoriparous glands are well developed. The deeper layers of the dermis and the tela subcutanea contain a layer of smooth muscle fibers, the *dartos,* which for the most part are arranged at right angles to the wrinkles of the surface and are the cause of the transverse ridges. The more superficial fibers of the dartos, like the rest of the integument, form a common investment for both halves of the scrotum, but the deeper ones of either side bend inward at the raphe and assist in the formation of the septum.

Internal to the dartos and closely related to it is a layer of laminated connective tissue, the *intercolumnar fascia.* It is destitute of fat and is continuous at the subcutaneous inguinal ring with the intercrural fibers. Internal to this is the *cremasteric fascia,* which contains the scattered loops of bundles of the cremaster muscle, the latter being derived from the internal oblique muscle and reaching the scrotum through the spermatic cord (fig. 453). Again internally is a thin layer of connective tissue, the *tunica vaginalis communis,* or infundibuliform fascia which is continuous with the transversalis fascia through the inguinal canal.

Forming the innermost layer of the scrotum is the *tunica vaginalis propria,* which forms the serous investment of the testis and is of peritoneal origin. Like other similar serous investments it has the form of a double sac, the outer or parietal layer of which is closely adherent to the tunica vaginalis communis. The inner or visceral layer is thinner and closely invests the testis and a portion of the epididymis, being reflected from the inferior and posterior parts of the latter to be continuous with the parietal layer. Toward the upper part of the lateral surface of the testis it is folded in between that structure and the epididy-

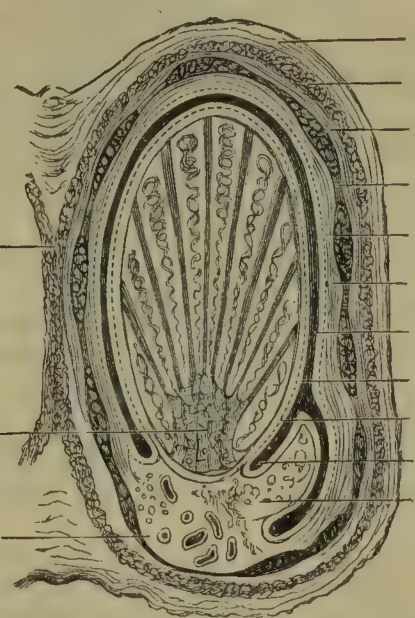


FIG. 1107.—HORIZONTAL SECTION OF THE SCROTUM AND TESTIS. (Diagrammatic.)

mis, forming a well-marked pocket, the *sinus epididymidis* (digital fossa) (figs. 1107, 1109), whose upper and lower lips form the *ligamenta epididymidis.*

In the living state the actual space between the parietal and visceral layers of the tunica vaginalis propria is small and contains only enough fluid to keep the glistening surfaces of the serosa moist and to permit free movement of the testes within the scrotum.

Vessels and nerves.—The skin and dartos of the scrotum are supplied partly by the perineal branch of the internal pudendal *artery* and partly by the external pudendal branches of the femoral. The deep layers are supplied by the spermatic branch of the inferior epigastric. The *veins* accompany the arteries, the external pudendals opening into the internal saphenous vein near its termination. The *lymphatics* terminate in the more medial inguinal nodes. Several *nerves* take part in the supply of the scrotum. The external spermatic branch of the genitofemoral gives sensory branches to the anterior and lateral surfaces and also supplies the cremaster muscle; the posterior surface is supplied by the perineal branch of the pudendal nerve; and the inferior surface by the perineal branches of the posterior femoral cutaneous. The anterior surface of the scrotum is also supplied by anterior scrotal branches of the ilioinguinal. The smooth musculature is probably supplied by the internal spermatic nerve from the hypogastric plexus.

Development.—In regard to the early development of the scrotum, there are two views, one of which is described in Section I. This view, also held by Felix in Keibel and Mall's Embryology, maintains that the scrotum is derived from that area between the urogenital sinus and the anus as an unpaired median swelling. The paired genital swellings become lost in the skin lateral to the base of the penis and do not take part in the formation of the scrotum. The septum is derived from the connective tissue which joins this area with the pars pelvina of the urogenital sinus. The other view which is older, but again more recently maintained by Spaulding, holds that the scrotum is formed from the paired genital swellings (scrotal-labial folds), thus making these folds the common progenitor of both the scrotum and the labia majora. In the male these folds migrate caudally and unite to form the two halves of the scrotum.

The cavities of the scrotum are formed later in connection with the descent of the testes. Each begins as a funnel-shaped out-pocketing from the peritoneal cavity, the *vaginal process,* which is carried into its respective scrotal compartment when the testes enter the scrotum. The neck of the vaginal process later becomes obliterated and the cavity of tunica vaginalis becomes entirely cut off from the peritoneal cavity (fig. 65). Along with downward growth

of the vaginal process of the peritoneum to form the *tunica vaginalis propria* certain layers of the lower abdominal wall are carried along with it. From within outwards these consist of (1) the *tunica vaginalis communis* (infundibular fascia) which is derived from the transversalis fascia and forms a comparatively thick and strong fibrous sheath; (2) the *cremasteric fascia and muscle*, derived as downward continuations of the muscle fibers of the internal oblique and transversalis muscles as well as the from the connective tissue fibers from their sheaths; (3) the *intercolumnar fascia*, a thinner coat derived from the aponeurosis of the external oblique.

Variations.—The size and shape of the scrotum depends upon the scrotal contents as well as upon the state of contracture or relaxation of its own musculature (the dartos and cremasteric muscles). It is pendulous and smooth walled when these muscles are relaxed and its attached portion may assume a bottle-neck shape. When its muscle fibers are stimulated to contract under the influence of cold or by emotional disturbances, the scrotum becomes much smaller, more rounded, and its attached area broader, while its surface becomes much wrinkled.

Congenital anomalies.—Owing to a developmental defect the cavity of the tunica vaginalis sometimes retains its direct communication with the peritoneal cavity. Such a condition favors the formation of a hernia, and should one form later on in life, the condition is known as a *congenital inguinal hernia* of the *vaginal type.* This condition can be satisfactorily differentiated from inguinal hernia of the acquired type only at operation, when the herniated loop of intestine is in contact with the testis. When the obliteration of the neck of the vaginal process is incomplete, a funnel-shaped pouch remains at the inguinal ring, and this may give rise to a congenital inguinal hernia of the *funicular type.* (See p. 1273.)

Infantile scrotum is associated with undescended testes. Depending upon the severity of the malformation the cavities of the scrotum may be partially or wholly lacking. The condition may be either unilateral or bilateral.

Bifid scrotum is a condition in which the two halves of the scrotum are separated by a deep cleft which reaches the perineum. It is seen only as an accompaniment of the severer degrees of hypospadias or hermaphroditism, in which the urethral orifice is found at the bottom of the scrotal cleft or in the perineum behind it. The anomaly is due to the failure of fusion of the paired genital swellings.

Clinical Considerations

In addition to conditions affecting the size of the testis and spermatic cord and to inguinal herniæ, the size of the scrotum may be increased by an excessive amount of fluid within the cavity of the tunica vaginalis, a condition known as *hydrocele.* The tissues of the scrotum are extremely vascular and its layers loosely applied to one another. While injuries heal readily they frequently produce marked edema of the scrotal wall, a condition due to lymphatic stasis. If the lymphatic stasis persists over a long enough period the walls of the scrotum become permanently thickened by the formation of connective tissue, and a condition known as *elephantiasis* results.

Operations upon the scrotum may be done for conditions of the scrotum itself or to reach the testes. Incisions into the scrotum can be made with impunity as healing is rapid and scars shrink down to insignificance. They are usually made on the anterior surface and in a longitudinal direction. The skin is drawn tightly over the scrotal contents and the skin and dartos incised. Owing to contraction of the smooth muscle fibers the skin edges soon become inverted. If the remaining laminations are picked up with forceps and incised one at a time, at least 8 to 10 thin layers can be made out before the cavity of the tunica vaginalis is reached.

In operations for carcinoma, elephantiasis, or for redundancy of the scrotum, partial ablation is usually made, the defect being covered by bringing the remaining edges of the scrotum together with sutures.

2. The Testes

The **testes** (figs. 1103 and 1107–1109) are the essential male organs of reproduction and are contained within the scrotum. They are two in number, each being of ovoid form and very slightly flattened from side to side. For descriptive purposes are recognized two *surfaces*, *medial* and *lateral*, two *borders*, *anterior* and *posterior*, and two *extremities*, *superior* and *inferior*. The medial and lateral surfaces and the anterior border are rounded and free of attachments, while the posterior border is attached to the spermatic cord and epididymis. The superior and inferior extremities are attached to the head and tail of the epididymis respectively. The testis is obliquely placed, so that the medial surface also looks somewhat forward and downward. The average dimensions of the testis are 4–5 cm. in length and 2.5–3 cm. in width.

The surface of the testis is covered by the visceral layer of the tunica vaginalis propria except where it is attached to the epididymis and spermatic cord. Internal to the visceral layer of the tunica vaginalis is a dense white inelastic capsule, the *tunica albuginea*, beneath which is a looser and more vascular layer. From the inner surface of the tunica albuginea, lamellæ of connective tissue, known as *septula*, converge toward the posterior border of the testis and toward its upper part unite to form the *mediastinum testis* (corpus Highmori). The blood-vessels and lymphatics enter and leave the testis through the mediastinum which also contains a meshwork of duct spaces known as the *rete testis*.

The testis is held in place by the reflection of the tunica vaginalis propria which gains attachment to the tunica vaginalis communis. It is also attached through the tissues of the lower end of the spermatic cord to the posterior wall of the scrotum. At the inferior extremity of the testis this forms the so-called *scrotal ligament*. Since these attachments are loose and elastic they permit free movement of the testis within the cavity of the tunica vaginalis yet are normally sufficient to prevent torsion and malposition of the testis. The main support of the testis is obtained from the scrotum and the spermatic cord.

The septula divide the substance of the testis into a number of segments or *lobules*, each of which is occupied by a number of slender, greatly contorted canals, the *seminiferous tubules* [tubuli seminiferi], from whose epithelial lining the spermatozoa are formed. The tubules of each lobule converge to form a single, almost straight duct and these *tubuli recti* extend toward the mediastinum, where they pass into the *rete testis*. In the lobules the seminiferous tubules are embedded in a loose connective tissue that contains the *interstitial cells*, to which has been attributed the formation of an internal secretion. For structure of the testis, see fig. 1110.

FIG. 1108.—RIGHT TESTIS, LATERAL SURFACE. The tunica vaginalis communis has been stripped from both testis and spermatic cord.

3. THE EPIDIDYMIDES

The **epididymis** (fig. 1109), is an elongated cord-like structure with a *body* [corpus epididymidis] which lies along the posterior border of the testis, a slightly enlarged *head* [caput] which rests upon the superior extremity of the testis, and a *tail* [cauda] which is attached to the inferior extremity. The epididymis is C-shaped and placed so that its concavity closely hugs the posterior border of the testis. Its medial surface is applied to the terminal portion of the spermatic cord through which it receives its blood-, nerve- and lymphatic supply. Its lateral and posterior surfaces are free and are covered by the visceral layer of the tunica vaginalis propria. Where this is reflected from the testis to the body of the epididymis there is a deep cleft, the *sinus epididymidis* (digital fossa).

The head of the epididymis is formed by 12–14 tubules, the *efferent ducts* (fig. 1110), which take their origin from the rete testis as almost straight tubules, but gradually become greatly coiled, so that each duct has the form of an elongated cone, its coiled portion forming what is termed a *lobulus epididymidis*. At their coiled ends the various efferent ducts open into a single tube, the *ductus epididymidis*. The body is formed by the convolutions of the ductus epididymis, which in the tail becomes continuous with the ductus deferens without sharp demarcation. The diameter of the ductus epididymidis is only about 0.4 mm., but it measures 6.0–7.0 meters (18–21 feet) in its entire length, being coiled so extensively as to be completely contained within the body and tail of the epididymis.

Vessels.—The principal *artery* supplying the testis is the internal spermatic, from which branches are also sent to the epididymis. The deferential artery, a branch of the superior vesical, also sends branches to the epididymis and enters into extensive anastomoses with the testicular branches of the internal spermatic, and anastomoses also occur with the vessels supplying the scrotum. The *veins* correspond to the arteries. The *lymphatics* of the testis and epididymis unite to form four to six large stems which pass upward in the spermatic cord to terminate in the lower lumbar nodes.

Development of the testis and epididymis.—As stated in Section I, p. 56, the testis or ovary arises from the medial surface of the Wolffian body. In embryos of about 5 mm. in length it is seen as a thickening of the visceral mesothelium which rapidly develops into a ridge, the *genital ridge*. Grooves develop along its sides and its broad attachment to the Wolffian body becomes converted into the narrow *mesorchium* or *mesovarium*.

A second vertical ridge, containing the *Wolffian duct*, forms on the postero-lateral border of the genital ridge. At its upper end there develops a funnel-shaped depression lined with

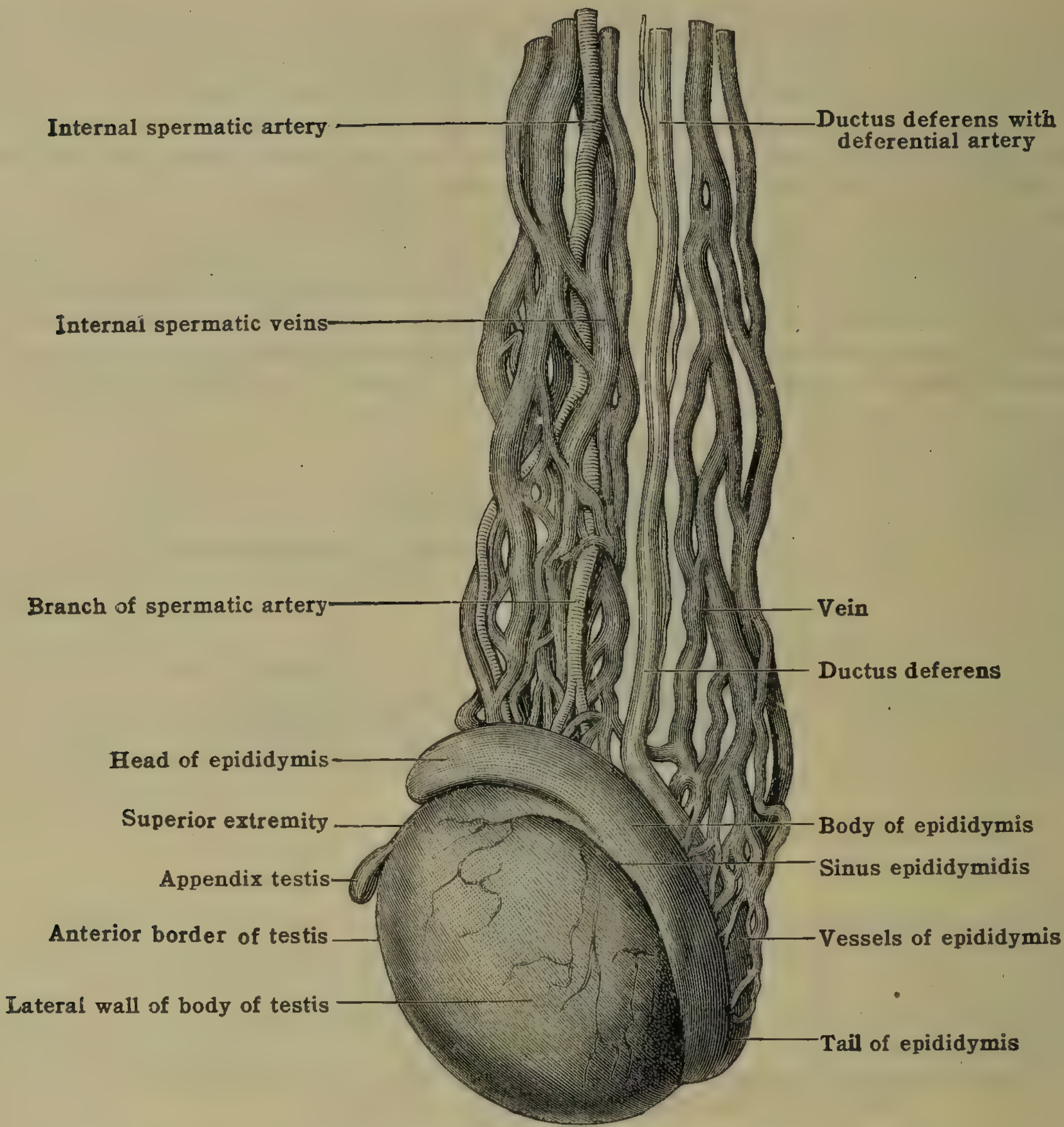


FIG. 1109.—THE LEFT TESTIS WITH VESSELS AND DUCT. (After Sappey.)

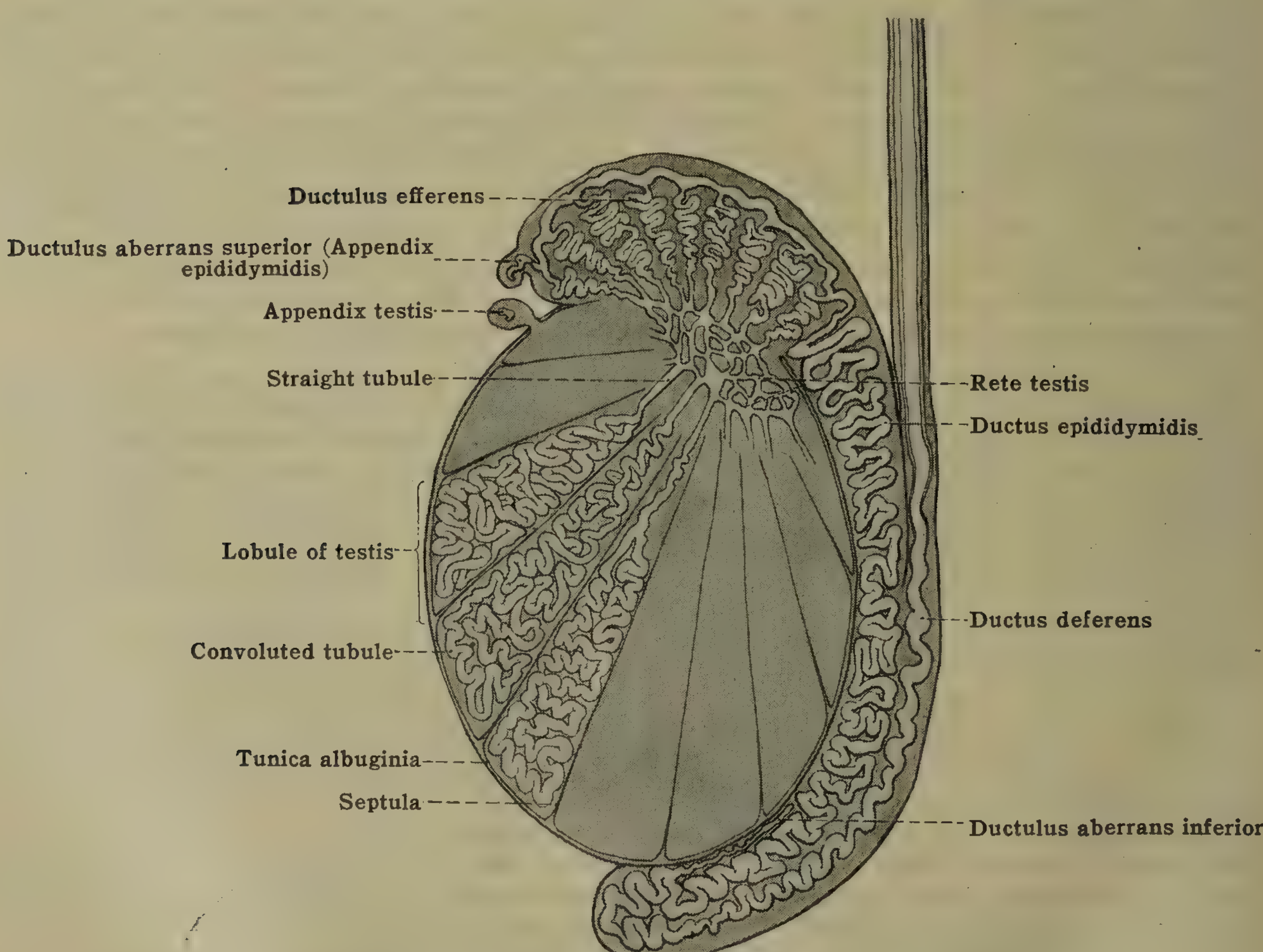


FIG. 1110.—DIAGRAM SHOWING TUBULES OF TESTIS AND EPIDIDYMIS.

mesothelium. The lower end of this grows downward into the genital ridge as a tube and it finally reaches the urogenital sinus, fusing in its lower portion with its fellow of the opposite side. This tube is the *Müllerian duct;* in its upper extremity it is in direct communication with the celomic cavity while in the lower part of its course it lies medial to the Wolffian duct. In the female it forms the vagina, uterus and uterine tubes; in the male it almost entirely degenerates, its extreme upper portion remaining to form the appendix testis while its extreme lower portion forms the prostatic utricle (fig. 1141).

That portion of the genital ridge destined to become the *gonad* rapidly enlarges and undergoes differentiation into either the testis or the ovary. In the development of the testis the mesothelium thickens and from it there arise the *medullary cords* of cells which push their way into the mesenchyme of the genital gland. These cords later become converted into the *convoluted* and *straight tubules* of the testis and their cells form both the germ cells and the supporting cells.

In the degeneration of the mesonephros certain of its tubules remain; they lose their connection with the mesonephric corpuscles but maintain their connection with the Wolffian duct. In the male they become closely related to the testis and finally occupy a position at its mediastinum. Here they are in position to unite with the tubules of the *rete testis.* This union takes place gradually, beginning in embryos of 60 mm., when the sex of the gonad is still indeterminable. From the foregoing it will be understood how the ductuli efferentia are derived from the mesonephric tubules, the ductus epididymidis from the upper portions of the Wolffian duct and the ductus deferens and ejaculatory duct from the remainder of the Wolffian duct. The seminal vesicle is derived from the lower end of the Wolffian duct first as a small fusiform swelling then as a bud-like growth (fig. 1121). It grows outward as a blind tube, becomes convoluted, and the diverticula develop from it as side branches.

Descent of the testis.—The manner in which the testis 'migrates' from the mid- or lower abdominal region to the scrotum is one which is of unusual interest. The older writers attributed the downward descent to the shortening of the *gubernaculum testis,* a fibromuscular ligament attached at one end to the testis and at the other to the genital swelling, later to become the scrotum. As stated in Section I p. 56, however, the early downward shifting of the testis within the abdomen is more apparent than real, being due, in part at least, to the rapid degeneration of the upper portion of the gland (Felix).

The descent of the testis through the future inguinal canal is preceded by the development of the saccus vaginalis (p. 56). This migration is attributed by Soulié, Frankl, and others to an actual shortening of the gubernaculum, but Felix believes that the gubernaculum acts only passively by uniting the testis to the anlage of the scrotal sac while this and other structures increase in size.

Variations and anomalies.—The testis is subject to considerable variation in size while its shape varies but little. During the prepuberal period it is small but during puberty it undergoes a period of growth and soon reaches its adult size. Race, individual size, bodily vigor, etc., all influence, or are influenced by, the size of the testis. The epididymis is also subject to variation, both in size and in the firmness with which it is attached to the testis. Likewise both the ductus deferens and the seminal vesicle vary considerably, the latter showing a marked difference in its empty and distended states.

Anomalies in number.—Anorchidism, the bilateral absence of the testes, although rare, occasionally occurs. The unilateral condition is known as *monorchidism.* Such cases are not to be confused with undescended abdominal testes. *Polyorchidism,* the presence of one or more supernumerary testes, is also a rare anomaly. Such supernumerary testes have their own excretory duct system, epididymis, ductus deferens, etc. The diagnosis can be established only by biopsy or post mortem since the presence of epididymal cysts, etc., frequently give the feeling of a supernumerary testis on palpation.

Anomalies of position.—Normally the superior extremity of the testis lies slightly anterior to the inferior extremity. Any change in these relations is known as *inversion of the testis.* Abnormal rotation may begin either forward or backward; thus the testis may assume a horizontal position with its superior extremity anteriorly (*anterior rotation*) or with its superior extremity posterior (*posterior rotation*). Abnormal rotations of 90°, 180°, or even 360° have been recorded in the literature.

Anomalies of migration.—Imperfect descent of the testes may be due to an *arrested migration* of the testis along its normal course, *cryptorchidism;* or to the migration of the testis to an abnormal position, *aberrant migration,* or *ectopia testis. Cryptorchidism* is one of the most frequent of anomalies of the genital organs, statistics showing that it occurs in 1 of every 500 individuals. It may be either unilateral or bilateral, the former occurring 5 to 12 times more frequently than the latter. The arrest of migration may occur at any point along the normal path of descensus; if within the abdomen it is known as the *abdominal* or *supra-inguinal* type of cryptorchidism; if within the inguinal canal, the *inguinal type;* while if between the subcutaneous inguinal ring and the scrotum, *subinguinal type.* Undescended testes usually are small and atrophic, and are often functionless so far as the formation of spermatozoa is concerned. The cause of cryptorchidism has been ascribed to a faulty development or absence of the gubernaculum testis but none of the various theories so far advanced is based upon sufficient anatomical observations.

Of the *aberrant migrations* wide variation in location of the testis have been described of which the following will be mentioned: in the true pelvis; in the femoral canal; in the femoral triangle; at the base of the penis; under the skin of the penis; under the skin of the abdomen above the inguinal ligament; or in the perineum. It may also be found in the scrotal sac of the opposite side (*transverse ectopia*) in which case its ductus deferens passes through the inguinal canal of the same side in company with the ductus of the other testis.

Anomalies of the seminal vesicles and seminal ducts.—The seminal vesicles may be absent or atrophic, or they may be greatly modified in shape and position in connection with other severe malformations, such as exstrophy of the bladder, open cloaca, or hermaphroditism. The abnormal opening of a ureter into the seminal vesicle, ductus deferens, ejaculatory duct,

or prostatic utricle has been described above, p. 1362. The ejaculatory ducts may fuse with one another to form a single duct before entering the urethra or they may open directly into the prostatic utricle.

Clinical Considerations

The testis is so located that it lends itself easily to palpation. Its shape, size, and consistency as well as that of the epididymis and the proximal portion of the ductus deferens can be determined from such an examination. The ampulla of the ductus deferens and the seminal vesicles can be palpated through the anterior rectal wall.

A small atrophic testis is frequently the result of mumps; an enlarged testis may be due to tumor or syphilis. Enlargement of the testis can be distinguished from hydrocele by transillumination if the fluid is clear or by aspiration with a small needle. In epididymitis, a common occurrence in gonorrhea or urinary infections, the epididymis becomes greatly swollen and a small amount of hydrocele fluid develops which upon palpation is suggestive of an enlarged testis. Occasionally small cysts develop in the paradidymis or in a closed-off portion of the epididymis itself, which may be mistaken for an anomalous third testis.

Varicocele is a very common condition in which there is an enlargement, thickening, and elongation of the veins of the pampiniform plexus of the spermatic cord. The veins hang down in the scrotum beside or below the testis where they can be readily palpated.

The testis and epididymis may be reached by an incision directly through the scrotum (p. 1370) or by an incision in the groin over the spermatic cord. In the latter procedure the skin and fasciæ are incised and the cord lifted up. Then by gentle traction on the cord and by exerting pressure on the testis the latter can be delivered through the incision. This includes the whole of the tunica vaginalis communis, which is easily separated from the cremasteric fascia. A second incision through the tunica vaginalis communis and propria exposes the testis and epididymis. In vasectomy the ductus deferens is reached by similar exposure of the spermatic cord and by a longitudinal incision through the tunica over the ductus, which can readily be distinguished by its size and its firm consistency. The seminal vesicles can be satisfactorily exposed only through the perineum (p. 1388).

4. The Ductus Deferentes

The **ductus (vas) deferens** is the continuation of the ductus epididymidis and extends from the tail of the epididymis to its termination on posterior surface of the prostate, where it is joined by the excretory duct of the seminal vesicle to form the *ejaculatory duct.* It has a total length of approximately 30 cm. not taking into consideration its convolutions. Within the tail of the epididymis the ductus epididymidis passes insensibly over into the ductus deferens. The proximal (epididymal) end of the ductus deferens is slender and tortuous but it gradually straightens out as it passes upward medial to the corpus epididymidis. In this portion (pars epididymica NK) the duct also becomes thicker and denser owing to the increased thickening of its muscular tunics. Entering the spermatic cord, the *funicular portion* of the ductus deferens courses within it first as the pars libera (NK), then through the inguinal canal (pars inguinalis NK) to the abdominal inguinal ring. Here it separates from the other constituents of the cord and, looping over the inferior epigastric artery near its origin, passes downward and backward along the lateral pelvic wall (pars pelvina NK). It passes medially to the distal end of the ureter and then bends downward and medially along the posterior wall of the bladder, lying medially to the seminal vesicle. The medial convergence continues until at its termination behind the prostate, it is contiguous with its fellow of the opposite side. In its course from the annulus inguinalis abdominalis to the middle of the seminal vesicle it lies beneath the peritoneum and medial to the ligamentum umbilicale laterale, the external iliac artery and vein, the obturator nerve and vessels, and the ureter. When the bladder is contracted the ductus deferens can be seen through the peritoneum but it is hidden from view by the lateral walls of the distended bladder.

After leaving the testis the ductus deferens presents a uniform diameter of 2 to 3 mm. until it reaches the medial border of the seminal vesicle. Here it broadens out, becomes irregular and nodular, and forms the *ampulla ductus deferentis,* whose lumen presents numerous sacculations [*diverticula ampullæ*]. Just before joining the excretory duct of the seminal vesicle the ductus deferens again becomes more rounded and slender.

Vessels and nerves.—The artery supplying the ductus deferens is the *deferential,* a branch of either the superior or the inferior vesical artery. It accompanies the ductus to the tail of the epididymis and also gives off a branch to the seminal vesicle. The *deferential vein* accompanies the ductus deferens to the base of the bladder where it breaks up into a plexus that communicates with seminal venous plexus. This joins with the vesical and pudendal plexus and so reaches the hypogastric vein. The lymphatics pass to the external iliac and hypogastric nodes. The nerves are derived from the hypogastric plexus.

5. Ejaculatory Ducts

The **ejaculatory duct** (figs. 1112, 1113) is formed by the union of the ductus deferens and the excretory duct of the seminal vesicle and represents the terminal portion of the seminal duct. Beginning on the posterior surface of the prostate, near the base of the latter, it pierces the substance of the prostate in a downward and anterior direction and opens into the urethra on the colliculus seminalis by a small slit-like orifice. The orifice lies lateral to, and usually below, the orifice of the **utriculus prostaticus**, a blind pouch which represents the remains of the fused Müllerian ducts. Occasionally the ejaculatory ducts open directly into the utriculus prostaticus.

The ejaculatory ducts measure about 1.5 to 2 cm. in length and about 1.5 to 2 mm. in diameter. The smallness of its caliber, as compared with the two larger ducts which unite to form it, is worthy of special note. The lumen of the ejaculatory duct presents several sacculations similar to, though much smaller than, those of the ampulla of the ductus deferens.

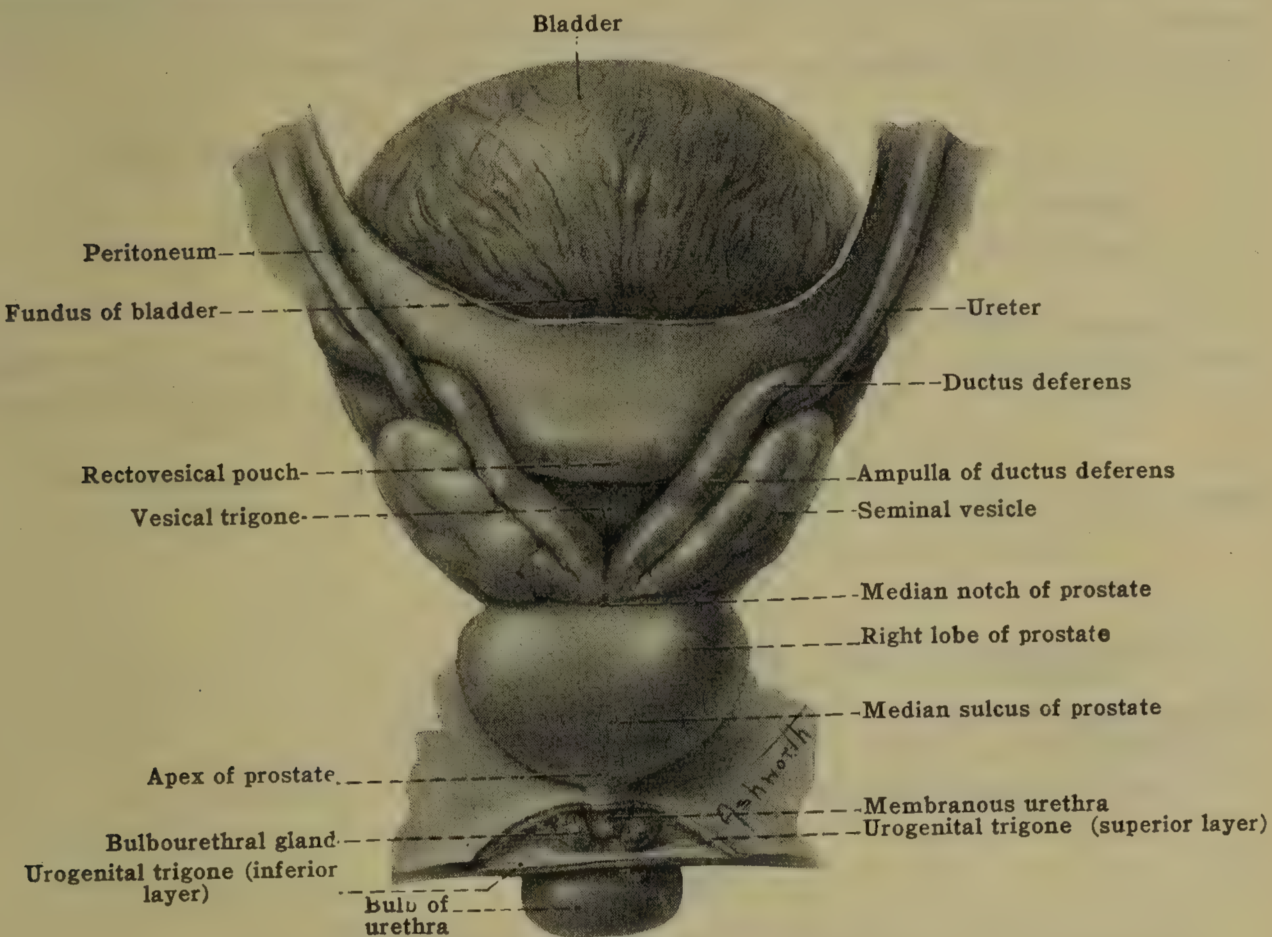


Fig. 1111.—Bladder, Prostate, Seminal Vesicles, etc., from Behind.

6. Seminal Vesicles

The **seminal vesicle** (glandula vesiculosa NK) (figs. 1111–1113, 1115) serves the double function of forming a part of the seminal fluid and of acting as a reservoir for spermatozoa. It is a club-shaped lobulated structure of about 4.5 to 5.5 cm. in length and with a greatest diameter of about 2 cm. It rests upon the posterior surface of the bladder, lying parallel with and lateral to the corresponding ductus deferens. It is obliquely placed so that its blind end lies lateral to, above, and behind its *excretory duct*, which joins the ejaculatory duct near the midline of the body. The vesicle is in reality a tubular structure of 10 to 12 cm. long which is folded back and forth on itself to be contained within its capsule. Arising from it at various levels are usually blind pockets or *diverticula*, similar in structure to the main tube.

Picker has shown from a series of dissections that **variations** in the tube of the seminal vesicle occur as follows: (a) main tube straight or twisted with large globe-like arranged diverticula—33 per cent; (b) short main tube with large irregular ramified branches—33 per cent; (c) thin twisted tube with or without diverticula—15 per cent; (d) thick twisted tube with or without diverticula—15 per cent; (e) simple straight tube—4 per cent.

Anteriorly the capsule of the seminal vesicle is firmly joined to the bladder by connective tissue; medially it is adherent to the ampulla of the ductus deferens;

posteriorly its upper third is covered by peritoneum while the remainder is separated from the rectum by a double layer of fascia (fascia of Denonvilliers) which extends downward over the prostate.

Vessels and nerves.—The seminal vesicle receives its blood supply from the *inferior vesical artery* by a direct branch, and also from the *deferential artery.* It may also receive a branch from the *middle hemorrhoidal artery.* The veins drain into the *plexus venosus seminalis.* The *lymphatic* vessels drain into the hypogastric lymph nodes. The *nerves* are received from the hypogastric plexus.

7. Spermatic Cord

In its descent through the inguinal canal into the scrotum the testis carries with it the ductus deferens and the testicular vessels and nerves. These structures coming together at the abdominal inguinal ring form collectively the *spermatic cord* [funiculus spermaticus]. This structure extends, therefore, from the abdominal inguinal ring, through the inguinal canal and the neck of the scrotal sack to the testis, and is enclosed within the same investing layers as the tunica vaginalis propria. These are from without inwards the *intercolumnar* fascia, derived from the aponeurosis of the external oblique muscle; the *cremasteric*

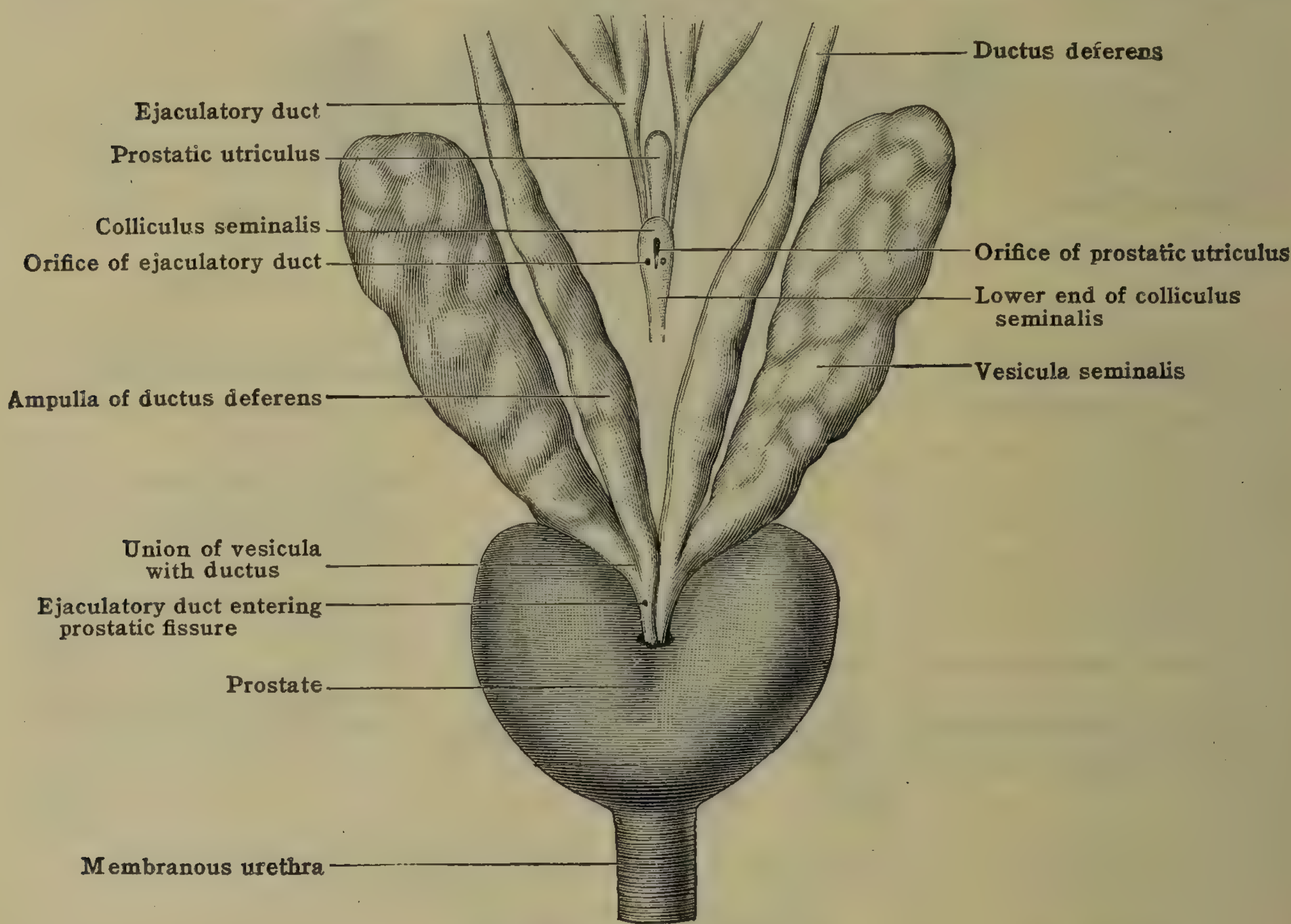


Fig. 1112.—Ductus Deferentes and Vesiculæ Seminales. (After Sappey.)

fascia, containg muscle fibers derived from the internal oblique, and the *tunica vaginalis communis,* from the transversalis fascia.

The various essential constituents of the spermatic cord are as follows (figs. 1109, 1114): (1) the *ductus deferens,* occupying the posterior surface of the cord and having associated with it the deferential artery and veins and the deferential plexus of nerve-fibers; (2) the *internal spermatic artery,* which occupies the axis of the cord and is surrounded by (3) the *internal spermatic veins* which form a complicated network, known as the *pampiniform plexus;* (4) the *testicular lymphatics;* and (5) the *internal spermatic plexus* of nerves from the hypogastric plexus and (6) branches of the *external spermatic vessels and nerve* for the supply of the cremaster muscle. All these structures are united by a loose connective tissue.

8. The Penis

The penis, the male organ of copulation, is a cylindrical organ which is composed of the root [*radix penis*] arising from the pubic arch, the body [*corpus penis*], and the terminal enlargement [*glans penis*] (fig. 1117). Externally it is

entirely covered by integument and presents two main surfaces, an anterior or dorsal [*dorsum penis*] and a ventral or urethral [*facies urethralis*].

The **body** of the penis is composed principally of erectile tissue which is arranged in three columnar bodies, the corpora cavernosa (fig. 1116), so-called because of the enlarged venous cavities which they contain. Two of these bodies

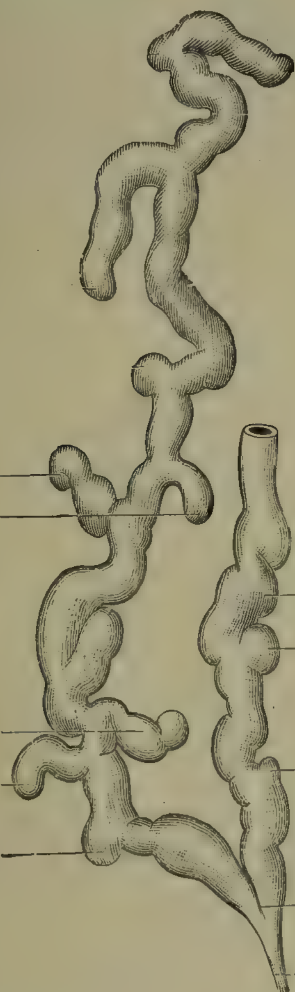


Fig. 1113.—Ductus Deferens and Vesicula Seminalis Dissected. (After Sappey.)

are arranged side by side on the dorsum of the penis [*corpora cavernosa penis*] while the third [*corpus cavernosum urethræ*] is somewhat smaller and lies in the midline along the urethral surface. It is traversed through its whole length by the urethra. Each cavernous body is enclosed by a dense fibro-elastic sheath

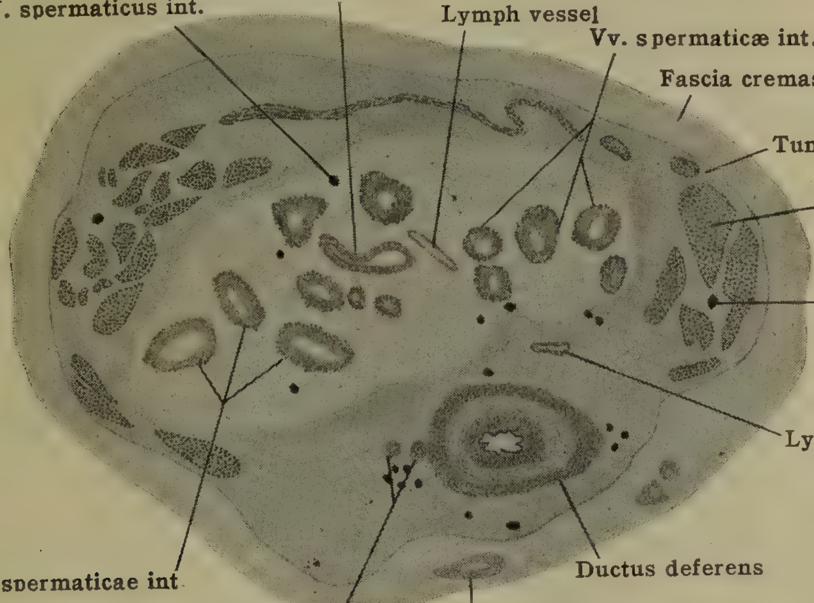


Fig. 1114.—Cross-section of the Spermatic Cord.

[*tunica albuginea*] and these are firmly bound together by strong connective tissue. Medially the united tunics of the corpora cavernosa penis constitute the *septum penis* (septum pectiniforme NK). All three cavernous bodies are contained within a common sheath, the *fascia penis*, surrounding which is a looser fascial

sheath containing numerous vessels and nerves, and which in turn is covered by the integument.

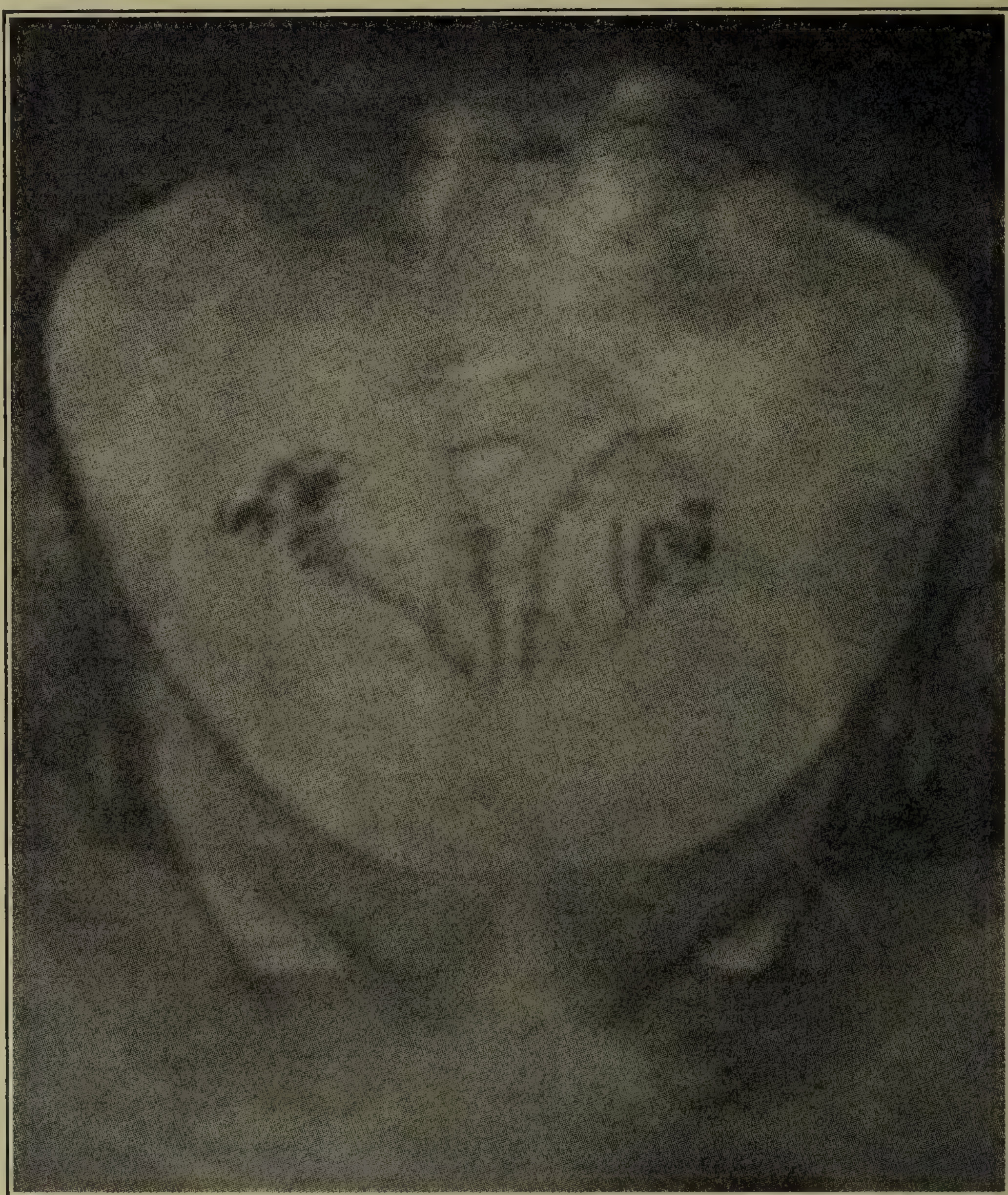


FIG. 1115.—VESICULOGRAM. The seminal vesicles and ductus deferentes have been injected with iodized oil. (From Belfield & Rolnick in Jour. of Urology, Vol. XVI.)

By means of its **root** [radix penis] the penis gains attachment to both ligamentous and bony structures. Upon reaching the pubic arch the corpora cavernosa penis separate from each other and form the *crura*. Each crus now

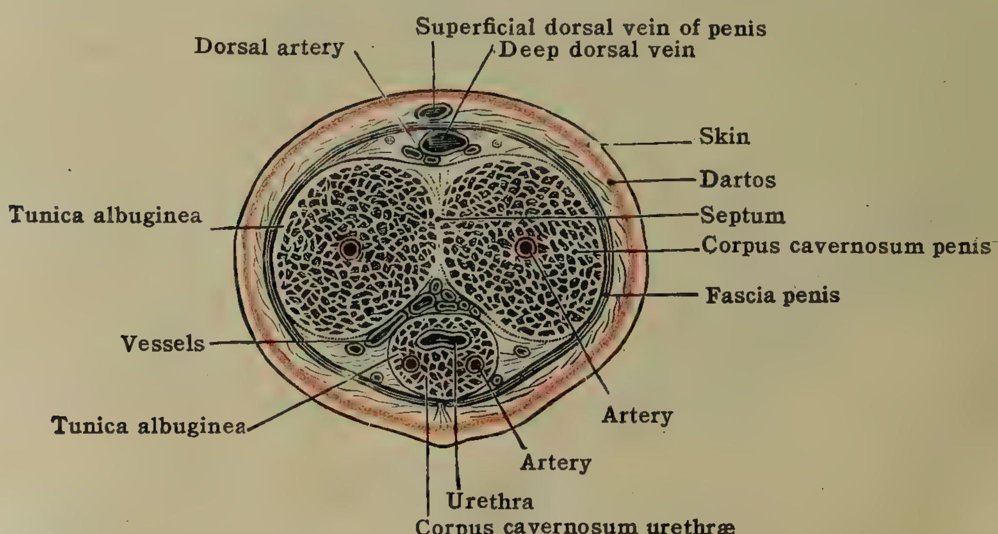


FIG. 1116.—TRANSVERSE SECTION THROUGH THE BODY OF THE PENIS.

bends sharply laterally and downward, paralleling and gaining attachment to the medial border of the inferior ramus of the pubis. Surrounding the crus,

except where it is in contact with the pubis, is the ischiocavernosus muscle, which is inserted more distally into its tunica albuginea. The corpus cavernosum urethræ expands into an elongated bulbous swelling, the *bulb of the urethra* [bulbus urethræ]. Its posterosuperior surface is firmly attached to the inferior surface of the urogenital diaphragm. The urethra, as it extends downward through the urogenital diaphragm, enters the superior surface of the bulb 1 to 1.5 cm. anterior to its posterior extremity. Except for its superior surface, the bulb is covered by and gives attachment to the bulbocavernosus muscle, which muscle extends anteriorly and is inserted into the tunica albuginea of the corpus cavernosum urethræ.

The penis also gains further attachment by means of the *suspensory ligament*, a triangular sheath of connective tissue which is attached above to the symphysis pubis and below to the sheath of the corpora cavernosa penis. A second less distinct ligament, *ligamentum fundiforme penis*, arises from the deep fascia over

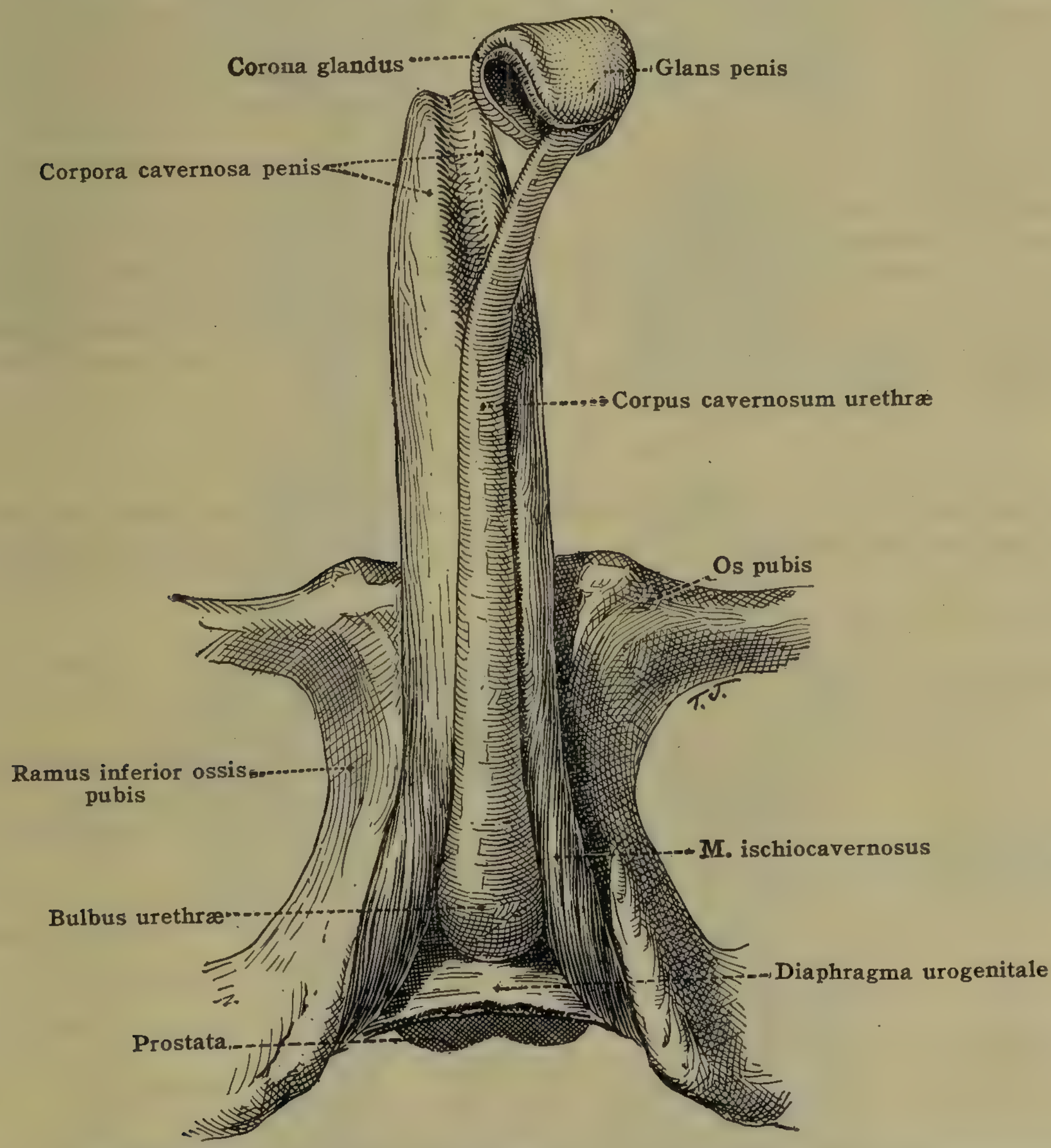


FIG. 1117.—DISSECTION OF THE PERINEUM SHOWING THE STRUCTURE AND RELATIONS OF THE PENIS.

the symphysis and splitting, passes down on either side of the penis to reunite below it, gaining attachment to the septum of the scrotum.

The **glans penis** is a cap-shaped expansion of the corpus cavernosum urethræ which is turned upward and backward covering the conical extremity of the united corpora cavernosa penis. It presents a rounded posterior border or *corona glandis* behind which is the constricted *neck* [*collum glandis*]. At its distal end is the opening of the urethra, the *external urethral orifice*, a longitudinal slit-like aperture. On the urethral surface both the corona and the neck extend nearly to the end of the glans, while in the midline there is a duplication of the thin integument, the *frenulum*, which extends from the inferior angle of the external urethral orifice to the inner sheath of the prepuce. The *prepuce* [*præputium*] is a circular fold of skin which covers the glans to an extent which varies with the individual. It is composed of an outer leaf, continuous with the skin of the body of the penis and an inner leaf which is thin and delicate and is

closely applied to, although freely movable over, the glans. At the neck it becomes continuous with the integument of the glans.

The *integument* of the penis is continuous with that of the scrotum and like it is pigmented and contains no fat. Hairs and sebaceous glands are few and usually limited to the proximal portion of the body. Immediately beneath the skin there is a poorly developed dartos, which entirely disappears at the neck. The integument of the glans is thin, smooth, and translucent. At the neck and on the inner leaf of the prepuce are found a few modified sebaceous glands [glandulæ præputiales] the secretion from which, with desquamated cells, gives rise to *smegma*, a foul-smelling cheesy substance which collects under the prepuce.

Vessels and nerves.—The principal *arterial* supply of the penis is derived from the internal pudendal artery (see p. 679), although the proximal portion of its integument is also supplied by the external pudendal branches of the femoral artery. The *veins* from the integument collect into one or more stems, the superficial dorsal vein, which runs along the dorsal midline and bifurcates, draining into the great saphenous vein of each side (fig. 599). The deep veins from the corpora cavernosa open into a median deep dorsal vein, which communicates with the internal pudendal veins and terminates in the pudendal plexus. Both the superficial and deep *lymphatics* terminate in the superficial inguinal nodes. The lymph-vessels from the glans are said to follow those of the urethra and end in the deep inguinal and external iliac nodes.

The *nerves* supplying the penis are the anterior scrotal branches of the ilioinguinal, and the perineal branches and dorsal nerve of the penis from the pudendal. Sympathetic fibers also pass to the penis from the hypogastric plexus and these with fibers from the third and fourth sacral nerves constitute what is termed *nervus erigens*, since stimulation of it produces erection of the organ. An anatomical provision for the production of this phenomenon has been found in the occurrence of peculiar thickenings of the intima of the arteries of the penis, by which the lumina of the vessels are greatly diminished or even occluded when in a state of moderate contraction, as when the organ is flaccid. When the arteries are dilated the intimal thickenings become reduced in height and the blood is afforded a free passage into the lacunar spaces of the corpora cavernosa, which thus become engorged.

9. The Male Urethra

The **urethra** is the canal which extends from the bladder to the extremity of the glans penis and serves for the passage of both the urine and the seminal fluid.

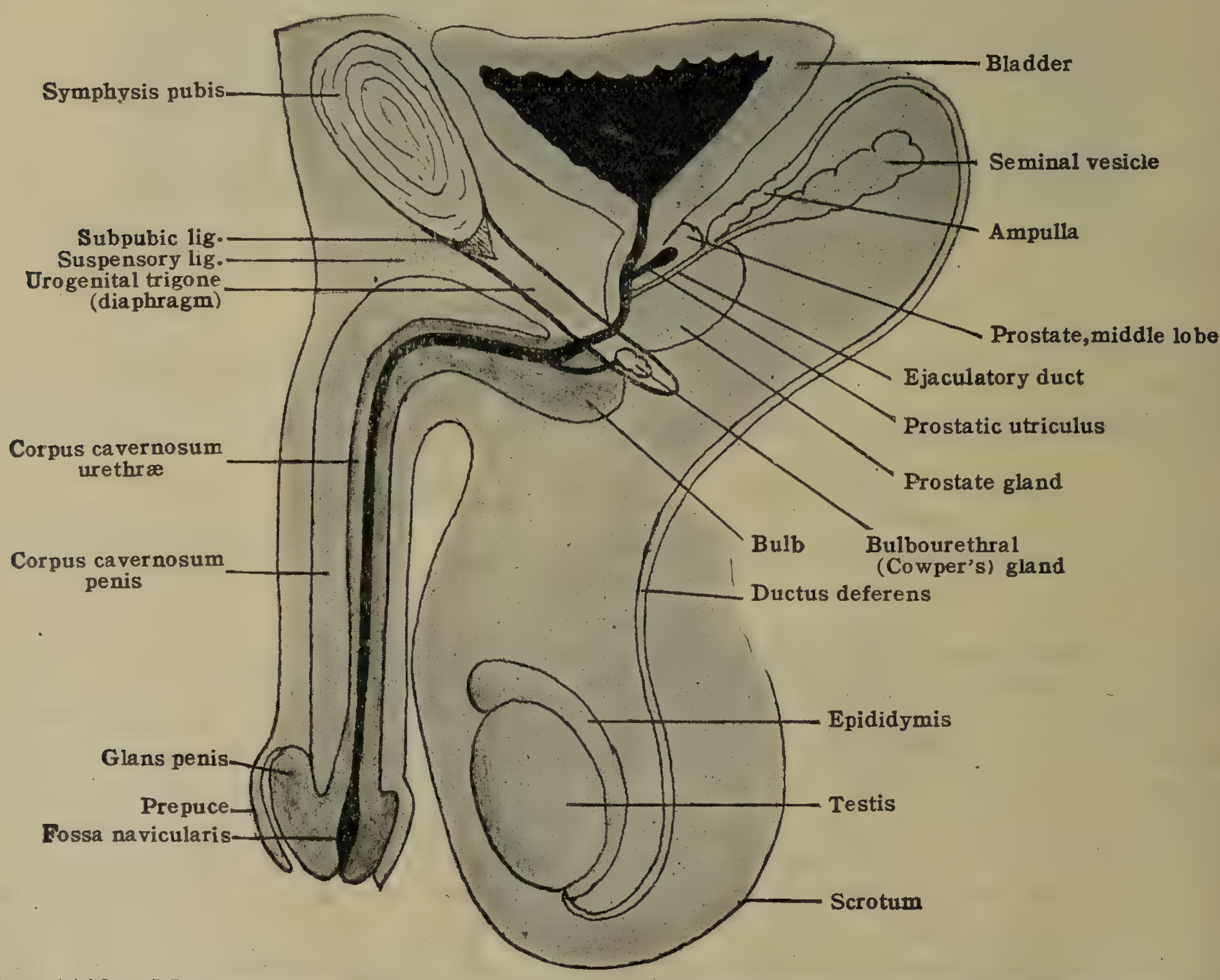


Fig. 1118.—Midsagittal Section (diagrammatic) Showing Male Bladder, Urethra, etc.

In its course (fig. 1119) it traverses first the prostate gland, then the urogenital diaphragm and then the entire length of the corpus cavernosum urethræ, and

for descriptive purposes is divided into three portions, prostatic, membranous, and cavernous.

The **prostatic portion** [pars prostatica] (fig. 1118) extends almost vertically downward from the neck of the bladder, traversing the substance of the prostate gland. Its walls are thrown into a number of longitudinal folds, all of which with the exception of a large one on the posterior surface, can be obliterated on distention. This large fold, the *crista urethralis*, at about its middle dilates into

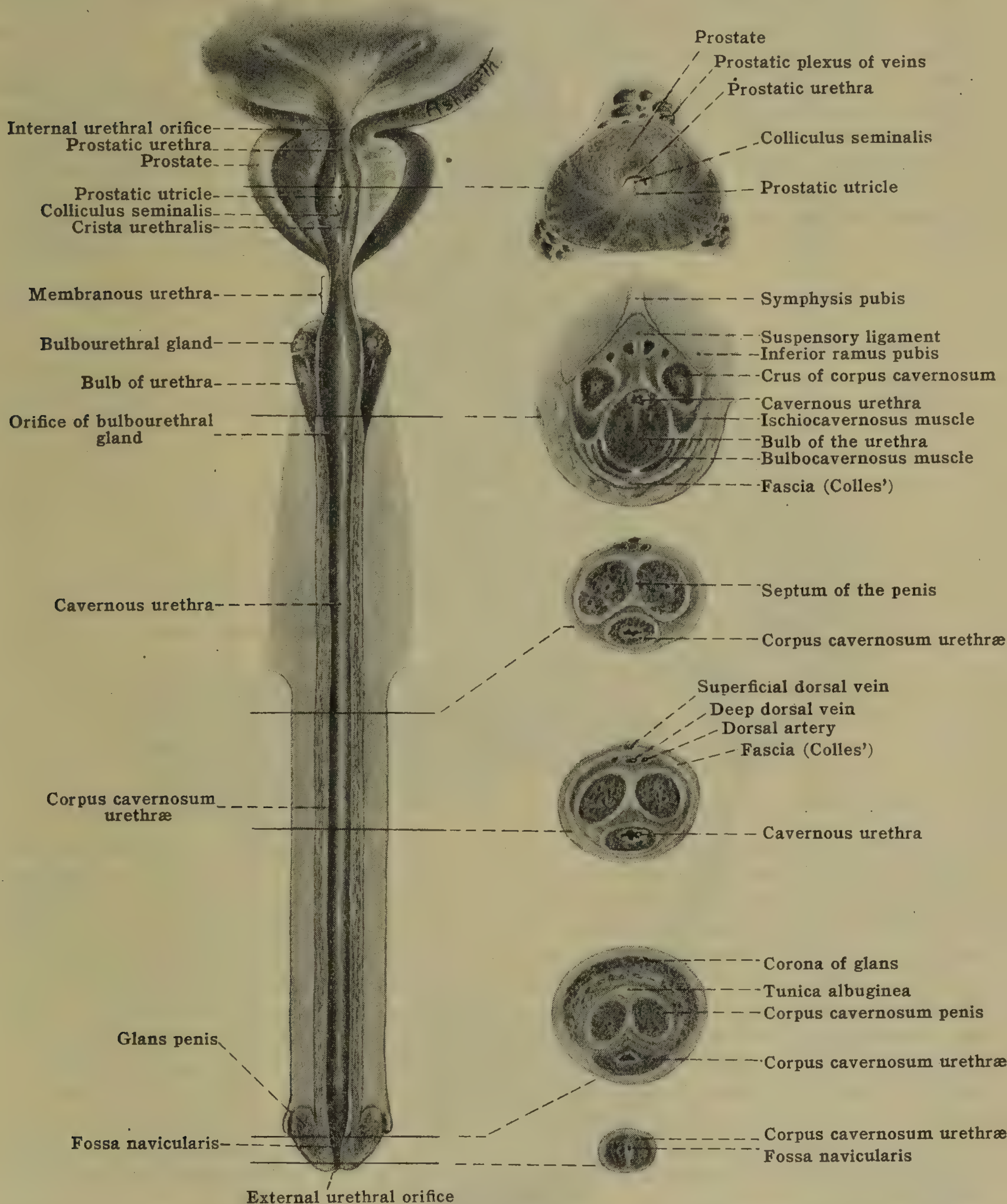


Fig. 1119.—Frontal Section of the Male Urethra with Cross-sections of the Penis at Different Levels. (Semi-diagrammatic.)

an oval enlargement, the *colliculus seminalis* (figs. 1104, 1119), to accommodate which there is a widening of the lumen of the urethra in this part of its course. At the center of the colliculus there is an elongated opening of a pouch of varying depth, termed the *utriculus prostaticus* ('uterus masculinus'), which corresponds to the lower part of the vagina in the female (see p. 1409). Situated one on either side and below the orifice of the utriculus are the smaller openings of the *ejaculatory ducts*. Owing to the prominence formed by the colliculus a cross-section of the urethra in this region is somewhat U-shaped, and near the bottom of the

furrows on either side of the median elevation are the minute openings of the numerous ducts of the prostate gland (fig. 1119). After leaving the apex of the prostate the urethra extends downward a distance of ½ to 1 cm. before reaching the urogenital diaphragm.

Penetrating the deep layer of fascia of the urogenital diaphragm the urethra enters the deep perineal interspace; this portion of its course is known as the **membranous portion** [pars membranacea] (pars diaphragmatica NK). Its direction is now downward and slightly forward, curving beneath the subpubic ligament, from which it is separated by a plexus of veins and by the fibers of the *sphincter urethræ membranaceæ,* which form an almost complete investment for it. The lumen of this part of the urethra is much narrower than that of the prostatic portion, and since it traverses the rather unyielding fascia of the urogenital diaphragm it is less dilatable than in other parts of its extent, with the exception of the external orifice.

Passing through the superficial layer of fascia of the urogenital diaphragm the urethra then enters the bulb of the corpus cavernosum urethræ (fig. 1118) and is invested throughout the remainder of its extent by this structure; hence this portion is known as the **cavernous portion** [pars cavernosa] (fig. 1120). In its prox-

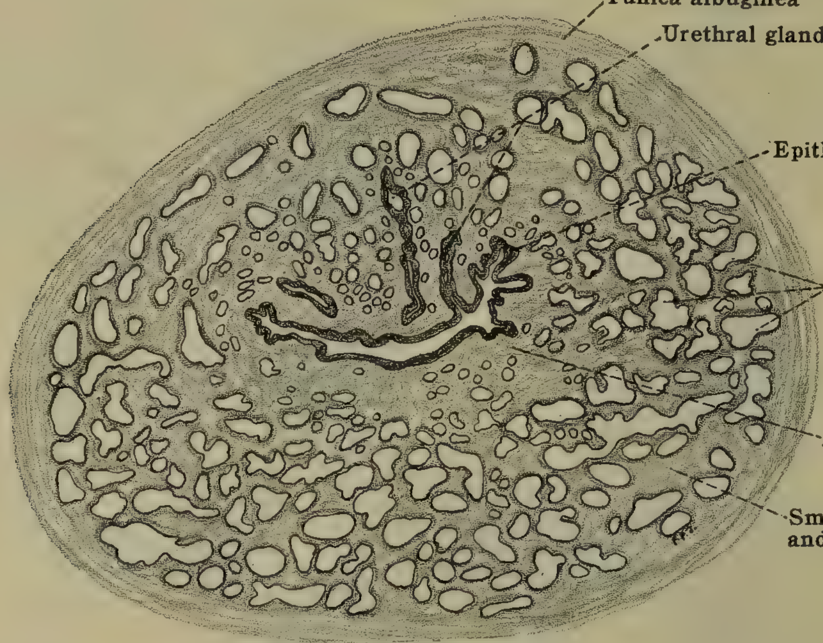


Fig. 1120.—Cross-section of Male Urethra, Cavernous Portion. (× 9.)

imal part this lies in the superficial interspace of the perineum and passes almost directly forward; but more distally, where it enters the body of the penis, it accommodates itself to the position of that organ, which it traverses lengthwise, lying in the midline near its ventral surface (fig. 1116). Thus the proximal portion of the cavernous and the whole of the membranous and prostatic portions have a fixed position, the *pars fixa* of the urethra, while the penile portion forms the *pars mobilis.* On entering the bulb the lumen of the urethra dilates somewhat and in this region has opening into it the ducts of the bulbourethral glands (fig. 1119), but as it enters the body of the corpus cavernosum it diminishes again and maintains a uniform diameter throughout the extent of that structure. When it reaches the glans penis it undergoes another dilation, which is known as the *fossa navicularis* (fig. 1119), beyond which it diminishes to the slit-like *external orifice,* situated at the extremity of the glans and forming the least dilatable portion of the entire urethral canal.

The walls of the membranous and cavernous urethræ are composed of a number of longitudinal folds, the summits of which are contiguous with one another when the urethra is collapsed but which disappear when it is distended. As a rule no glands open into the membranous urethra, but the bodies of the bulbourethral glands lie between the two layers of the urogenital diaphragm opposite this portion of the urethra; their ducts, however, open into the bulbous portion of the cavernous urethra. Numerous other small glands [glandulæ urethrales (Littréi)] open into the cavernous urethra. Their orifices are found in the sulci between the longitudinal folds; consequently in the distended urethra they are seen to be arranged in rows. The majority of these glands are found in the proximal two-thirds of the cavernous urethra. The larger of the gland orifices have been termed *lacunæ urethrales* [Morgagnii].

Development of the penis and urethra.—The manner in which the phallus arises at the anterior end of the cloaca from the genital tubercle as the *genital* or *phallic eminence* has been

described on p. 55. As the eminence grows in length its terminal end is early marked off by a slight constriction, designating that portion which is to become the glans (fig. 1140).

The urogenital sinus, now divisible into an anterior *pars phallica* and a posterior *pars pelvina,* and closed off to the outside by means of the *urogenital membrane,* opens up to the outside in embryos of about 12 mm. by a resorption of the membrane. It then grows forward as a deep cleft along the ventral aspect of the phallus, the *urethral groove.* In the male the urethral groove is converted into the tubular *urethra* by a fusion of its lips which are known as *genital folds.* The closure proceeds from *behind forward,* and keeps pace with the growth of the

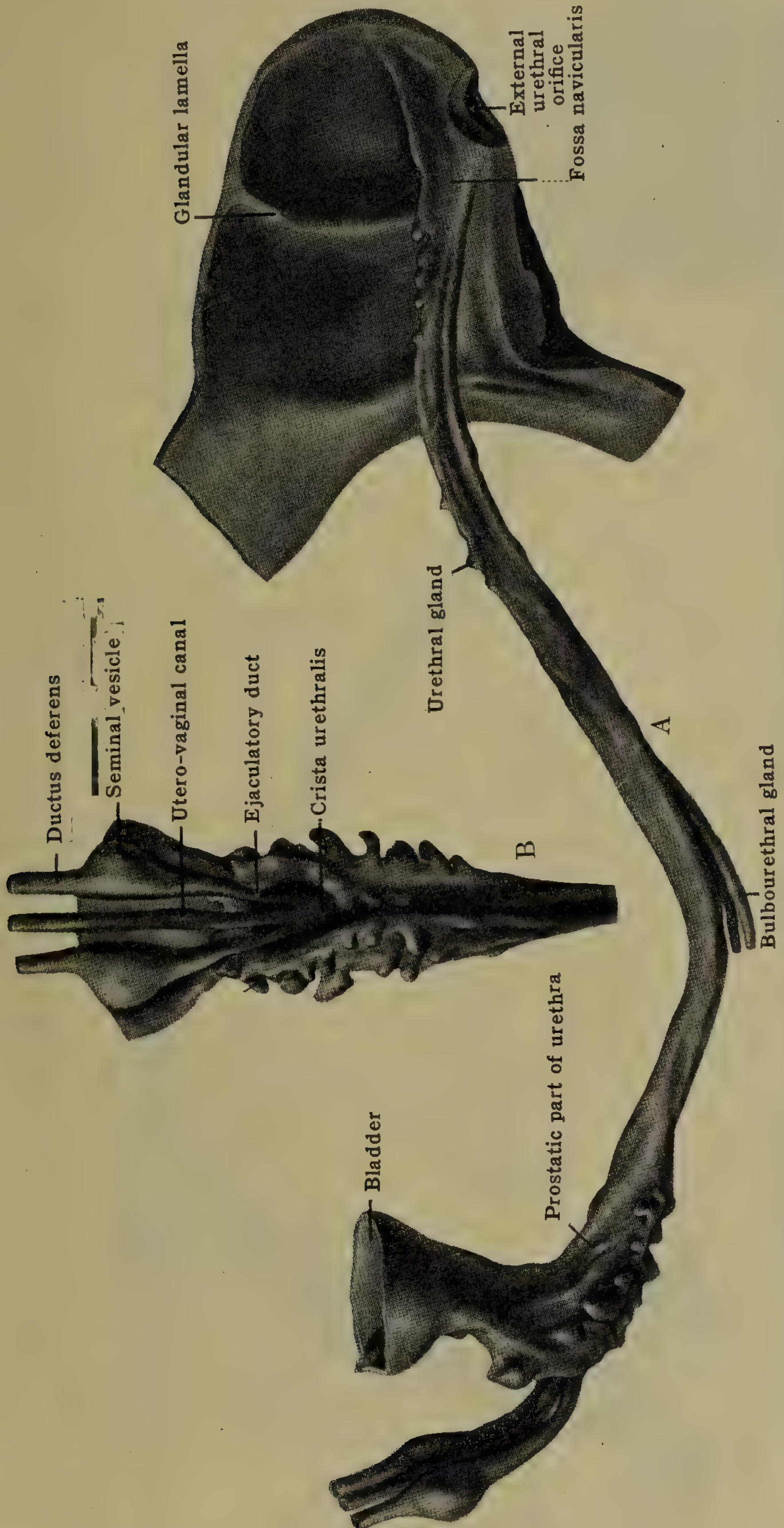


Fig. 1121.—A. Lateral View of a Wax Reconstruction of the Urethral Epithelium of a Male Human Embryo of 65-mm. Crown-rump Length. ×33. B. Posterior View of Same. ×33. (After Johnson, Jour. of Urology, Vol. IV.)

penis, which continues to carry the urethral groove further forward. An opening, the *primitive urethral orifice,* constantly remains which is to be found on the ventral surface of the penis just proximal to the glans. The *definitive external urethral orifice* is formed at the anterior extremity of the penis through the agency of the *sinus plate,* a median plate of epithelium within the glans (figs. 1121 and 1122). This plate undergoes a longitudinal splitting forming a deep cleft continuous proximally with the primitive urethral opening. The closure of the latter now becomes complete but a coalescence of the lips of the split sinus plate proceeds forward along the ventral surface of the glans, leaving just the terminal portion unclosed. By this process the external urethral orifice and the fossa navicularis are formed.

The *prepuce* develops from the *glandular lamella,* which appears as a solid epithelial sheet growing into the mesenchyme of the phallus at right angles to its surface epithelium (figs. 1121, 1138). It is deficient ventrally, but dorsally and laterally marks the corona of the glans penis. With the further growth of the phallus, the attached border of the glandular lamella gradually shifts anteriorly, while its deep or free border becomes curved and remains stationary (fig. 1122). In succeeding stages, the attached border of the glandular lamella approaches the external urethral orifice and enters it. Finally just before birth the lamella undergoes a splitting process

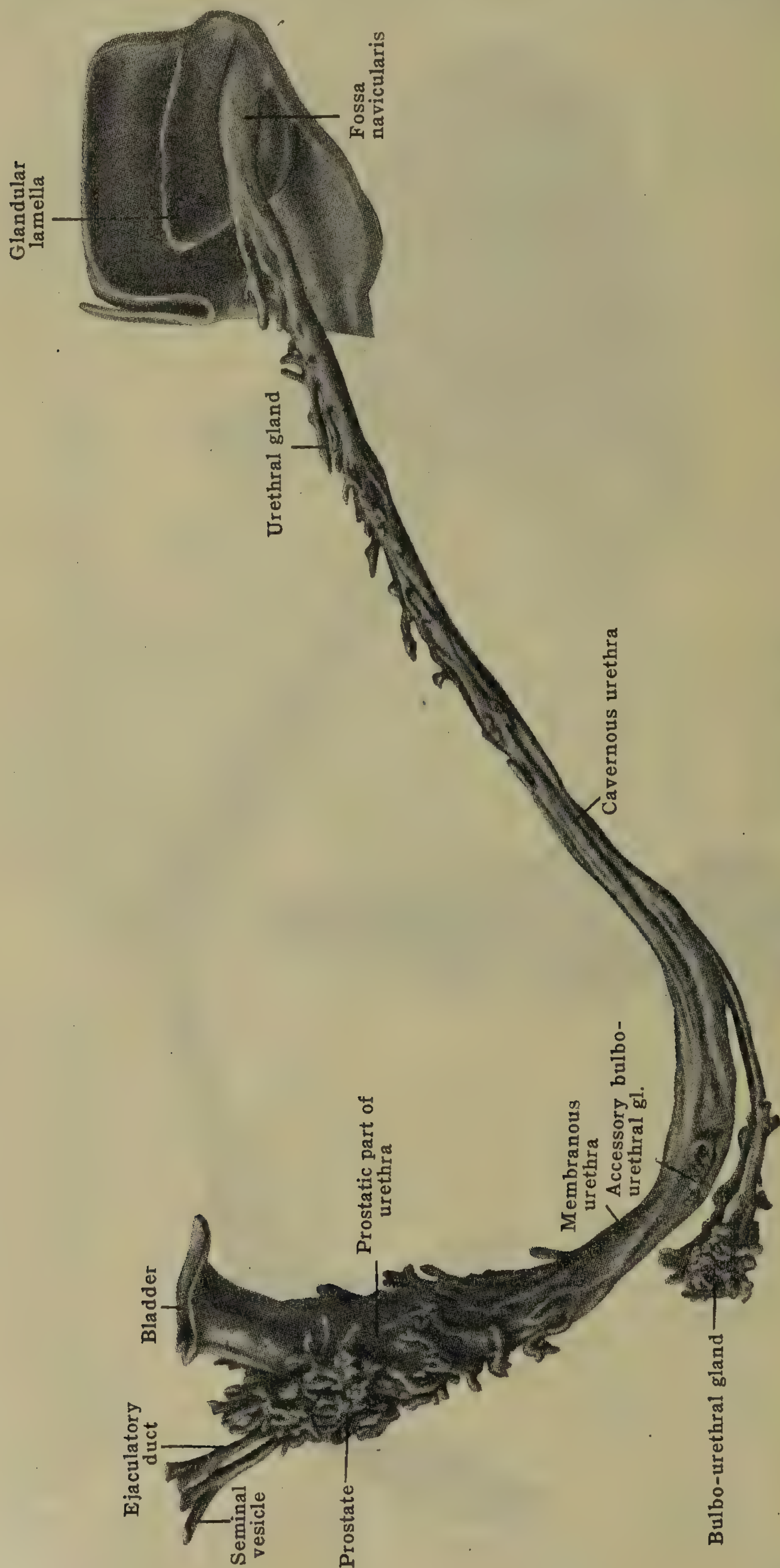


Fig. 1122.—Lateral View of a Wax Reconstruction of the Urethral Epithelium of a Male Human Embryo of 130-mm. Crown-rump Length. ×17. (After Johnson, Jour. of Urology, Vol. IV.)

whereby its single layer of epithelium becomes two layers with the preputial space between them.

Variations.—The flaccid penis varies from 8 to 12 cm. in length and 3 to 4.5 cm. in diameter, being subject to wide variations both in individuals and in races. It is also physiologically subject to variation in size. Under the influence of cold or certain emotional states it becomes smaller, owing to the contracture of its musculature, including its dartos. During erection it increases in both length (12–18 cm.) and breadth (4–5 cm.); and, as would be seen in cross-sec-

tion, it assumes a more triangular shape, its dorsum becoming flatter. The length of the urethra also varies within wide limits, the average usually being about 21 cm. When not functioning, the longitudinal folds of the urethra are brought into apposition with one another and the lumen is completely collapsed. During urination the walls balloon out and if sufficient force is applied the longitudinal folds become obliterated. The normal urethra should be able to take a No. 26 sound (French scale, meaning 26 mm. in circumference) without undue stretching.

Congenital anomalies.—Both *absence* of and *double penis* are rare anomalies and are usually associated with other severe malformations. The shape of the penis is often altered by anomalies of the urethra, as *hypospadias*, *epispadias*, *hermaphroditism*, etc., a brief description of which will be found below. *Phimosis* is that condition in which the circular opening of the prepuce is so small that it cannot be retracted backward over the glans. It is such a common condition that it can hardly be considered an anomaly. Associated with it are adhesions between the prepuce and glans, especially in the region of the corona. Phimosis prevents removal of the smegma and leads to inflammation; its treatment is circumcision.

Absence of the urethra may be a true absence, associated with absence of the penis, or it may be due to a congenital obliteration, either partial or complete, after the urethra has once formed. Cases of *atresia* of the external urethral orifice fall into this category. A few cases of *true duplicity* of the urethra, within a single penis, each urethra possessing internal and external urethral orifices, have been reported. Under the term *incomplete duplication*, or *accessory urethral canals*, have been recorded a variety of anomalies, in which an accessory channel lies either dorsal or ventral to the normal urethra. Some of these channels lead off from the urethra at some point along its course forming a bifid urethra, and terminate separately on either the dorsum or urethral surface of the penis. Others have been traced upward to terminate either blindly in the region of the symphysis, or into some other organ as the prostate, ejaculatory ducts, or rectum.

Paraurethral ducts are small blind pits which open on the glans usually near the external urethral orifice. Usually they are but a few millimeters in depth but may be longer, and occasionally they communicate with the urethra. A *lacuna magna* is a blind pocket which is found within the meatus, lying dorsal to the fossa navicularis and paralleling the urethra. The fold of mucous membrane separating it from the urethra has been termed a 'valve of Guerin.'

Congenital valves of the urethra are confined to the prostatic urethra and are modified folds of mucous membrane usually associated with the crista urethralis. They are important clinically as they frequently give rise to urinary obstruction and cause hydronephrotic atrophy of the kidney with marked dilation of the ureters.

In *hypospadias* the external urethral orifice is located proximal to its normal position on the urethral surface of the penis or in the perineum. It is the most frequent of urethral anomalies, occurring in one of about every 300 individuals. In the mildest type of the anomaly, which is also the commonest, the orifice is found on the glans just behind the normal site or at the neck of the penis. However the orifice may be located at any point along the body of the penis, at its root, in the scrotal region or in the perineum behind it. Thus a number of anatomical varieties have been described among which may be mentioned the *glandular*, *penile*, *penoscrotal*, *scrotal* and *perineal*. In all types the prepuce is malformed; it does not entirely cover the glans, but is redundant and frequently described as hood-like. As the prepuce is absent from the urethral surface, the frenulum, as such, is absent. In the penile and more severe types, the penis is small, and presents a ventral curvature, *congenital chordee*.

In the scrotal and perineal types of hypospadias the scrotum is *bifid* and the testes usually undescended, the external genitalia resembling those of the female; a pseudovagina may even be present (*false hermaphroditism*). Embryologically hypospadias is explained as a failure of the urethral groove to close properly. In the glandular type only that portion of the urethral groove which is formed by the splitting of the glandular lamella fails to close.

Epispadias is that condition in which the external urethral orifice is found on the dorsum of the penis. It is much rarer than hypospadias and frequently occurs in association with exstrophy of the bladder. It may be *glandular* in type, the orifice being located on the glans or at the neck, but more frequently it is *penile*, the orifice being located on the body of the penis, or at its root, a shallow groove extending from the orifice to the end of the penis. The penis is usually flattened dorso-ventral and the glans broad and deeply notched dorsally. The prepuce is atrophic dorsally but may be redundant ventrally. The pubic bones may be ununited, a deep cleft marking the position of the symphysis. The sphincter of the membranous urethra is absent or incomplete while the internal sphincter is poorly developed. Incontinence is a frequent symptom even when exstrophy is absent. The cause of epispadias is obscure. Its frequent association with bladder exstrophy is significant and implies a faulty development at a much earlier stage than hypospadias. The most acceptable theory is that it is due to a relative displacement anteriorly of those cells which later form the cloacal membrane; thus when the phallus appears the cloacal membrane is found on its dorsal rather than on its ventral surface.

Clinical Considerations

The urethra can be palpated with ease throughout the greater part of its course, first along the penis, then through the scrotum to the perineum where it is lost on account of its upward curvature. By rectal palpation it may again be felt as it comes through the urogenital diaphragm and enters the apex of the prostate. It cannot be felt within the prostate, but if a sound be introduced, this can readily be palpated through the substance of the prostate as far as the vesical neck.

The interior of the urethra from one end to the other can be viewed through a urethroscope. It is thus possible to examine the colliculus seminalis (verumontanum) and to observe and inject the utriculus prostaticus and the ejaculatory duct orifices.

The external urethral orifice presents the least distensible and frequently the narrowest portion of the urethra. It is often necessary to enlarge it by slitting it ventrally (meatotomy) in order to enlarge the urinary stream or to facilitate the passage of urethral instruments.

Instruments with a 'urethral curve' are more liable to follow through the urogenital diaphragm without getting caught in the bulbous portion. The membranous urethra lying within the urogenital diaphragm is firmly fixed. Therefore, when straight instruments such as cystoscopes are introduced into the bladder, the other portions of the urethra are brought into line with it. The parts are sufficiently elastic so that this can be done without undue discomfort.

The surgery of the penis and urethra includes circumcision, amputation for carcinoma, plastic operations for malformations, etc. Strictures, which most frequently are found within the bulbous region, may require *external urethrotomy.* For this purpose a median incision is made in the perineum usually over a sound or other instrument which has been introduced into the urethra to serve as a guide. The skin, two layers of fascia, the bulbo cavernosus muscle, and the erectile tissue of the corpus cavernosum urethræ must be incised before the urethra is reached.

Urinary extravasation into the soft tissues surrounding the urethra occasionally occurs in cases of stricture where there has been a break in the urethral mucosa proximal to the stricture. The most frequent site of gonorrheal strictures is that portion of the urethra within the bulb and this is also the most favorable site for extravasations. When the urine escapes from the urethra under pressure from above it penetrates the soft tissues and, following the path of least resistance, travels upward until it comes in contact with the inferior layer of the urogenital diaphragm (fig. 1103). It then is directed posteriorly but cannot reach the rectum or ischiorectal fossa because of the attachment of the superficial perineal (Colles') fascia to the posterior border of the urogenital diaphragm. It therefore passes downward and then forward beneath Colles' fascia through the perineum, over the surface of the scrotum, and upward on either side of the root of the penis. Here it may extend downward on the penis as far as the glans to which Colles' fascia is attached (Wesson). Occasionally the extension to the penis is blocked, supposedly by a fusion of Colles' to Buck's fascia at the base of the penis. Any further escape of urine follows upward over the abdominal wall under the superficial abdominal (Scarpa's) fascia which is directly continuous with Colles' fascia. In severe cases the extravasated urine may travel upward under the superficial abdominal fascia as high as the axillæ. When the extravasation takes place above the urogenital diaphragm it cannot travel backward because of Denonvilliers fascia which bears the same relation to the superior layer of the urogenital diaphragm that Colles' fascia does to the inferior layer (Wesson). It therefore travels forward and into the prevesical space.

Abscesses of the prostate and seminal vesicles usually are not confined by the fascial planes and frequently break into the ischiorectal fossa or rectum.

10. The Prostate Gland

The **prostate gland** [prostata] (figs. 1103, 1104, 1111, 1118 and 1119) is an organ composed of glandular and muscular tissue which surrounds the proximal portion of the male urethra. It is a more or less flattened conical structure whose *base* [basis prostatæ] (facies vesicalis NK) is directed upward and is in contact with the lower surface of the bladder while the *apex* [apex prostatæ] points downward and is located just above the deep fascia of the urogenital diaphragm. Its *anterior surface* [facies anterior] (f. pubica NK) is directed toward the symphysis pubis, from which it is separated by the pudendal plexus of veins and a considerable amount of areolar or adipose tissue in the lower part of the prevesical space of Retzius. Its *posterior surface* [facies posterior] (f. rectalis NK) is separated from the anterior wall of the lower portion of the rectum by a double layer of fascia (Denonvilliers), which is continued upward over the seminal vesicles while laterally it joins with the endopelvic fascia (fig. 1103). *Laterally* the prostate is in relation with the levatores ani and the venous prostatic plexus.

The *urethra* enters the base of the prostate near its anterior surface and descends through it almost vertically, so that the greater portion of the gland is posterior to the canal. On the posterior surface of the gland is a more or less distinct median vertical groove, (*median sulcus*) which serves to separate the *lateral lobes* [lobus dexter et sinister], although the demarcation is merely superficial. The groove terminates above in a well-marked notch on the posterior border of the base (*median notch*) and immediately in front of this there is a deep funnel-shaped depression of the surface, which receives the ejaculatory ducts (figs. 1112, 1118).

Beginning at this depression two grooves pass forward and slightly lateralward across the base of the prostate, marking off a more or less pronounced median elevation, which, when enlarged, constitutes what is termed the *middle lobe* [lobus medius] (fig. 1118). Ordinarily, however, this middle portion of the prostate, seen in median section between the urethra and the ejaculatory duct, forms merely a commissure [*isthmus prostatæ*] joining the lateral lobes (partes laterales NK).

Dimensions.—The longest *axis* of the prostate, which is almost vertical in the erect posture measures 2.5–3.0 cm., the *transverse* diameter at the base is 4.0–4.5 cm. and the *thickness* 2.0–2.5 cm. Its *weight* is normally 20–25 grms. but in old age it may be double that, its dimensions having correspondingly increased.

Structure.—The prostate consists of some 15–30 branched tubular glands imbedded in a stroma of connective tissue, containing a large amount of smooth muscle-tissue and forming at the surface of the prostate a strong fibromuscular *capsule* (capsula prostatæ NK) from which prolongations are contributed to the pubovesical ligaments and muscles. The glands, which vary greatly in their development, are outgrowths from the mucous membrane of the urethra, into which their ducts open at the bottom of the grooves that lie lateral to the crista urethralis; similarly, the matrix with its muscle-tissue is evidently the modified muscular coat of the urethra. Consequently there is no distinct demarcation between the wall of the urethra and the substance of the prostate, and from the developmental standpoint the prostate is to be regarded as the modified wall of the urethra.

Vessels and nerves.—The *arterial* supply of the prostate is derived from the inferior vesical and middle hemorrhoidal branches of the hypogastric artery. The *veins* form a rich prostatic plexus in the immediate vicinity of the gland, this being part of the pudendal plexus around the lower part of the bladder and communicating posteriorly with the hemorrhoidal plexus and superiorly with the vesical plexus. It drains finally into the hypogastric vein. The *lymphatics* are very abundant and form a network on the posterior surface of the gland from which several vessels pass to the hypogastric nodes. The *nerves* are derived from the hypogastric plexus.

11. The Bulbourethral Glands

The **bulbourethral glands** [gl. bulbourethralis (Cowperi)] or **Cowper's glands** (figs. 1111, 1118, 1119) are two small tubuloalveolar glands which lie one on either side of the membranous portion of the urethra, imbedded among the fibers of the sphincter urethræ membranaceæ and between the two fascial layers of the urogenital diaphragm. Each is a rounded body with a diameter of 4.0–9.0 mm. and is drained by a duct [ductus excretorius] which perforates the superficial fascia of the urogenital diaphragm, traverses the substance of the bulb of the corpus cavernosum urethræ and opens on the floor of the bulbar portion of the urethar after a total course of 3.0–4.0 cm. They form a mucoid secretion which is a component of the seminal fluid. The glands are supplied by the *artery to the bulb*.

Development of the prostate and bulbourethoral glands.—The prostatic tubules arise as solid epithelial sprouts from the prostatic urethra in embryos of 50–55 mm. (fig. 1121). They arise at about the same time from the posterior, lateral and anterior walls of the urethra and penetrate the mesenchyme in which myoblasts are already discernible. The tubules grow rapidly in length, branch, and acquire lumens. The glands arising from the posterior wall above the ejaculatory ducts form a group which becomes the median lobe: the remaining ones are closely packed together (fig. 1122). As the glands leave the urethra they are directed outwards (away from the urethra) and bladderward, a characteristic which obtains in the adult.

The bulbourethral glands appear somewhat earlier than the prostate (embryos of 30 mm.) but like the latter they begin as solid epithelial outgrowths. They are located on the ventral surface of the urethra in the bulbous portion and grow bladderward paralleling the urethra. Their ducts grow rapidly in length, soon acquire lumens, and pierce the proximal sheath of the bulb. The distal end of the duct branches to form the body of the gland which lies between the two layers of the urogenital diaphragm and behind the M. sphincter urethræ membranaceæ. Other branches arise later from that portion of the duct which traverses the bulb, intrabulbar branches, but these form a small portion of the gland as compared with the *extrabulbar* portion.

Variations and anomalies. Besides the ordinary size variations of the normal prostate it may show considerable variation in form as determined by rectal examination. There is usually a sulcus in the midline on the posterior surface but it may be either wide or narrow, deep or shallow, and occasionally it may be absent. The same is true of the median notch in which the median sulcus terminates above.

Congenital malformations of the prostate are frequent in anomalies which seriously affect other portions of the urogenital system such as epispadias, exstrophy, and the severer forms of hypospadias. In these one may find complete absence of the prostate or it may be reduced to a few scattered glands. Anomalies of the bulbourethral glands usually affect their ducts; there may be a single duct for both glands, or one duct may become obliterated, the gland then giving rise to a cyst which, if it becomes large enough, may appear in the septum of the scrotum. Accessory bulbourethral glands are not infrequent: they may open into the membranous urethra or into the bulbous portion of the cavernous urethra, distal or proximal to the openings of the main ducts.

Clinical Considerations

The prostate is subject to infections which may enter it either from the urethra or through the blood stream. It frequently is infected during the course of a gonorrheal urethritis when it may take the form of a diffuse swelling or of a prostatic abscess. Treatment of the prostate by massage consists in inserting the finger into the rectum and rubbing it in the direction from its upper and lateral borders towards its apex. In this manner the prostatic tubules are stripped of their secretion which can be obtained from the urethra and studied microscopically. In cases of unoperated prostatic abscesses, there may be a rupture of the abscess into the urethra or into the rectum, or it may extend into the ischiorectal fossa.

Operations upon the prostate are carried out for abscesses and for tumors, both benign and malignant. In the former (prostatostomy) a median incision in front of the anus is usually employed and the prostate approached between the rectum and the bulb. In adenoma of the prostate (hypertrophied prostate) the tumor mass lies in each lateral and in the median lobes. The result is obstruction to urination either by pressure upon the urethra by the two lateral

lobes, or by the ball valve action of the median lobe which grows into the bladder and closes off the internal orifice.

In the removal of an adenoma of the prostate the gland may be approached either transvesically or by way of the perineum. In the former (*suprapubic prostatectomy*) a cystostomy is first made (p. 1368) and the adenoma is reached by inserting a finger into the internal orifice and tearing through the vesical wall, now much thinned out on account of the intravesical bulging of the tumor. In *perineal prostatectomy* an inverted U-shaped incision is made about 2–3 cm. in front of the anus and just behind the central point of the perineum. The fibers of the sphincter ani externus which join the central point are cut transversely and careful dissection proceeds upwards anterior to the rectum and behind the bulb. A small group of muscle fibers, the rectourethralis muscle, which joins the rectum with the urethra, is cut across allowing the rectum to fall backward. With a sound as a guide the urethra is opened just above the urogenital diaphragm which also marks the apex of the prostate. The fascial sheath (Denonvilliers) on the posterior surface of the prostate is then picked up and its two layers divided. The prostate is exposed by separating these two loosely united layers, one of which remains adherent to the rectum, and the other to the prostate. An incision through the prostatic capsule exposes the adenoma which is then enucleated with the finger.

THE FEMALE REPRODUCTIVE ORGANS

The organs of reproduction in the female consist of (1) the *ovaries*, in which the ova are developed; (2) the *uterine tubes* (Fallopian tubes), which serve to convey

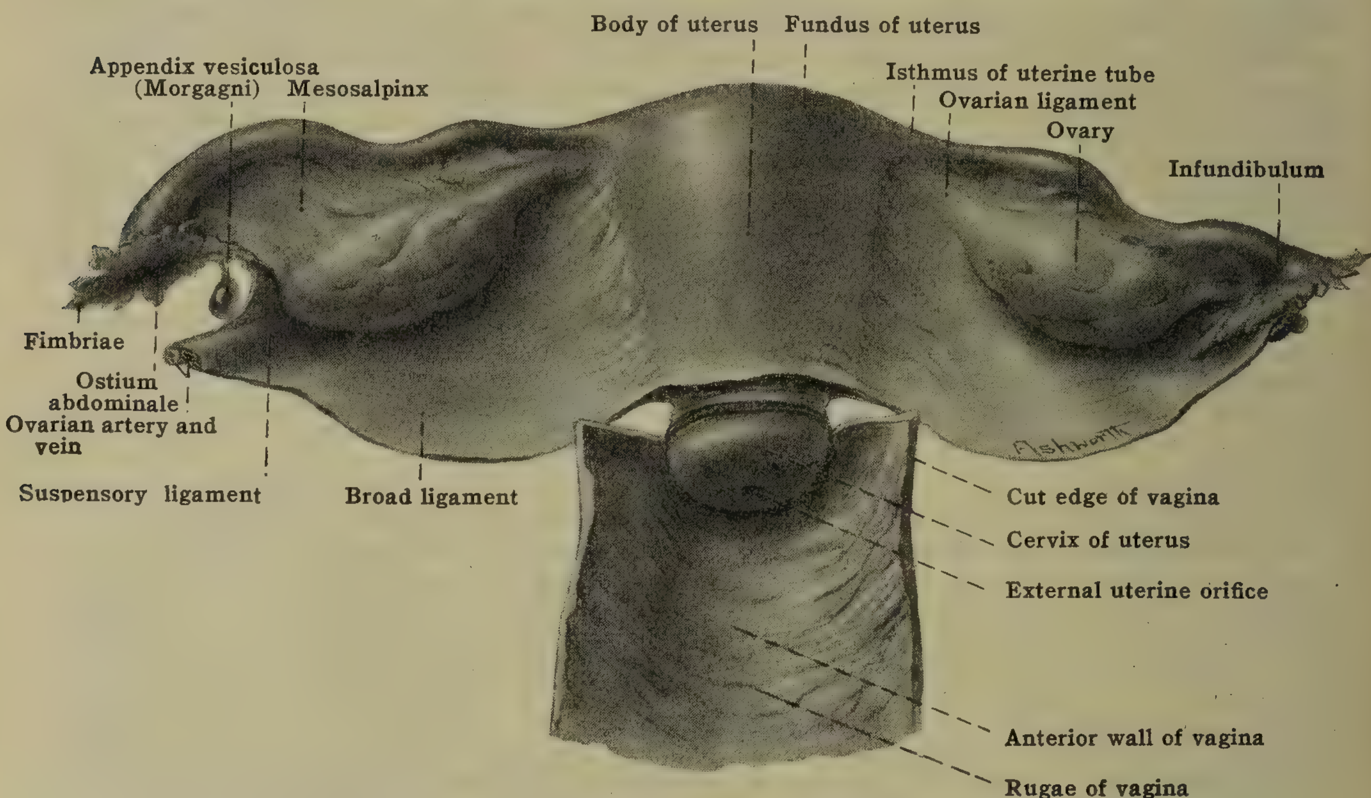


Fig. 1123.—Female Organs of Reproduction, as Seen from Behind. The posterior wall of the vagina has been opened and spread about.

the ova to (3) the *uterus*, in which the embryo normally undergoes its development; (4) the *vagina*, a canal by which the uterus is placed in communication with the exterior; and (5) the *external genitalia*. In addition the female *urethra*, although not belonging primarily to the reproductive organs, on account of its intimate relationship to them, will be considered here.

Broad ligament.—The ovaries, uterine tubes and uterus are entirely contained within the minor pelvis and are associated with a transverse fold of peritoneum which rises from the floor of the pelvic cavity between the bladder and the rectum, incompletely dividing the cavity into an anterior and a posterior compartment. It is known as the *broad ligament* (or ligaments) of the uterus [lig. latum uteri] (figs. 1123, 1124, 1127).

The usual description of the broad ligament does not make it clear whether this is to be regarded as a paired structure, i. e. right and left broad ligaments, or as a single unpaired structure with right and left halves, the uterus lying in the mid-line between its two layers. Just as the uterus is formed from the union of right and left Müllerian ducts, the broad ligament is formed by a fusion of peritoneal folds of the two sides. To regard it as an unpaired structure is not, therefore, illogical. From a purely descriptive point of view, however, it appears preferable to recognize right and left broad ligaments, along with the paired structures (ovarian ligament, round ligament, uterine tube, etc.) which each contains.

When the uterus is in its normal position the medial portion of each broad ligament is tilted forward so that its *anterior surface* is directed downwards as

well as forwards, and its *posterior surface* upwards as well as backwards. Laterally, however, where it is attached to the pelvic wall, it is more nearly vertical in

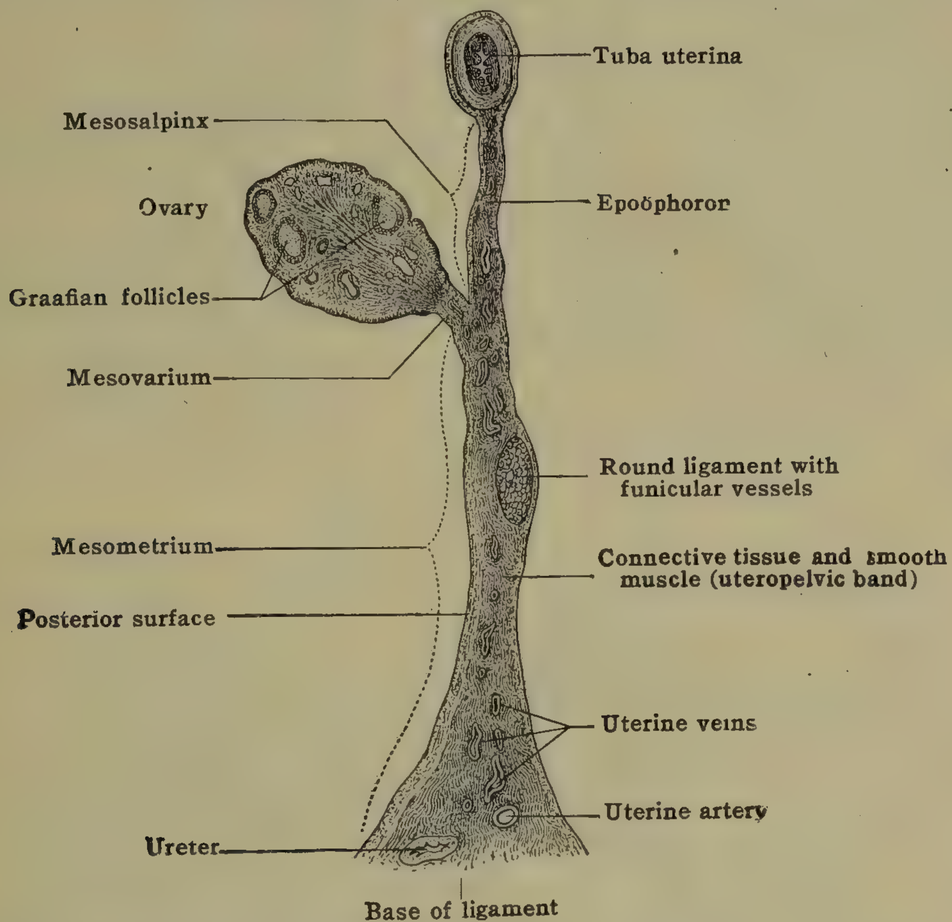


FIG. 1124.—DIAGRAMMATIC SAGITTAL SECTION OF THE BROAD LIGAMENT.

position. Its broad inferior border is attached to the floor of the pelvis below, where the two layers are reflected, the one upon the anterior wall of the pelvis

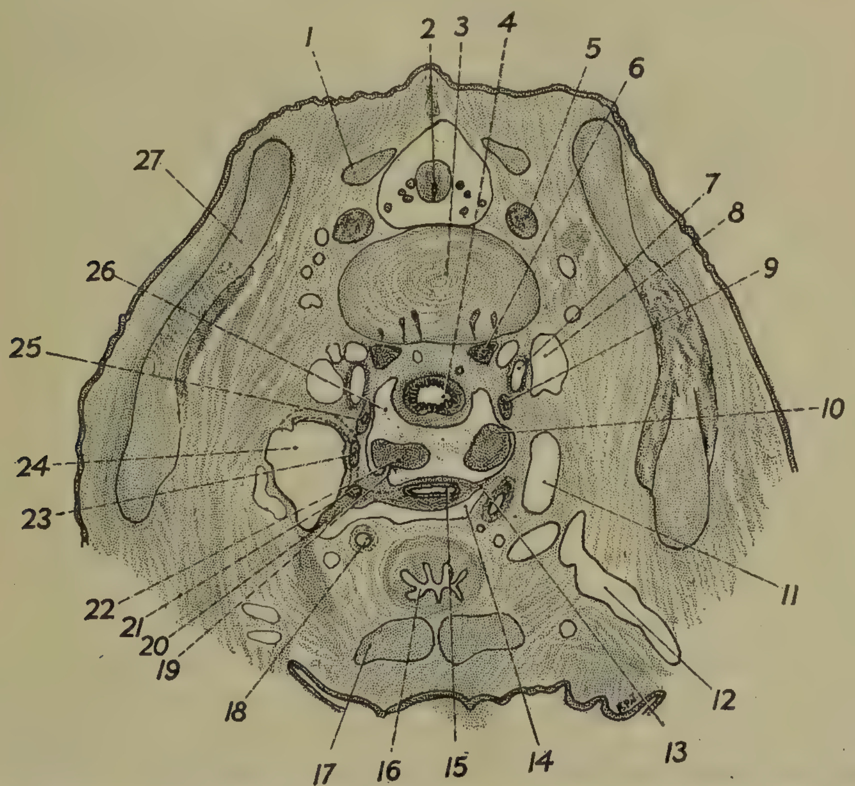


FIG. 1125.—CROSS-SECTION THROUGH THE PELVIS OF AN EMBRYO OF 99 MM. (Carnegie Embryological Collection No. 3327.) The course of the right uterine tube is shown by a dotted line.

1, Neural arch. 2, Spinal cord. 3, Body of vertebra. 4, Colon. 5, Dorsal ganglion. 6, Sympathetic ganglion. 7, Umbilical artery. 8, Umbilical vein. 9, Ureter. 10, Ovary. 11, Part of celom. 12, External iliac vein. 13, Broad ligament (mesometrium). 14, Vesico-uterine pouch. 15, Body of uterus. 16, Bladder. 17, Pubis. 18, Umbilical artery. 19, Mesovarium. 20, Gubernaculum (round ligament). 21, Uterine tube. 22, Ovary. 23, Uterine tube. 24, Part of celom. 25, Ureter. 26, Celom. 27, Ilium.

and the superior surface of the bladder, and the other posteriorly over the floor of the pelvis to the posterior pelvic wall and the rectum, forming the anterior

wall of a deep depression between the rectum and uterus, known as the *rectouterine pouch* (*of Douglas*) [excavatio rectouterina (cavum Douglasi)] (figs. 1126, 1132). The lateral border rests upon the pelvic fascia of the side of the pelvis. The upper border is free and contains the uterine tube while the medial border is attached to the lateral border of the uterus. The most lateral portion of the upper border forms the *suspensory ligament of the ovary* (figs. 1126, 1132), through which the ovarian vessels enter the broad ligament. It is to be noted that the broad ligament in its upper part is not straight but is folded back upon the lateral walls of the cavity, following the course of the uterine tubes.

The ovary, which projects into the posterior compartment of the pelvis, is attached to the posterior layer of the broad ligament a little below its upper border by a thick short fold, the **mesovarium.** The portion of the broad ligament above this is known as the **mesosalpinx,** while that below is termed the **mesometrium.** The remaining structures that occur between the two layers of the broad ligament are the ovarian ligaments, the round ligaments, the uterine arteries and veins, the epoöphoron and the paroöphoron, all of which will be described with the organs with which they are associated.

The different parts and structures of the broad ligament are best seen when it is removed from the pelvis and spread out flat as in figs. 1123 and 1127. The student should bear in mind that its relationships are greatly distorted by such dissections.

Development.—The broad ligament is the adult representative of the fold of peritoneum which encloses the embryonic excretory organ, the mesonephros. This is for a time a voluminous organ, projecting under cover of the peritoneum from the dorsal wall of the abdomen and bearing upon its medial wall a thickening, the **genital ridge** from which the reproductive gland develops (fig. 62, B). In the free edge of the peritoneal fold two ducts occur, (1) the **Wolffian duct,** which is the duct of the excretory organ and becomes the ductus deferens of the male, and (2) the **Müllerian duct.** With the progress of development the two Müllerian ducts fuse in the lower portions of their course to form the uterus and vagina (prostatic utricle of the male), while in their upper parts they remain separate and form the tubæ uterinæ. By this fusion the two peritoneal folds are brought into continuity at their edges, and (the mesonephros degenerating with the formation of the permanent kidney) constitute the broad ligament (fig. 1125). This structure therefore contains between its two layers the uterus and the remains of the mesonephros, and has the ovary attached to its posterior surface.

1. The Ovaries

The **ovaries** [ovaria] (figs. 1123, 1124, 1126), are two whitish organs, situated one on either side of the pelvic cavity, each being about the size and shape of an unshelled almond. It measures 2.5 to 5 cm. in length, 1.5 to 3 cm. in breadth (antero-posteriorly) and .7 to 1.5 cm. in width, and weighs from 4 to 8 gms. For descriptive purposes are recognized two surfaces, *medial* and *lateral;* two borders, an *anterior* [*margo mesovaricus*] and a *posterior* [*margo liber*]; and two extremities, an *upper* [*extremitas tubaria*] and a *lower* [*extremitas uterina*]. The *medial surface* is rounded and posteriorly may show numerous rounded elevations, scars, and serrations, which mark the position of developing and ruptured follicles. Its upper portion is in relation to the fimbriated extremity of the uterine tube while the remainder lies in contact with a loop of the intestine. The *lateral surface* is similar in shape and lies in relation to the pelvic wall, where it forms a distinct depression, the *fossa ovarica.* This fossa is lined by peritoneum and is bounded above by the external iliac vessels and below by the obturator vessels and nerve; its posterior boundary is formed by the ureter and uterine artery and vein, while anteriorly is the pelvic attachment of the broad ligament. The *mesovarial border* is more or less straight and as the name implies, serves for the attachment of the short *mesovarium* by which the ovary is attached to the broad ligament. Related to this border medially is a portion of the uterine tube. Since the vessels, nerves, and lymphatics enter the ovary through the mesovarial border it is spoken of as the *hilus* of the ovary. The free border is more convex and broader and is directed into the rectouterine pouch. The *tubal extremity* is large and rounded and lies in relation to the free extremity of the uterine tube. The *suspensory ligament* of the ovary has its origin from this extremity. The *uterine extremity* is smaller, is directed toward the uterus and serves for the attachment of the *ovarian ligament* (chorda uteroovarica NK).

Ligaments.—In addition to its attachment to the broad ligament through the *mesovarium,* the ovary is also connected to the side of the uterus by the *ovarian ligament* [lig. ovarii proprium] (figs. 1123, 1126), a band of connective tissue with which numerous smooth muscle-fibers are intermingled. This lies

between the two layers of the broad ligament, on the boundary line between the mesosalpinx and the mesometrium, and extends from the uterine pole of the ovary to the side of the uterus. Here it is attached just below the origin of the tuba uterina and above the point of attachment of the round ligament of the uterus, with which it is primarily continuous. Another ligament, termed the *suspensory ligament* of the ovary (figs. 1126, 1132), extends laterally between the two layers of the broad ligament, from the tubal extremity of the ovary to the pelvic walls, forming the lateral portion of the free boundary of the broad ligament. It is formed chiefly by the vessels and nerves (ovarian) passing to and from the ovary, and from the point where it meets the lateral pelvic wall it may be traced upward for some distance upon the posterior wall of the abdomen, behind the peritoneum, which it elevates into a more or less distinct fold, whose lateral wall on the right side becomes continuous above with the peritoneum lining the subcecal fossa.

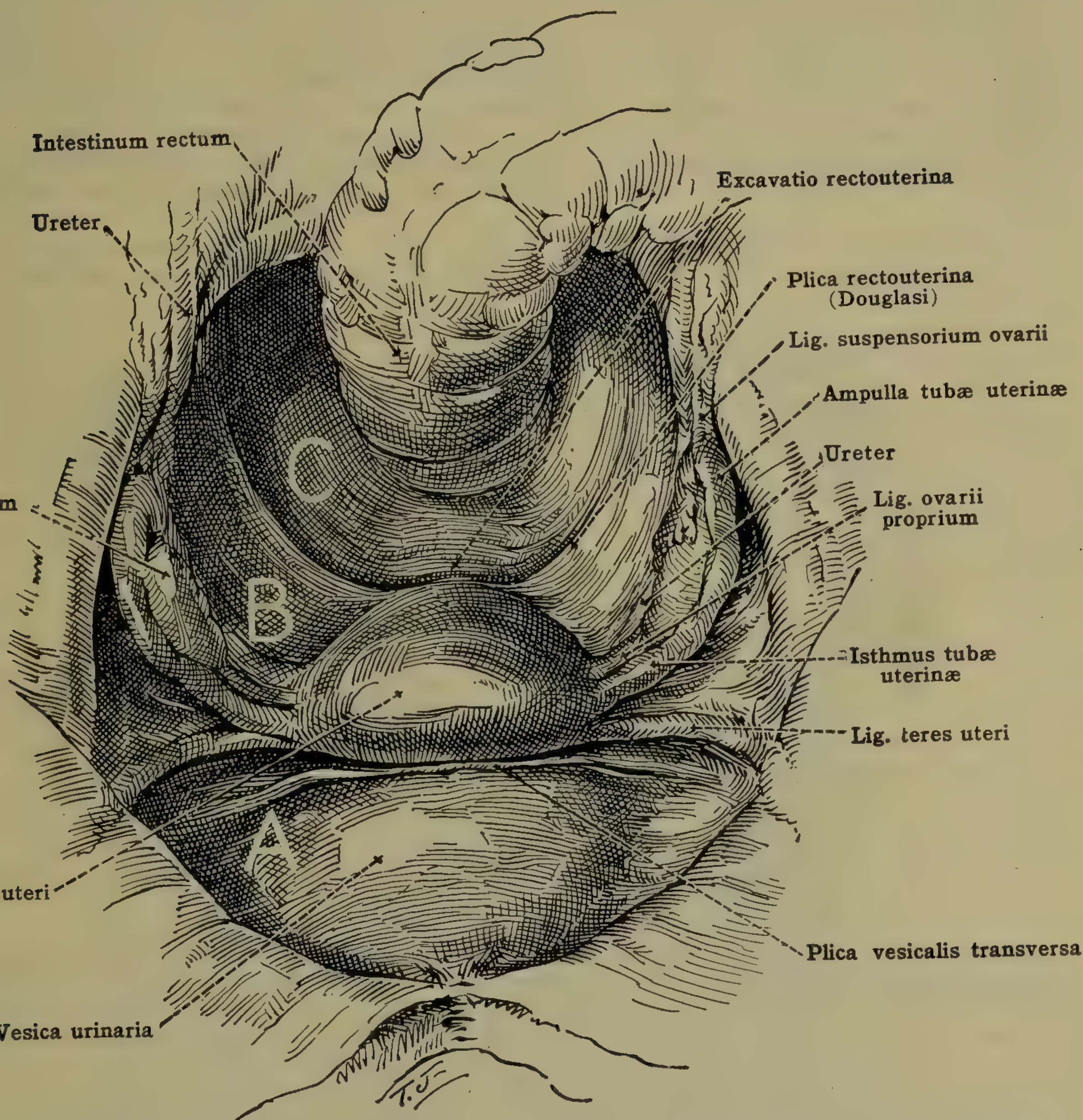


FIG. 1126.—THE FEMALE PELVIC ORGANS VIEWED FROM ABOVE. (Spalteholz.) A, paravesical fossa; B, paragenital fossa; C, pararectal fossa.

Structure.—The ovary is covered by a layer of columnar epithelium which is continuous with the peritoneal epithelium along the line of the attachment of the mesovarium. This epithelium, derived primarily from the celomic epithelium, constitutes a modified peritoneum, although a peritoneal lining such as is present around other abdominal viscera, does not exist around the ovary. It is supported by a network of connective tissue, in which smooth muscle-fibers also occur, which is known as the *stroma*. The more central portions of this are largely occupied by blood-vessels but in the cortical portions are multitudes of immature ova, surrounded by their follicle-cells [folliculi oophori primarii]; and also numbers of cavities of various sizes, lined with follicle-cells and filled with fluid, each containing an ovum [ovulum] in a more or less advanced stage toward maturity. These are the *Graafian follicles* [folliculi oophori vesiculosi (Graafi)], and as they ripen they increase in diameter and approach the surface, upon which they may form marked prominences (fig. 1124). When mature the follicle bursts allowing the escape of the ovum, and the follicle becomes transformed into a *corpus luteum*. This in turn is later replaced by scar-tissue, forming a *corpus albicans*. If the ovum becomes fertilized and pregnancy results, the corpus luteum becomes larger and persists longer (*corpus luteum of pregnancy*).

Epoöphoron and paroöphoron.—Closely associated with the ovaries are two rudimentary organs situated between the layers of the mesosalpinx and representing the remains of the mesonephros of the embryo. The larger of these is the *epoöphoron* (parovarium; organ of Rosenmüller) fig. 1127). It consists of a longitudinal duct [ductus epoöphori longitudinalis Gartneri)], lying parallel with the uterine tube and closed at either extremity, and also 10–15 transverse ducts [ductuli transversi] which open into the longitudinal duct. It is the remains of the upper or reproductive portion of the mesonephros and therefore is the homolog of the head of the epididymis of the male, the longitudinal duct being the remains of the Wolffian duct while the transverse ducts are the remains of the mesonephric ducts (fig. 1141). In addition there is frequently to be found in the neighborhood of the epoöphoron and close to the mouth of the tuba uterina one or more stalked, oval cysts, the *appendices vesiculosi* (*hydatids of Morgagni*), which may reach the size of a small pea (figs. 1123 and 1141).

The other rudimentary organ is the *paroöphoron.* It is much smaller than the epoöphoron and usually disappears before adult life, but when present consists of a small group of coiled tubules usually visible only with a lens, representing a portion of the excretory part of the mesonephros. Its equivalent in the male is the paradidymis (fig. 1141).

Vessels and nerves.—The chief *artery* is the ovarian, which together with the ovarian veins and lymphatics passes to the ovary in the suspensory ligament. An additional blood supply is furnished by the ovarian branch of the uterine artery. The *veins* follow the course of the arteries. As they emerge from the hilus they form a well-developed plexus (*pampiniform plexus*) between the layers of the mesovarium. Smooth muscle-fibers occur in the meshes of the plexus and the whole structure has much the appearance of erectile tissue. The *lymphatics* accompany the blood-vessels and terminate in the lumbar nodes. *Nerves* pass to the ovary with the ovarian artery from the ovarian plexus and from the hypogastric plexus.

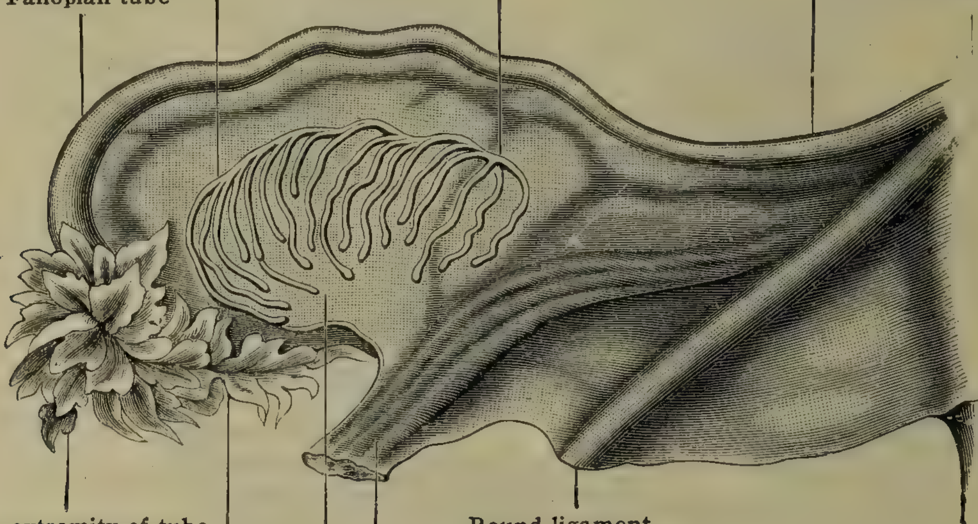


Fig. 1127.—The Broad Ligament and its Contents, Seen from the Front. (After Sappey.)

Development.—The ovary develops at the postero-mesial border of the Wolffian body from the genital ridge, and its early development is similar to that of the testis (see p. 56). Although sex of the individual is determined at the time fertilization of the ovum takes place, it is not manifested so far as the form and structure of the tissues are concerned until a much later period. If the genital gland is to become a testis medullary cords grow down into the stroma from the modified celomic epithelium; if an ovary, cells similarly grow downward but definite medullary cords are not formed. This differentiation becomes apparent in embryos of 11 to 13 mm. in length. The subsequent histogenesis of the ovary consists in growth changes in certain of these epithelial cells which become the sex cells or ova, and in the formation of the Graafian follicles from others.

In the embryo the genital ridge (later to form the ovary) is an elongated organ extending from the diaphragm to the pelvis; in late fetal stages, as in the adult, the ovary lies entirely within the pelvis. This apparent migration is, according to Felix, not a true descensus but is brought about by a degeneration of the abdominal portion of the genital ridge and a retention of its pelvic portion. The ligaments which unite to form the gubernaculum in the male, fail to unite in the same way in the female because of the retention of the fused Müllerian ducts. The homologue of the gubernaculum testis in the female includes the ovarian ligament, a part of the wall of the uterus, and the round ligament.

Variations.—In addition to the wide variation in size of normal adult ovaries, mentioned above, there are certain physiologic states that affect its size. In the early postnatal and in the prepuberal period it is smaller than in the adult but varies markedly on account of variation in size of its Graafian follicles. During pregnancy, because of the development of the large 'corpus luteum of pregnancy' the organ increases in size. In old age, because of the lack of follicles and the contracture of the corpora albicantes, the ovary may be reduced to one-third its original size and weight.

Variations in position are frequently caused by a displacement of the fundus of the uterus. This in turn drags the uterine extremity of the ovary through the medium of the ovarian liga-

ment toward the midline. The long axis of the ovary thus becomes oblique, approaching more or less the horizontal.

Congenital anomalies.—Bilateral absence of the ovaries is a rare anomaly and is found only in non-viable monsters. *Unilateral absence* has been reported associated with absence of the corresponding uterine tube. Such cases of true absence are, however, to be distinguished from atrophy of a once formed ovary. *Supernumerary ovaries* associated with a third uterine tube, although very rare, have been reported. *Divided ovaries* (*ovaria bipartita*) are more common and are due to an early division of the ovarian anlage.

The *anomalies of position* include cases in which there is a failure of the gubernaculum to unite with the fundus of the uterus. The ovarian and round ligaments become continuous, as do their homologues in the male, and by a failure to lengthen pull the ovary down through the inguinal canal into the labium majus. A persistent peritoneal pouch, known as the *canal of Nuck*, which corresponds to the vaginal process of the male, is occasionally found.

Clinical Considerations

The most apparent function of the ovary is the formation of mature ova. These develop from the germ cells, but they are aided by other epithelial and supporting cells which give rise to the Graafian follicles above described. When mature the Graafian follicle ruptures through the epithelial lining of the ovary and the ovum escapes and enters the uterine tube. This constitutes *ovulation*, which takes place in cycles of approximately 28 days, probably alternately from one ovary and then the other. In addition the ovary is known to give rise to an internal secretion or hormone which determines the secondary characteristics of the female, and probably others which regulate menstruation.

Palpation of the ovary is possibly only bimanually. The fore-finger of one hand is placed deeply into the posterior fornix of the vagina. The other hand is placed on the lower abdominal wall on the side to be examined and by making firm pressure inward and downward the ovary is pushed toward the examining finger in the vagina where it can be felt.

Operations upon the ovary are principally for cystic or solid tumors, or for pelvic inflammatory disease. The approach is usually a mid-rectus incision which begins just above the symphysis and extends to the umbilicus. The anterior sheath of either rectus muscle is opened close to the linea alba and the rectus muscle pulled laterally. An incision is then made through the posterior rectus sheath and the peritoneum but lateral to the anterior one, in order thus to lessen the danger of a subsequent hernia. In order to obviate opening the bladder, catheterization is a preliminary step to the operation. When greater exposure is demanded the incision is carried upward *to the left* of the umbilicus thus avoiding the round and falciform ligaments of the liver. In the removal of an ovary its two-fold arterial supply, the ovarian artery and ovarian branch of the uterine, must be remembered, each of which requires careful ligation.

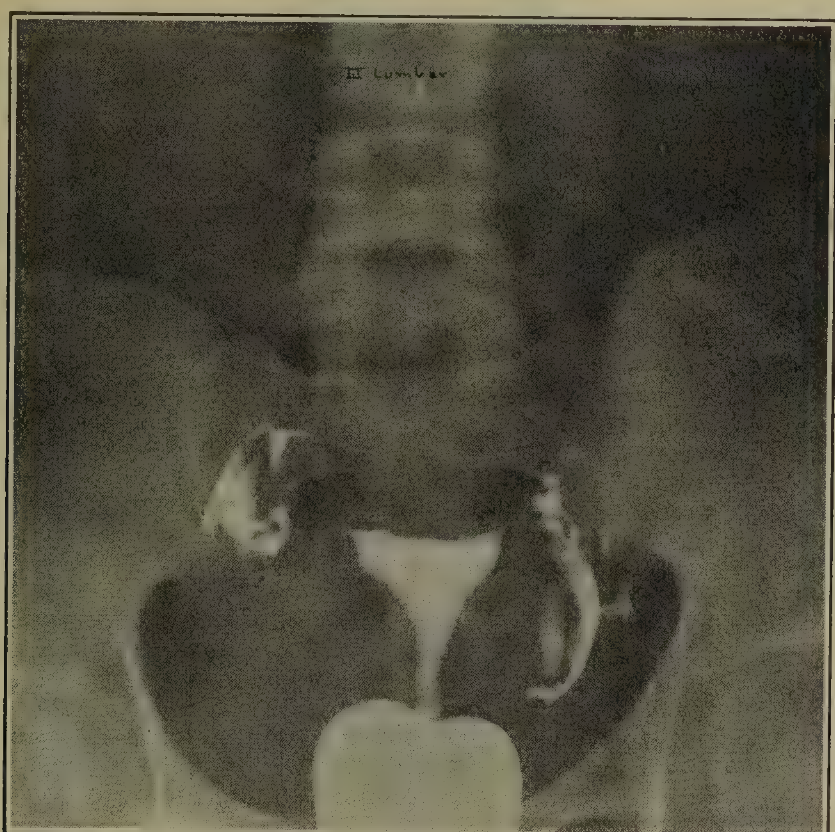


Fig. 1128.—Uterogram. The uterus and uterine tubes have been filled with lipiodol. Since the tubes are patent the fluid escapes into the peritoneal cavity, hence the irregular masses on either side.

2. The Uterine Tubes

The **uterine or Fallopian tubes** [tubæ uterinæ] (figs. 1123 to 1127) serve to convey the ova to the uterus. They are two trumpet-shaped tubes, continuous with the superior angles of the uterus and running in the superior border of the

broad ligament (mesosalpinx) to come into relation with the ovaries distally. Each tube opens proximally into the uterine cavity and distally communicates with the pelvic portion of the peritoneal cavity by a funnel-shaped mouth, the **ostium abdominale,** which under normal conditions is closely applied to the surface of the ovary, so as to receive the ova as they are expelled from the Graafian follicles. Each tube is from 7 to 14 cm. in length and consists of a narrow straight portion, the **isthmus,** immediately adjoining the uterus, followed by a broader more or less flexuous portion, the **ampulla,** which terminates in a funnel-like dilation, the **infundibulum.** The margins of the infundibulum are fringed by numerous diverging processes, the **fimbriæ,** one of which, the **fimbria ovarica,** is much longer than the rest and extends along the free border of the mesosalpinx usually reaching the tubal pole of the ovary.

From its attachment to the uterus, the course of each tube is at first almost horizontally laterally and backward until reaching the lateral wall of the pelvis, it comes into relation with the uterine extremity of the ovary (figs. 1128, 1136 and 1142). It then bends at right angles and passes upward along the mesovarial border of the ovary until it reaches its tubal extremity, where it curves downward and backward so that the mouth of the infundibulum and the fimbriæ rest upon the medial surface of the ovary.

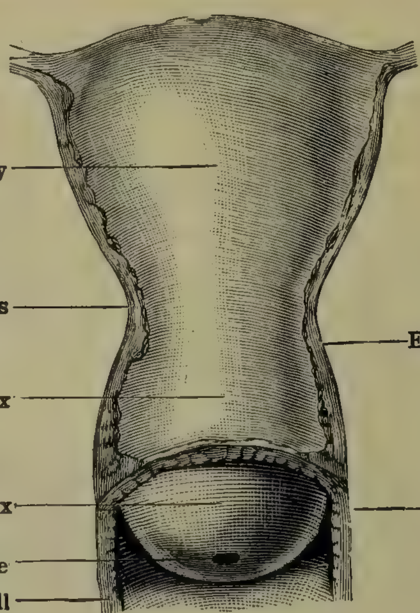


FIG. 1129.—THE POSTERIOR SURFACE OF THE UTERUS. (After Sappey.)

Structure.—The tubes occupy the upper free edge of the mesosalpinx and are therefore enclosed within a *peritoneal covering* [tunica serosa] except a small strip along their lower surface (fig. 1124) where the mesosalpinx is attached. At the margins of the infundibulum and the borders of its fimbriæ the peritoneal epithelium becomes directly continuous with the mucous membrane lining the interior of the tube. The *subserous areolar* tissue [tunica adventitia] in the immediate vicinity of the tube is lax and contains the blood-vessels and nerves by which the tube is supplied; it forms a loose connection between the peritoneum and the *muscular wall* [tunica muscularis] of the tube. This consists of two layers of smooth muscle-fibers, an outer longitudinal and an inner circular layer, and reaches its greatest development toward the uterine end of the tube. The inner layer [tunica mucosa] of the tube is lined by a columnar ciliated epithelium which is raised into numerous folds [plicæ tubæ], simple in the region of the isthmus, but becoming higher and more complex in the ampulla, where, in transverse sections, the lumen seems to have a labyrinthine form. The beat of the cilia is toward the uterus.

Vessels and nerves.—The *arteries* of the tubes are derived from the ovarian and uterine, each of which gives off a tubal branch, which passes between the two layers of the mesosalpinx, the one medially and the other laterally, and anastomose to form a single stem. The *veins* accompany the arteries. The *lymphatics* accompany those from the ovary and fundus uteri and terminate chiefly in the lumbar nodes (fig. 662). The *nerves* of the ampulla are given off from the branches passing to the ovary, while those of the isthmus come from the uterine branches.

CLINICAL CONSIDERATIONS

The function of the uterine tube is to convey the ovum from the ovary to the uterus. Fertilization takes place (at least frequently) at the fimbriated extremity, or in the first part of the tube, spermatozoa having made their way through the uterus and tube against the action of the cilia. Occasionally it takes place on the surface of the ovary as is evidenced by ovarian pregnancies; it seems improbable that it ever takes place after it has reached the uterus. The fertilized ovum, while traversing the uterine tube, undergoes segmentation, and by the time it reaches the uterus (probably five days) has formed a chorionic vesicle.

If for any reason the progress of the ovum through the uterine tube is arrested, such as occurs by destruction of the ciliated cells through inflammatory changes, development of the ovum

continues within the tube (*tubal pregnancy*). In such cases a true decidua does not form but the chorionic vesicle is embedded in the wall of the tube and obtains its blood supply from the tubal vessels. As the vesicle enlarges the tube expands, but not being adapted to so great an expansion, finally ruptures. The ensuing hemorrhage is so great that immediate operation is necessary in order to save the mother's life.

The normal uterine tube cannot be palpated bimanually as above described for the ovary; pathological conditions, however, can frequently be made out. Diagnostic methods to determine the patency of the uterine tubes consist of insufflating air (or carbon dioxide) into the uterus; if either tube is open the gas will escape into the abdominal cavity. X-ray visualization of the tubes is made possible through the injection of lipiodol; such pictures show the course, position, size, and if present, the point of occlusion of the tube (fig. 1128).

Operations upon the uterine tube are frequently performed for inflammatory conditions including tuberculosis, and for tumors, and tubal pregnancies. The abdominal incision is the same as for operations upon the ovary. Removal of the uterine tube (salpingectomy), which becomes necessary frequently, requires ligation of its uterine end and careful ligation of the blood vessels which reach the tube through the mesosalpinx.

3. The Uterus

The **uterus** (figs. 1123 to 1127) is an unpaired organ, situated between the two layers of the broad ligaments. It communicates above with the uterine tubes and below with the vagina. It is pyriform in outline, although flattened antero-

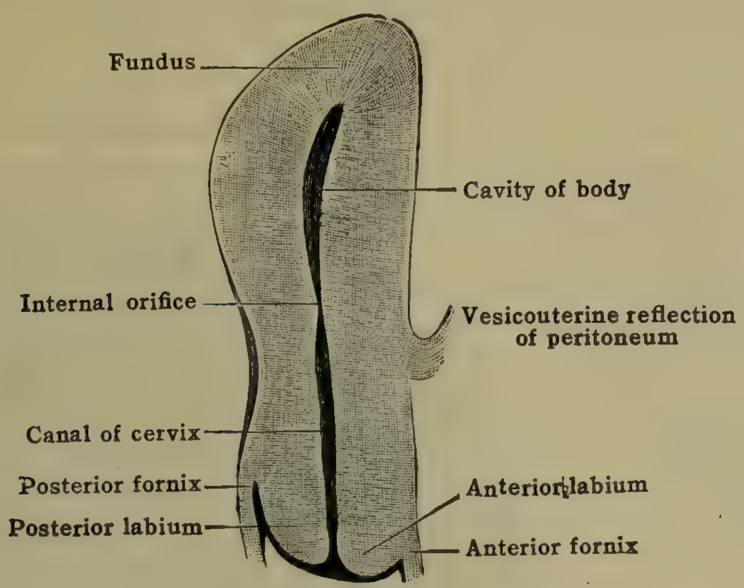


Fig. 1130.—Sagittal Section of the Virgin Uterus. (After Sappey.)

posteriorly (figs. 1129, 1130) and it is divided into two main portions, the **body** [corpus uteri] and the **cervix**, by a transverse constriction, the **isthmus**.

According to the NK nomenclature, the *isthmus uteri* is recognized as a separate segment, with a *canalis isthmi, orificium internum isthmi* and *orificium externum isthmi.*

The **body** is the portion above the isthmus and in adults, especially in women who have borne children, is much larger than the cervix, although the reverse is the case in children. At puberty the two parts are about equal in size. Its **anterior** or *vesical surface* [facies vesicalis] is almost flat (fig. 1130), while its **posterior** or *intestinal surface* [facies intestinalis] (f. rectalis NK) is distinctly convex. The two surfaces meet in the rounded *lateral margins*, at the upper extremities of which the tubæ uterinæ are attached. That portion of the body which extends above the plane passing through the points of attachment of the two tubes is thick and rounded, forming what is termed the *fundus uteri*. The *cavity* [cavum uteri] of the body is flattened anteroposteriorly (fig. 1130) but when viewed from in front or behind has a triangular form (figs. 1128 and 1131), broad above where it communicates on either side with the cavity of the uterine tubes, but narrow below where it communicates with the cavity of the cervix. This communication, which corresponds in position to the isthmus, forms the *internal orifice* [orificium internum] (internal os uteri).

The **cervix** is more cylindrical in form, though slightly expanded in the middle of its length, and is divided into a *supravaginal* [portio supravaginalis] and a *vaginal portion* [portio vaginalis] by the attachment to it of the vagina (fig. 1129). The line of this attachment is oblique, about one-fourth of the anterior surface of the cervix and about one-half of the posterior surface belonging to the vaginal portion. At the lower extremity of the cervix is the *external orifice* [orificium

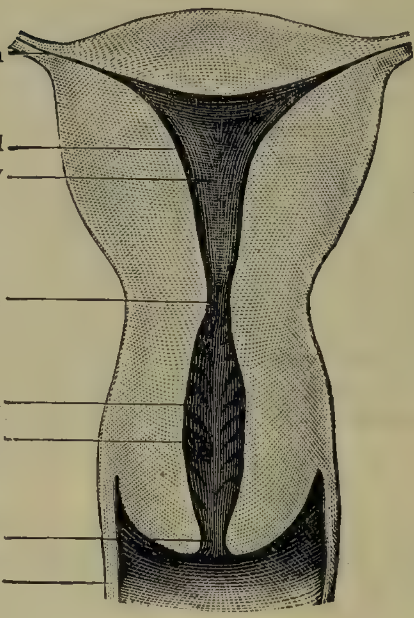


FIG. 1131.—FRONTAL SECTION OF THE VIRGIN UTERUS. (After Sappey.)

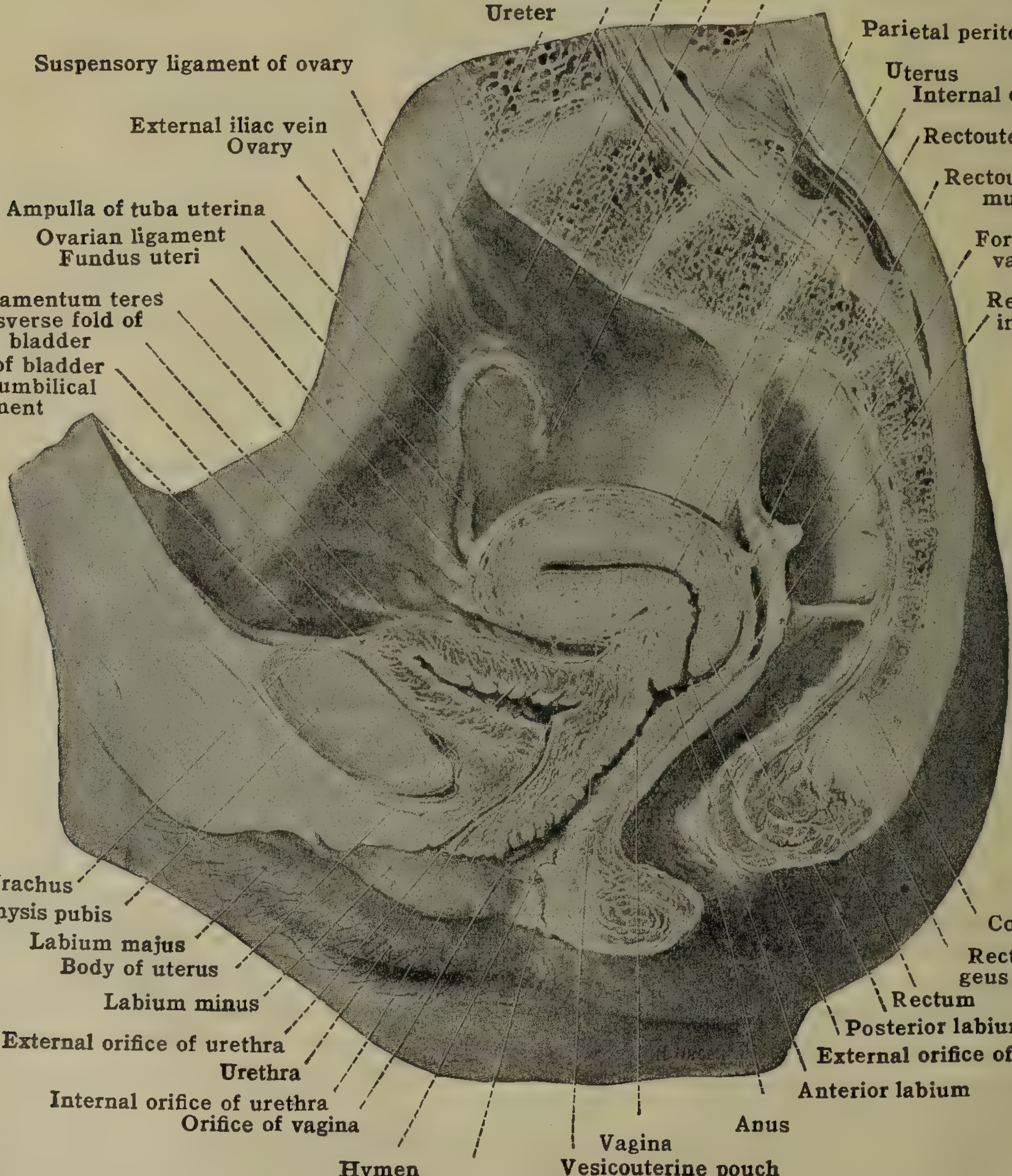


FIG. 1132.—MIDSAGITTAL SECTION OF THE FEMALE PELVIS. (Spalteholz.)

externum] (external os uteri), which is round or oval before parturition has taken place but takes the form of a transverse slit in women who have borne children. The external orifice is bounded by two *labia*, anterior and posterior which are more prominent in uteri of the latter type. The anterior labium [labium anterius] is shorter and thicker than the posterior [labium posterius] and with the uterus in the normal position reaches a lower level (figs. 1130, 1132). The *cavity of the cervix* [canalis cervicis] is fusiform in shape, and extends from the internal to the external orifice. On its anterior and posterior walls are folds known as the *plicæ palmatæ* (fig. 1131), consisting of a median longitudinal ridge from which shorter elevations extend laterally and slightly upward. These are most distinct in young individuals and are apt to become obliterated by parturition.

Position.—The direction of the axis of the uterus is apparently variable within considerable limits, not only in different individuals, but also in any one individual in correspondence with the degree of distention of the bladder anteriorly and of the rectum posteriorly. In what may be regarded as the typical condition the external orifice lies at about the level of the upper border of the symphysis pubis and in the plane of the spines of the ischia. The normal position of the body of the uterus is approximately horizontal when the woman is standing erect and when the bladder is empty. The cervix is directed slightly downward and backward, the bend occurring at the isthmus. The degree of anteflexion varies in different individuals there being no sharp line between the normal and pathological states of anterior angulation.

Relations.—The anterior surface of the uterus rests upon the upper and posterior surfaces of the bladder (figs. 1126, 1132), from which the body is separated by the uterovesical pouch of peritoneum. The anterior layer of the broad ligament and the peritoneal covering of the anterior surface of the uterus forms the posterior wall of this pouch, the peritoneum being reflected forward to the superior surface of the bladder at about the level of the isthmus (figs. 1130, 1132), so that the whole of the anterior wall of the cervix is below the floor of the pouch and is separated from the posterior surface of the bladder only by connective tissue. Posteriorly, however, the peritoneal covering of the uterus, which here forms the anterior wall of the rectouterine pouch (of Douglas), extends down as far as the uppermost portion of the vagina and consequently invests the entire surface of the uterus, whose convex posterior wall is thus separated from the rectum by the rectouterine pouch (figs. 1126, 1132). Coils of the small intestine rest upon the posterior surface of the body and may occasionally be interposed between the cervix and the rectum. An important relation is that of the ureters to the cervix; these ducts, as they pass to the bladder, course parallel with the cervix at a distance of from 8 to 12 mm. from it.

Ligaments.—The *broad ligaments* which are attached to the lateral margins of the uterus have already been described (p. 1388). In addition there is attached to each border of the uterus, immediately below the point of attachment of the ovarian ligament, the *ligamentum teres* (round ligament) (chorda uteroinguinalis NK) (figs. 1126, 1127), which is a fibrous cord containing smooth muscle-tissue. It extends downward, laterally and forward between the two layers of the mesometrium toward the abdominal inguinal ring; and, traversing this and the inguinal canal, terminates in the labium majus by becoming continuous with its connective tissue.

The round ligament is accompanied by a funicular branch of the ovarian artery and a branch from the ovarian venous plexus, and in the lower part of its course by a branch from the inferior epigastric artery, over which it passes as it enters the abdominal ring. In its course through the inguinal canal it is accompanied by the ilioinguinal nerve and the external spermatic branch of the genitofemoral.

The *uterosacral ligaments* are flattened fibromuscular bands which extend, one on each side, from the upper part of the cervix uteri to the sides of the sacrum opposite the lower border of the sacroiliac articulation. They produce the *rectouterine folds* (fig. 1126) of peritoneum, which form the lateral boundaries of the mouth of the rectouterine pouch (of Douglas) and their muscle-fibers [m. rectouterinus] are continuous at one extremity with the muscular tissue of the uterus and at the other with that of the rectum. The so-called *anterior ligament* of the uterus is the vesicouterine fold of peritoneum which is reflected on the bladder from the front of the uterus, while the *posterior ligament* is the rectovaginal fold which is reflected on the front of the rectum from the back of the posterior fornix of the vagina.

Structure.—The peritoneum which invests the uterus forms the serous covering [tunica serosa] of the organ and is sometimes termed the *perimetrium*. Over the fundus and the greater portion of the body it is thin and firmly adherent to the subjacent muscular substance of the uterus, so that it cannot readily be separated. Over the posterior surface of the cervix and the lower part of the anterior surface of the body, however, it is thicker, and is separated from the muscular substance by a layer of loose connective tissue, the *parametrium*, which also extends upward along the sides of the uterus between the two layers of the broad ligament, with whose subserous areolar tissue it is continuous. Owing to this disposition of the parame-

trium the whole of the cervix may be amputated without encroaching upon the peritoneal cavity.

The main mass of the uterus is formed by the muscle-tissue [tunica muscularis] or *myometrium,* whose fibers have a very complicated arrangement. Two principal layers may be distinguished, an outer, weak one, composed partly of longitudinal fibers continuous with those of the tubæ uterinæ, and of the round and uterosacral ligaments, and a much stronger inner one, whose fibers run in various directions and have intermingled with them in the body of the uterus large venous plexuses. The inner surface of the myometrium is lined by a mucous membrane [tunica mucosa] or *endometrium,* which has a thickness of from 0.5 to 1.0 mm. and is composed of tissue resembling embryonic connective tissue, bearing upon its free surface a single layer of ciliated columnar epithelium. On account of its structure the tissue is rather delicate and friable, and numerous simple tubular glands, which open into the cavity of the uterus, traverse its entire thickness. In the cervix the mouths of some of the glands may become occluded, producing retention cysts, which appear as minute vesicles projecting from the surface between the plicæ palmatæ; they are known as *ovula Nabothi,* after the anatomist who first described them.

Vessels and nerves.—The principal *artery* of the uterus is the uterine, whose terminal portion ascends along the lateral border of the uterus in a tortuous course through the parametrium (fig. 571), giving off lateral branches to both surfaces of the uterus. Above, it anastomoses with the ovarian artery, which thus forms an accessory source of blood supply during pregnancy. The *veins* (fig. 607) form a plexus that is drained by the ovarian and uterine veins, a communication with the inferior epigastric being also made by way of the vein accompanying the round ligament. The *lymphatics* from the greater portion of the body pass to the iliac nodes; those of the fundus accompany the ovarian vessels to the lumbar nodes. A vessel also accompanies the round ligament to terminate in one of the superficial inguinal nodes. The lymph-vessels from the cervix terminate in the external iliac, hypogastric and lateral sacral nodes. The *nerves* of the uterus come from two sympathetic ganglia, situated one on either side of the cervix, whence they are termed the cervical ganglia, and form part of the *plexus uterovaginalis.* Branches pass to the ganglia from the hypogastric plexus and also from the second, third and fourth sacral nerves.

Various physiological states of the uterus.—*In the fetus and newborn* the uterus is larger in relation to the whole body than in the adult, and the cervix and body are of approximately the same size. Its position within the pelvis is almost vertical, the cervix entering the vagina at a somewhat more obtuse angle than in the adult. The isthmus is poorly marked, the whole uterus being more cylindrical in shape and without the anteflexion characteristic of the adult. The cavity is also cylindrical, the internal orifice faintly marked, and the plicæ palmatæ extending throughout the cervix and body. *Immediately after birth* the uterus undergoes a marked reduction in size (Scammon) probably due to a withdrawal of a placental hormone at the time of birth. *In the child* there is but little change in the size of the uterus until the prepuberal period when a stage of active growth sets in, which, *during puberty,* results in the adult virginal size, shape, and position.

Activated by changes which are taking place in the ovary, probably through the agency of special hormones, the mucous membrane of the uterus passes through the phases of the *menstrual cycle* in periods of approximately 28 days. During the *premenstrual period* (1st to 5th day) the mucosa becomes thickened and congested through the enlargement of its blood vessels and its glands. This is followed by the period of *menstrual flow* (6th to 11th day) in which the vessels rupture through the epithelium and blood escapes from the vagina along with portions of the epithelium of the surface and glands. During the *postmenstrual period* (12th–19th days) there is a gradual repair of the mucosa and a return to its normal condition. The interval or *resting period* (20th–28th day) follows without change. Although our knowledge of the time relationship between ovulation and menstruation is still incomplete there is sufficient evidence to believe that ovulation takes place during the postmenstrual period.

During *pregnancy* the body of the uterus undergoes marked enlargement and increase in weight. It becomes rounded or ovoid in shape and during the 9th lunar month almost reaches the ensiform process. Its muscle fibers hypertrophy and form distinct interlacing bands, while its mucous membrane looses its epithelium and glands and is transformed into the deciduæ. The blood vessels likewise increase in size in accordance with the needs of the developing fetus. The cervix does not take part in the initial increase in size but it early undergoes a softening which is so characteristic that it is regarded as one of the presumptive diagnostic signs of pregnancy. During the first stage of labor the cervical canal becomes dilated through pressure exerted upon it by the bag of amniotic fluid. Under normal conditions the cervix dilates sufficiently to permit the birth of the child without serious laceration, but in so doing it is reduced to a thin iris-like structure. The postpartum changes of the uterus consist in its return to its normal size, a process called *involution,* which with few exceptions is remarkably complete. The external orifice, however, becomes a transverse slit, with irregular fissures on its anterior and posterior lips, while the plicæ palmatæ usually disappear.

The menstrual function ceases at the *menopause* (45th–50th year) following which there is a gradual atrophy of the uterus; this involves both cervix and body.

Clinical Considerations

Examination of the uterus is made by palpation, inspection and X-ray. The cervix of the uterus can be felt by vaginal examination, its size, shape, consistency, and position and mobility being determined. When the uterus is in its normal position, the examining finger first comes in contact with the anterior labium of the cervix, it being necessary to insert the finger further to feel its posterior labium. Findings contrary to these denote a malposition of the uterus. The fundus of the normal uterus can be palpated bimanually, the fingers of one hand pressing in the abdominal wall just above the symphysis while one or two fingers of the other hand pushes the body of the uterus ventrally. Changes in the size of the body of the

uterus due to tumors, pregnancy, etc., as well as changes in its position, are thus determined. The use of a vaginal speculum makes it possible to view the vaginal portion of the cervix, to pass uterine sounds to determine the length of the uterine cavity, its direction, etc. It also makes it possible to inject the uterine cavity with lipiodol and thus obtain uterograms (fig. 1128).

Malpositions of the uterus are common and may affect either the position of the cervix, or the body alone but more frequently both are affected. Changes which affect the angulation at the isthmus are known as flexion—*anteflexion* or *retroflexion;* those which affect the direction of the axis of the whole uterus as version—*anteversion*, *retroversion* or *lateral version.* The normal uterus, however, is anteverted as far as is possible and partially anteflexed; the term *hyperanteflexion* has been suggested (Graves) to denote an abnormal degree of anteflexion. A combination of retroversion with retroflexion is the most common and important of malpositions from a clinical point of view. Normally the position of the uterus is maintained by the proper tone of its anatomical supports, by the elasticity of its musculature, and by abdominal pressure upon its intestinal surface (Graves). If through childbearing or congenitally weak ligaments loops of the intestine enter the vesicouterine pouch, the abdominal pressure is exerted on its vesical surface and the body of the uterus is forced backward.

In *prolapse* of the uterus the organ descends from its normal level toward the vaginal outlet; when the cervix appears at the vaginal outlet it is known as *procidentia.* Its usual cause is laxity of the uterine ligaments due to childbirth. The main support of the uterus, however, comes from the urogenital diaphragm, acting through the bladder, its ligaments serving merely to maintain its horizontal position. When the uterus is retroflexed to a vertical position this support is largely removed and the organ may descend into the vagina, drawing its adnexa downward with it.

Operations upon the uterus are performed to correct malpositions, to remove tumors, both benign and malignant, and for excessive degrees of pelvic inflammatory disease. The abdominal approach is the mid-rectus incision described above (p. 1368). The removal of the uterus is known as *hysterectomy;* in *supravaginal hysterectomy* the body and that portion of the cervix lying above the vagina alone are removed. The operation consists in careful dissection of the cervical portion from the posterior wall of the bladder, without injury to the bladder, careful ligation of the ovarian and uterine vessels and amputation in the region of the isthmus. The cervical canal is then closed by sutures, the stumps of the broad ligaments sutured together to the stump of the cervix. The close proximity of the ureters to the cervix is an important relationship, as they must be avoided in ligating the vessels as well as in suturing. In certain cases where the urogenital diaphragm and perineal muscles are sufficiently relaxed the uterus may be removed through the vagina; this is known as *vaginal hysterectomy.*

4. The Vagina

The **vagina** (figs. 1132, 1133) is a muscular, highly dilatable canal lined by mucous membrane. It extends from the uterus to the vestibule of the external

Fig. 1133.—Horizontal Section of Vagina and Adjacent Structures. (After Henle.)

genitalia, where it opens to the exterior. Its long axis is practically parallel with that of the lower part of the sacrum and it therefore meets the cervix of the uterus at approximately a right angle. Because of this position of the cervix in the upper end of the vagina, its *anterior wall,* which measures about 7 cm., is shorter than the *posterior wall,* which measures 1.5 to 2 cm. longer. The wall of the vagina joins the cervix some distance above the lower extremity

of that structure (fig. 1129), which thus projects into the lumen of the vagina; there is thus formed a circular fissure between the wall of the vagina and the vaginal portion of the cervix. This fissure, called the *fornix*, is for descriptive purposes usually divided into halves, an *anterior* and a *posterior fornix*, the latter being the deeper.

In its ordinary condition the lumen of the vagina is a fissure, which in transverse section resembles the form of the letter **H** with a rather long transverse bar (fig. 1133). On each wall, anterior and posterior, there is a well-marked longitudinal ridge in the median line, the *columna rugarum*, which is especially distinct in the lower part of the anterior wall, where it lies immediately beneath the urethra and forms what is known as the *urethral carina*. From both columnæ other ridges pass laterally and upward on either side, forming the *rugæ vaginales*. Both these and the columnæ diminish in distinctness with advance in age and with successive parturitions. Toward its lower end the vagina traverses the urogenital diaphragm, being much less dilatable in this region than elsewhere. Its orifice (ostium vaginæ NK) is partially closed by a fold of connective tissue, rich in blood-vessels, and lined on both surfaces by mucous membrane. This structure, known as the *hymen*, has usually a somewhat semilunar form, covering the posterior portion of the orifice, but it may take the form of a circular curtain pierced by one or several apertures.

Relations.—*Posteriorly* the uppermost part of the vagina is in relation with the peritoneum forming the floor of the rectouterine pouch (of Douglas) for a distance of about 1 cm. Below this the vagina rests almost directly upon the rectum (figs. 1132, 1133), being separated from it by a layer of the pelvic fascia. Toward the lower end of the vagina the rectum turns back sharply and the distance between the vagina and rectum greatly increases. This space is filled with muscle fibers, connective tissue, and fat, and is commonly called the 'perineal body.' *Anteriorly* the vagina is in intimate relation with the posterior wall of the bladder and the urethra (figs. 1132, 1133). *Laterally* it is crossed obliquely in its upper portion by the ureters (fig. 571) as they pass to the base of the bladder, and in its lower two-thirds by the edges of the anterior portion of the levatores ani. The *duct of Gartner*, the remains of the lower portion of the Wolffian duct may occasionally be found at the side of the upper half of the vagina as a minute tube or fibrous cord. The external orifice is surrounded by the fibers of the bulbocavernosus muscle, which may be regarded as a sphincter (*sphincter vaginæ*).

Structure.—The wall of the vagina is formed mainly of smooth muscle-tissue, whose fibers are indistinctly arranged in two layers, an outer longitudinal and a less distinct inner circular one. The submucous tissue is abundantly supplied with a dense plexus of veins and possesses numerous smooth muscle-fibers thus resembling to a certain degree erectile tissue. The vagina has no true glands; the mucus found in it is derived from the glands of the uterus. It is lined by stratified squamous epithelium.

Vessels and nerves.—The *arteries* of the upper part of the vagina are derived from the vaginal branch of the uterine; its middle portion is supplied by a vaginal branch from the inferior vesical and its lower part by the middle hemorrhoidal and internal pudendal. The *veins* form a rich plexus on the surface (fig. 607) and drain into the hypogastric vein. The *lymphatics* are very numerous and drain for the most part into the hypogastric and lateral sacral nodes; some of those from the lower portion of the canal joining with those from the external genitalia to pass to the inguinal nodes. The *nerves* passing to the vagina are derived from the hypogastric plexus and from the fourth sacral and pudic nerves.

Clinical Considerations

The vagina may be explored by digital examination, it being possible, except in virgins, to introduce two fingers. The least dilatable portion is near the entrance of the vagina where it passes through the urogenital diaphragm. Inspection of the vaginal wall may be made by the use of the bivalve speculum, the patient being in the dorsal position. A better view can be obtained with the patient in the knee-chest position as the abdominal viscera, tending to fall toward the diaphragm, create a negative pressure within the pelvis, so that when a single-bladed Sim's speculum is introduced, the atmospheric pressure balloons out the walls of the vagina.

The relation of the posterior fornix to the peritoneum of the floor of the recto-uterine pouch is one which is of importance as it is possible to drain the pelvic cavity through the vagina by an incision at this point (posterior colpotomy). The close proximity of the bladder and urethra anteriorly makes possible through injuries the formation of vesico-vaginal or urethro-vaginal fistulæ. Posteriorly the upper portion of the vagina lies in contact with the rectum, where recto-vaginal fistulæ sometimes occur, but lower down the two are separated by the thick and very dense perineal body.

The *hymen* which in virgins usually takes the form of a cresentic fold posteriorly occasionally forms a complete diaphragmatic membrane over the entrance of the vagina, which

may or may not show slight perforations. Such cases require surgical treatment at the onset of menstruation. The hymen in virgins frequently appears ruptured; more often rupture takes place with the first coitus, after which the remains of the hymen appear as small irregular nodules, the *carunculæ hymenales*. On the other hand it may persist unruptured until the first partuition. The presence or absence of an unruptured hymen cannot, therefore, be used as a criterion of a woman's virginity.

Cystocele is that condition in which the posterior wall of the bladder, due to lack of proper support, falls downward, pushing the anterior wall of the vagina before it. *Rectocele* is a similar condition involving the anterior wall of the rectum and the posterior wall of the vagina. In both of these conditions, which frequently coexist, the vaginal outlet is wide open and the bulging anterior and posterior walls of the vagina appear at the orifice. The condition, brought on by childbirth, is due to lacerations of the pelvic supports (urogenital diaphragm and pelvic fascia) and relaxation of the perineal musculature, etc. Plastic operations to correct cystocele and rectocele are known as anterior and posterior colporrhaphy (or perineorrhaphy) respectively and have as their aim the repair of the ligamentous structures of the pelvic floor.

Development of the uterine tubes, uterus, and vagina.—The uterine tubes, uterus, and vagina develop from paired tubular structures known as the Müllerian ducts, fig. 63, B. In embryos these lie parallel and close to the Wolffian ducts and like the latter unite with the urogenital sinus. The two Müllerian ducts fuse together in their lower portion to form a single tube, the *uterovaginal canal*, while their upper portions remain separate.

Each Müllerian duct develops from the genital ridge, which (as described above), also forms the genital gland (ovary or testis). It appears in embryos of about 10 mm. in length as a funnel-shaped depression on the ventro-lateral border of the genital ridge, lying immediately lateral to the Wolffian duct. The apex of the funnel grows downward in the form of a tube, the lower end remaining closed. The tube lies between the celomic epithelium of the genital ridge laterally and the Wolffian duct medially, and is entirely surrounded by mesenchyme. Continuing its downward growth it inclines medially, crosses in front of the Wolffian duct and meets its fellow of the opposite side (fig. 63, B). In its lowermost portion it bends ventrally, following the curvature of the Wolffian duct and finally reaches the posterior wall of the urogenital sinus at *Müller's tubercle* (embryos of 21–28 mm.) At about the same time the lower portions of the two Müllerian ducts unite; at first this is only an external union, but gradually the medial walls of the tubes become a septum, which upon resorption results in a single lumen, the *uterovaginal canal*. From this is derived the vagina and cervix of the uterus. The ununited (tubal) portions of the Müllerian ducts, especially their ostia, undergo a descensus so that later they extend horizontally outward from the uterovaginal canal like the cross-bar of the letter T (fig. 1141). The body of the uterus is formed by a widening of the medialmost parts of the tubal portions, while the uterine tubes are formed from their remainder. The boundary between the cervix and vagina is formed by a solid epithelial process which grows outward and upward from the uterovaginal canal. Later when this splits it forms the fornix, thus giving the vaginal portion of the cervix its characteristic form. The lower end of the vagina is closed off from the cavity of the urogenital sinus until late stages by its own epithelium on one side and by that of Müller's tubercle on the other. This double layer of epithelium with a slight amount of connective tissue between, becomes compressed and gives rise to the *hymen*. That the hymen is derived in this way from Müller's tubercle is further indicated by the fact that when there is a persistent Wolffian duct it is found to enter the urogenital sinus through the hymen. The glands of the cervix first appear in embryos of 110 to 175 mm. Those of the body of the uterus are variable in the time of their appearance; they may be present at birth or absent until puberty. The outer fibrous and muscular coats of the uterus, tubes and vagina are derived from the condensed mesenchyme surrounding the epithelial canals.

At the time of its formation the tubal ostium abdominale lies at the level of the 8th or 9th thoracic segment. Due to both an unequal growth and a true migration it reaches the level of the 1st sacral segment in embryos of about 70 mm. The body of the uterus, cervix and vagina likewise undergo a passive descensus, since they are fixed below to the urogenital sinus and their growth is less rapid than that of the body segments in which they lie.

Anomalies of the uterine tubes, uterus, and vagina.—*Absence* of the uterine tubes, uterus and vagina probably occurs only in nonviable monstrosities; unilateral absence of the Müllerian duct has been reported (*uterus unicornis verus*). The principal anomalies of the female urogenital organs result from a lack, or faulty union, of the two Müllerian ducts. This results in a duplication of the uterus, either incomplete or complete, which may be combined with a similar duplication of the vagina. In the most marked of these anomalies there is a complete duplication of the uterus and vagina (*uterus didelphys* or *uterus et vagina duplex separatus*); in the mildest form there is found only a partial septum at the fundus (*uterus septus*). Between these two extremes all gradations of incomplete and complete duplication of the uterus and vagina may occur. A common form is *uterus bicornis* in which is found a single vagina and cervix with duplication of the body of the uterus.

5. The Female External Genitalia and Urethra

The female **external genitalia** [partes genitales externæ] (figs. 1134, 1135) are known collectively as the vulva [pudendum muliebre] and comprise the following parts: (1) labia majora, (2) labia minora, (3) clitoris, and (4) vestibule.

Labia majora.—The labia majora are two elongated rounded folds of integument which form the lateral boundaries of the vulva. Ordinarily each labium majus is 7 to 9 cm. long and 2 to 2.5 cm. wide but they are subject to a wide variation in size dependent upon age, race, the degree of general obesity, child bearing, etc. The lateral borders are in contact with the inner surface of the thighs, with which they form a deep cleft when the limbs are brought together.

Anteriorly they unite and are continuous with the *mons pubis* (*Veneris*) an enlarged rounded eminence which overlies the symphysis pubis and which is formed by a firm pad of fat beneath the integument. Posteriorly the labia majora become narrower and less elevated and terminate 3 to 4 cm. anterior to the anus. The medial surfaces of the labia majora lie close together but may be separated from one another by protruding labia minora. Anteriorly the medial surfaces unite at the lower border of the symphysis to form the *anterior commissure* whilst posteriorly a *posterior commissure* may or may not be definable.

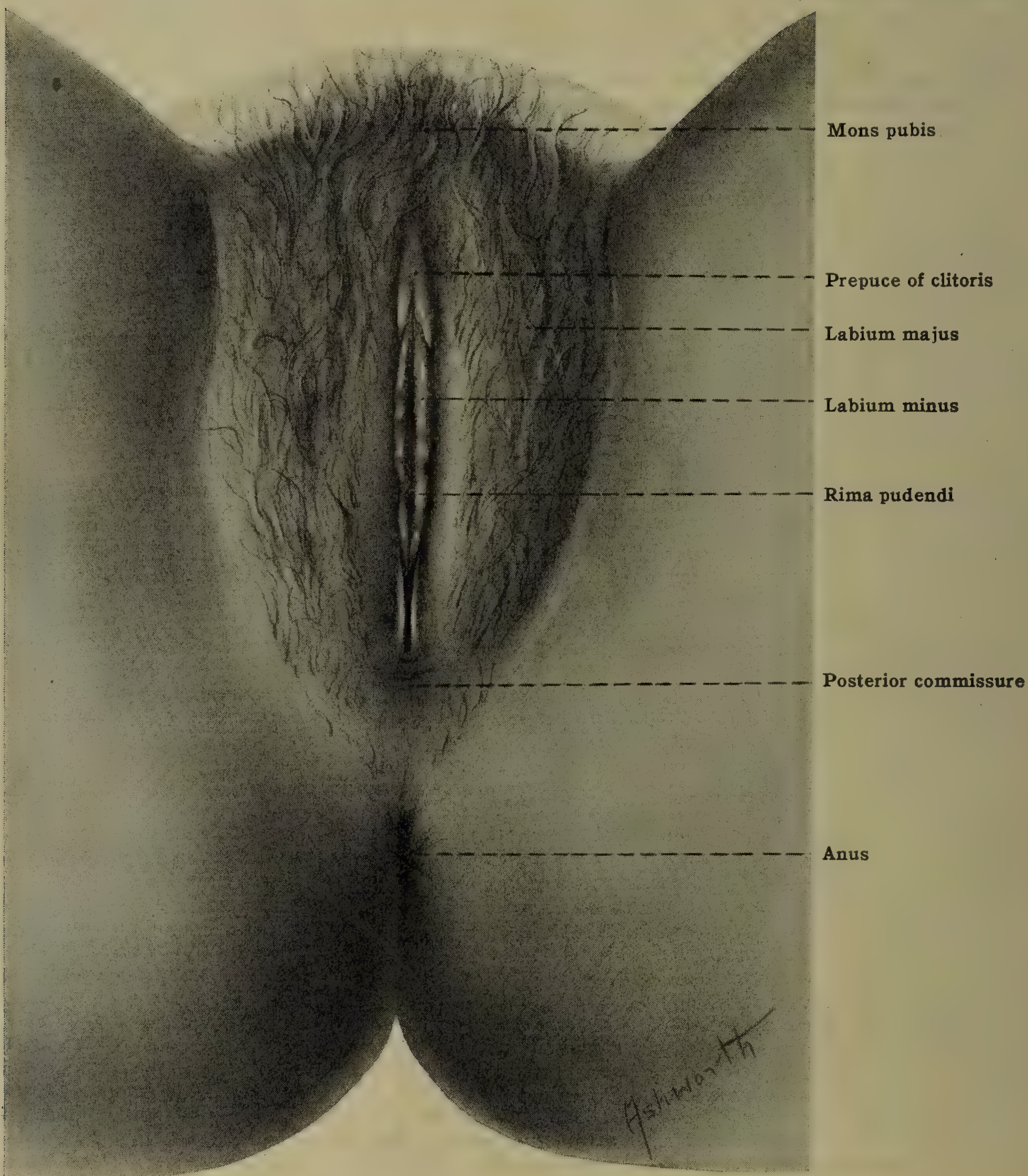


FIG. 1134.—THE EXTERNAL GENITALIA OF A FEMALE 24 YEARS OLD.

The cleft between the two medial surfaces is termed the *rima pudendi*, which normally must be spread apart in order to view the remaining structures of the vulva (fig. 1135).

The integument of each labium majus is slightly pigmented and may be thrown into small irregular folds, less marked but resembling those of the scrotum. It is covered with pubic hair, thicker anteriorly where it is continuous with that of the mons pubis, but less dense posteriorly where it is continuous with that around the anus. The medial surfaces which come in contact with one another are relatively free of hairs but they contain sebaceous and sweat glands. Beneath the integument of the labia majora may be found a thin, poorly developed *tunica dartos labialis*. The main body of the labia, however, is composed of adipose and areolar tissue, rich in elastic fibers. The round ligament of the uterus

which passes downward through the inguinal canal, attaches itself to this tissue in the upper part of the labium.

Inguinal hernia, although rare in the female may enter the labium majus after traversing the inguinal canal. A persistent processus vaginalis (canal of Nuck) may also reach the labium.

Labia minora.—The labia minora are two thin folds of integument which lie within the rima pudendi and measure 4 to 5 cm. in length and 5 mm. in thickness. They begin anteriorly at the level of the glans clitoridis and extend posteriorly one on either side of the urethral and vaginal orifices. Their degree of development varies markedly; as a rule in virgins they are hidden by the labia

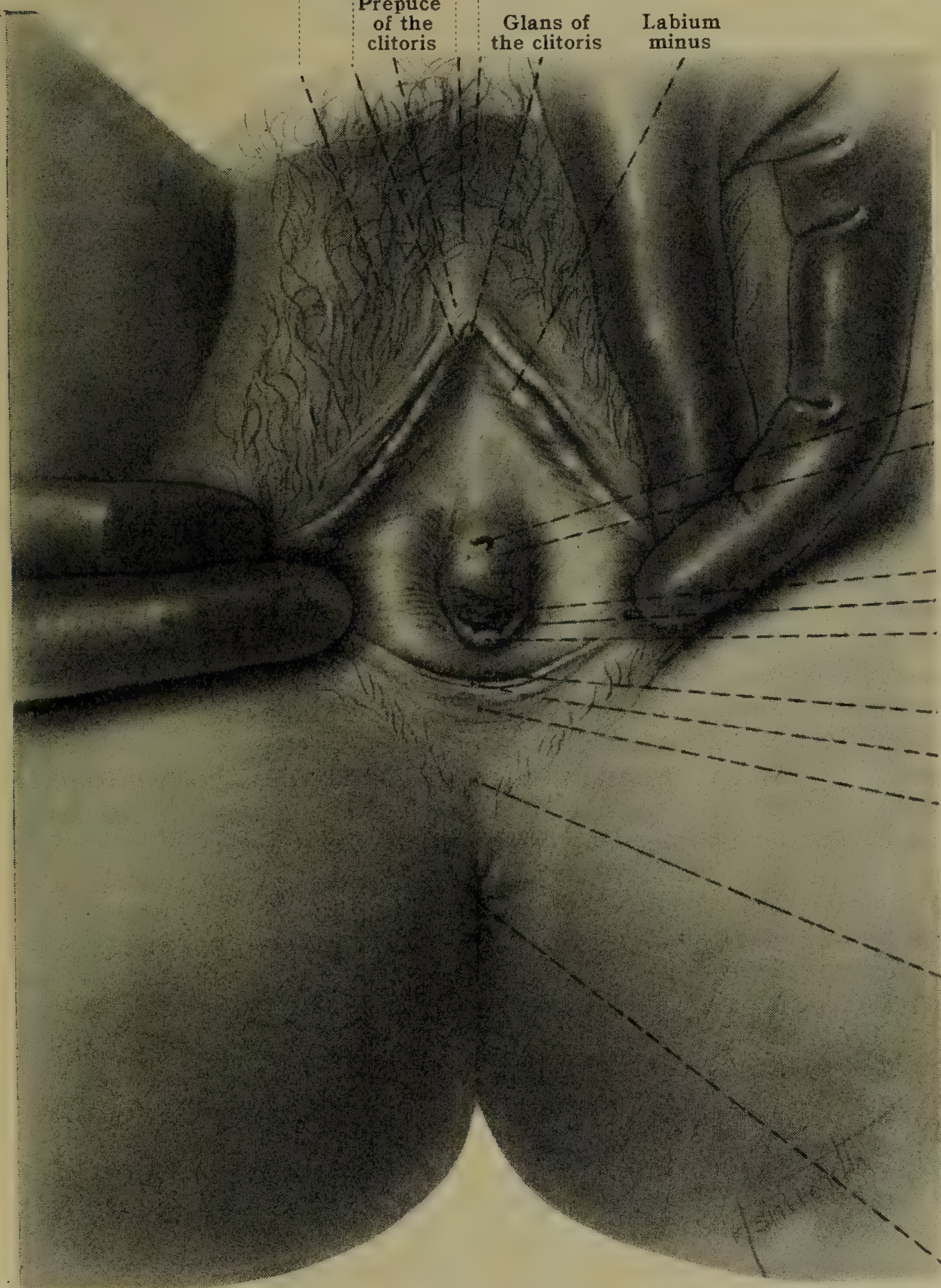


Fig. 1135.—The External Genitalia of the Same Subject Shown in Fig. 1134. The labia are held apart as shown.

majora but in women who have borne children they protrude outward between the medial surfaces of the larger labia. Anteriorly each labium minus divides to form two smaller folds one of which extends above, the other below the distal extremity of the clitoris. They unite with similar folds of the opposite side to form the *prepuce* [præputium clitoridis] on the dorsum of the clitoris and the *frenulum clitoridis* on its urethral surface. Posterior to the clitoris the labia minora diverge and usually reach their greatest height in the first one or two centimeters of their length, after which they become smaller and blend with the

medial surfaces of the labia majora or unite with one another anterior to the posterior commissure, forming the *frenulum labiorum pudendi* (fourchette). The lateral surfaces are smooth and lie in contact with the medial surface of the labia majora, forming with the latter a deep elongated fissure, while the medial surfaces lie in contact with one another. The anterior free margin is bluntly rounded and marked with serrations and irregularities giving an appearance which has been likened to a cock's comb.

The integument of the labia minora is smooth and pigmented, and of a reddish pink color. It contains a few small sebaceous and sweat glands but no hairs. Between its epithelial layers is areolar tissue, rich in blood vessels but devoid of fat.

The clitoris.—The clitoris, the homolog of the penis, is an erectile organ which is located at the anterior extremity of the rima pudendi just beneath the symphysis pubis. It consists of a body [corpus clitoridis], two crura [crura clitoridis] and a glans [glans clitoridis]. The body is not free like that of the penis but is entirely embedded in the tissues of the vulva. It is formed by the fusion of the two corpora cavernosa which differ from those of the penis only in size. It extends from the pubic arch above to the glans below and measures 2 to 2.5 cm. in length. It is directed downward (posteriorly) and is held in this position by the epithelial floor of the anterior portion of the vulva, through which the form of its dorsal surface may be seen. A third cavernous body is lacking in the body of the clitoris. Reaching the lower border of the pubic arch, just posterior to the small *suspensory ligament* of the clitoris, the two corpora cavernosa separate from one another and bending sharply downward, outward, and backward, follow the inferior borders of the inferior rami of the pubic bones to which they gain attachment. These constitute the *crura* of the clitoris which like those of the penis are covered by the ischiocavernosus muscles. Anteriorly the *glans* is attached to the end of the fused corpora cavernosa in much the same manner as in the male. It is composed of erectile tissue which is continuous with the pars intermedia of the bulbi vestibuli. The glans usually cannot be seen unless the hood-like *prepuce* is retracted upward. To the ventral surface of the glans is attached the two-fold *frenulum clitoridis* which constitutes a part of the labia minora as described above.

The vestibule.—The vestibule [vestibulum] is a space which is the remains of the urogenital sinus of the embryo, and into which open both the urinary and genital tracts. Laterally it is bounded by the labia minora, anteriorly by the clitoris, whilst posteriorly lies the frenulum labiorum pudendi or posterior commissure. In its floor are found the orifices of the urethra and vagina, the ducts of the vestibular and paraurethral glands, and the bulbs of the vestibule.

The *external urethral orifice* [orificium urethræ externum] is situated approximately 3.5 cm. posterior to the glans clitoris, its lips being slightly elevated and irregular. Its form may be stellate, crescentic or cleft-like, this being dependent upon the number, character and degree of protrusion of the mucosal folds of the urethra, the lower ends of which extend to the orifice. On either side of the posterior portion of the urethral orifice may frequently be found the minute openings of two elongated slender ducts, the *paraurethral ducts* (*ducts of Skene*) which are of importance as they may harbor gonococci.

The *orifice of the vagina* (ostium vaginæ NK), which in the virgin is partially closed posteriorly by the crescentic shaped *hymen*, is situated just posterior to the external urethral orifice. Its form and size varies markedly, it being larger and more prominent in women who have borne children. The walls of the vagina are seen through the orifice, the *carina urethralis* of the anterior wall being partially prominent in the virgin.

The orifices of the larger vestibular glands [glandulæ vestibulares majores] or glands of Bartholin are small and are located in the angle between the attached border of the labium minus and the vaginal orifice on either side. The lesser vestibular glands [gll. vestibulares minores] are several in number and open into the floor of the vestibule at various places by minute orifices, usually too small to be seen by the unaided eye.

Beneath the floor of the vestibule and resting upon the superficial layer of the urogenital diaphragm are two oval masses of erectile tissue, the *bulbi vestibuli* (fig. 1136), homologous with the corpus cavernosum urethræ of the male. They consist principally of a dense venous network enclosed within a thin investment of

connective tissue. From the main mass of each bulbus a slender prolongation, the *pars intermedia,* extends anteriorly past the side of the urethra, to join the glans clitoridis.

The **muscles** of the female external genitalia (fig. 1136) correspond to the perineal muscles of the male (see Section IV). There are two *transverse perineal* muscles, which have the same relations as in the male, and two *ischiocavernosi,* which are related to the crura clitoridis just as those of the male are to the crura

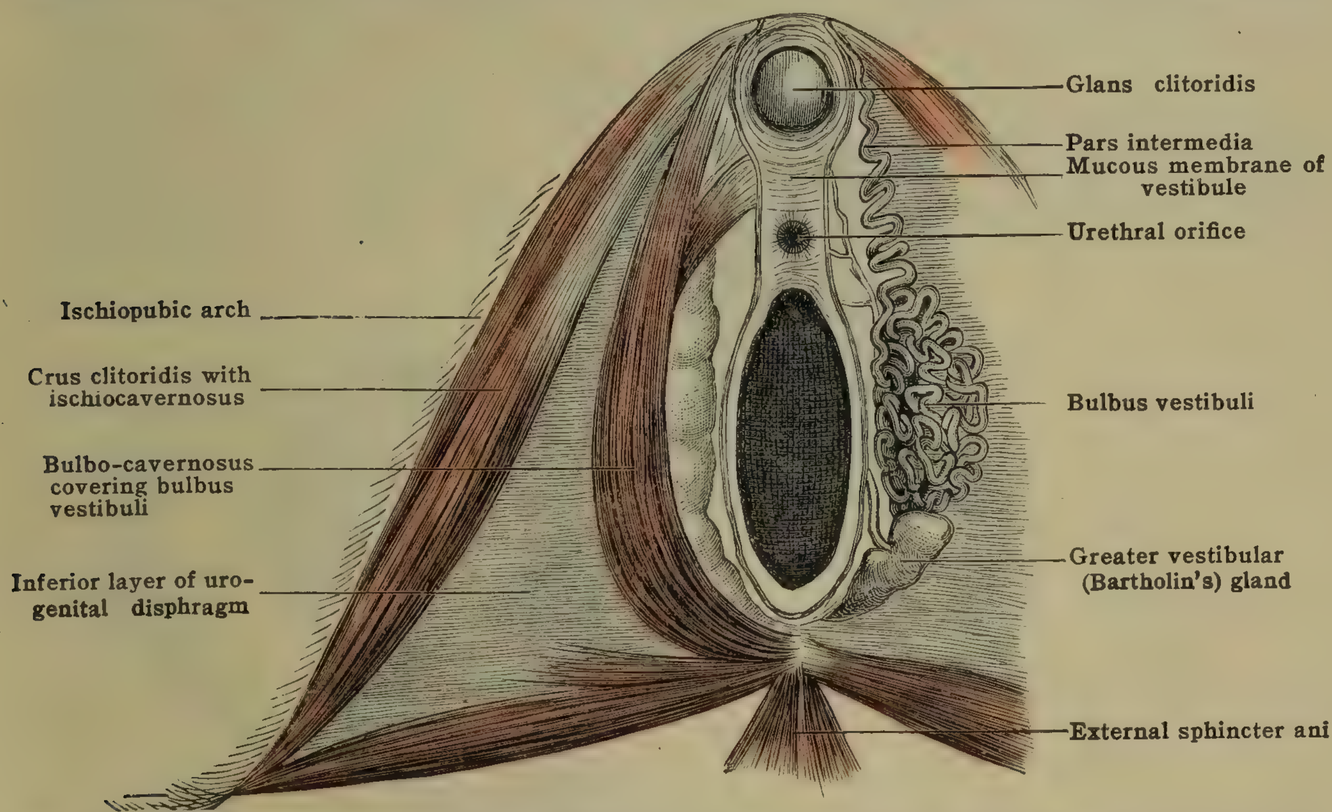


FIG. 1136.—DIAGRAMMATIC REPRESENTATION OF THE PERINEAL STRUCTURES IN THE FEMALE.

penis. The *bulbocavernosi,* however, present somewhat different relations, each being band-like in form, arising from the central point of the perineum and extending forward past the orifice of the vagina, over the greater vestibular gland and the bulbus, to form with its fellow of the other side a tendinous investment of the body of the clitoris. Together two muscles act as a sphincter to the vagina to which the term *sphincter vaginæ* has been applied.

The urethra.—The urethra of the female [urethra muliebris] (u. feminina NK) (figs. 1132, 1133), which corresponds in the male to that portion of the prostatic

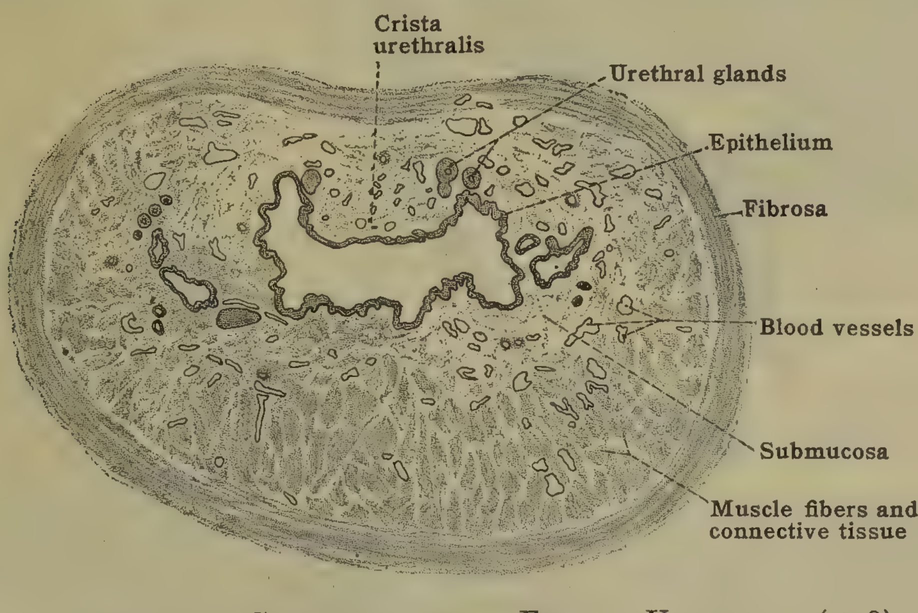


FIG. 1137.—CROSS-SECTION OF FEMALE URETHRA. (× 9)

urethra which lies above the prostatic utricle, is a relatively short canal, measuring from 3.0 to 4.0 cm. in length. At its origin from the bladder it lies about opposite the middle of the symphysis pubis and thence extends downward and slightly forward to open into the vestibule between the glans clitoridis and the orifice of the vagina. Its posterior wall is closely united with the anterior wall of the

vagina, especially in the lower part of its course where it forms the *urethral carina* of the vaginal wall; laterally and anteriorly it is surrounded by the pudendal plexus of veins. Above it is separated anteriorly from the symphysis pubis by the lower part of the prevesical space of Retzius.

Structure.—Its walls are very distensible, and are lined by a mucous membrane with numerous longitudinal folds, one of which on the posterior wall is more prominent and is termed the *crista urethralis* (fig. 1137). The mucosa contains numerous small glands [gl. ureth-

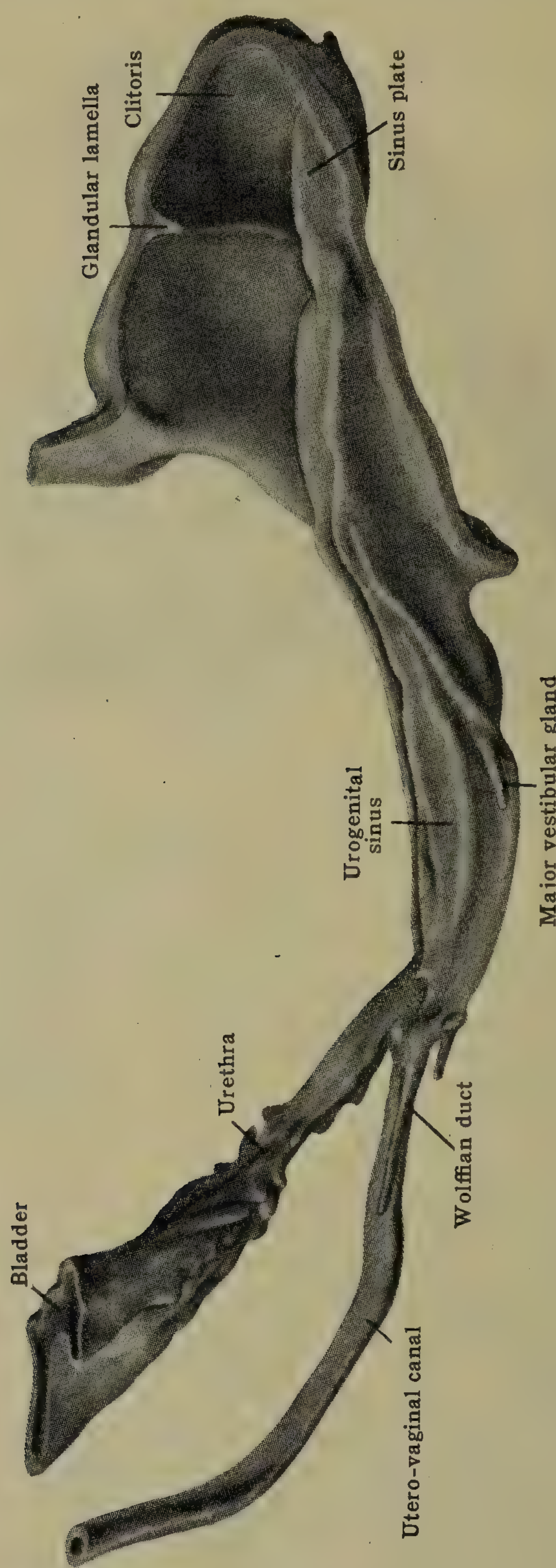


Fig. 1138.—Lateral View of a Wax Reconstruction of the Urethra and Associated Epithelial Structures of a Female Embryo of 60 mm. ×33 Diameters. (After Johnson, Jour. of Urology, Vol. VIII.)

rales] (gll. paraurethrales NK), a group of which on each side is drained by the inconstant *ductus paraurethralis*, opening into the vestibule as mentioned above. All of these glands are the homologue of the prostate in the male (fig. 1143). External to the loose submucosa is a sheet of smooth muscle, whose fibers are arranged in an outer circular and an inner longitudinal layer, a rich plexus of veins lying between the two and giving the entire sheet a somewhat spongy appearance. The circular fibers are especially developed at the vesical end of the canal, forming there a strong sphincter, and striped muscle-fibers, derived from the bulbocavernosus form a sphincter around its vestibular orifice.

Vessels and nerves.—The *arteries* supplying the external female genitalia are the internal and external pudendals, and the *veins* terminate in corresponding trunks. The *lymphatics*, which are very richly developed, drain for the most part to the inguinal nodes; those from the urethra pass to the iliac nodes. The *nerves* are partly sympathetic pandartly spinal; the formar

are derived from the hypogastric plexus, the latter principally from the pudendal, the anterior portions of the labia majora being supplied by the ilioinguinal and the external spermatic branch of the genitofemoral.

Development of the female external genitalia and urethra.—The *labia majora*, usually regarded as the exact homolog of the scrotum in the male, are derived from the paired genital (labia-scrotal) swellings (figs. 64, 1140). In earlier stages these are represented by the genital tubercle, from which also develops the phallus (fig. 1142). They lie one on either side of the urogenital cleft and undergo little change except in growth. In embryos of about 50 mm. however, their posterior ends grow toward one another and unite in the mid-line to form the posterior commissure (Spaulding). This fusion takes place at about the time of their caudal migration and fusion in the male to form the raphe of the scrotum. The anterior portion of the original genital tubercle forms the mons pubis.

The *labia minora* are developed from the urethral (genital) folds which lie on the under surface of the phallus on either side of the urethral groove (fig. 1140). Whereas in the male these close over the urogenital sinus to transform it into a portion of the urethra, in the female they remain separated, one on either side of the primitive urogenital orifice. The labia minora are represented in the male by the urethral surface of the penis, it being impossible to delineate their homolog sharply.

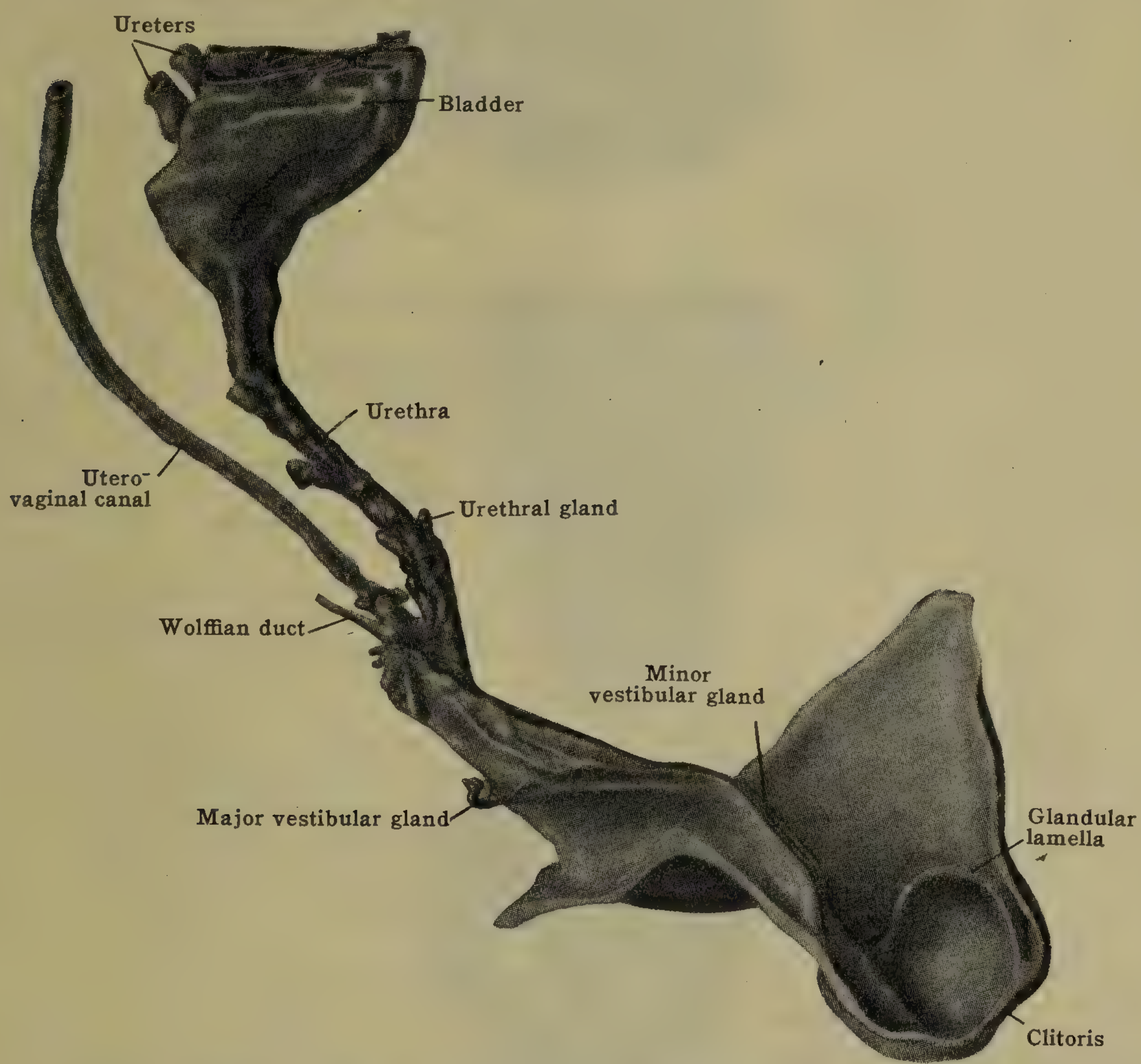


Fig. 1139.—Lateral View of a Wax Reconstruction of the Urethra and Associated Epithelial Structures of a Female Embryo of 75 mm. × ca. 18 Diameters. (After Johnson, Jour. of Urology, Vol. VIII.)

The *clitoris* is the homolog of the penis and has an early developmental history quite similar to it. The chief points of difference are its shorter urethral groove and the failure of this to become transformed into an urethra; the downward curvature of the clitoris; and its marked retardation in growth as compared to the penis.

The *vestibule* is derived from the urogenital sinus. In the early stages (figs 1138 and 1139) this has pelvic and phallic portions like those of the male. The tendency of the uorgenital sinus in the female is to grow in diameter (both antero-posteriorly and from side to side) at the expense of its length. This excessive widening transforms the urogenital sinus into a relatively shallow space into which open both the urethra and the vagina.

The *major vestibular* (*Bartholin's*) *glands* develop as solid epithelial outgrowths from the floor of the urogenital sinus (figs. 1138 and 1139) quite similar to the bulbourethral glands in the male, and later become branched tubular glands. The ultimate position of the orifices of their ducts is in no way due to a migration but to the widening-out process of the urogenital sinus to form the vestibule. The minor vestibular glands are the equivalents of the urethral glands (Littré) of the male (figs. 1121, 1139, 1143); they are fewer in number and their position on the floor of the vestibule has the same explanation as that of the major vestibular glands. Owing to the wide-open nature of the urogenital sinus in the female the erectile tissue which surrounds

this structure in the male (corpus cavernosus urethræ) is found on either side of the vestibule and gives rise to the paired bulbs of the vestibule.

Congenital anomalies.—*Hypospadias* in the female is quite dissimilar morphologically and embryologically from the condition described under the same term in the male. It signifies that condition in which the urethra terminates in the vagina; in the complete form the urethra may be entirely wanting and the bladder then empties by a funnel-shaped opening directly into the vagina. However, what is here termed the vagina is really an elongated vestibule or urogenital sinus, which from an embryological point of view makes the anomaly easily understood.

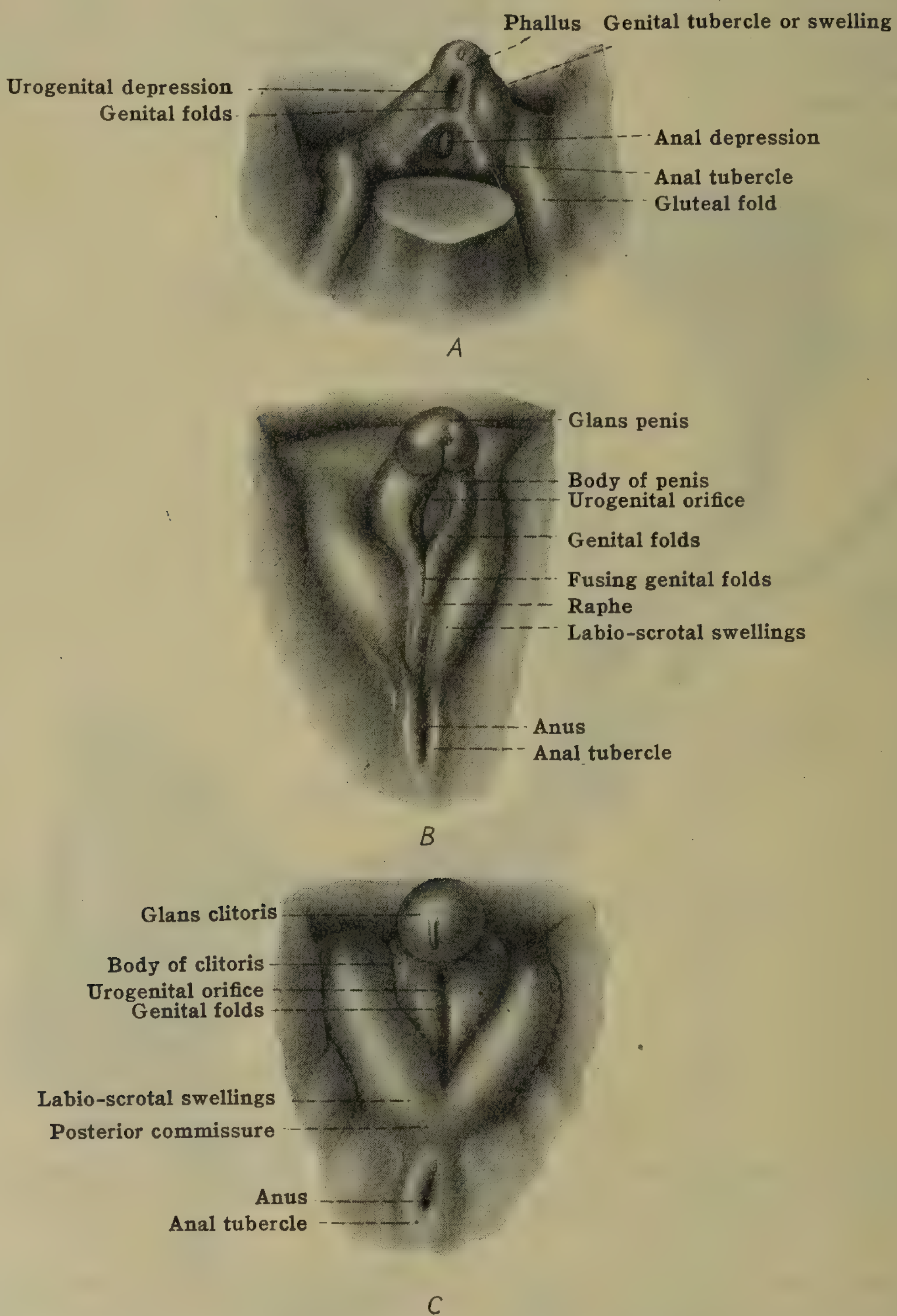


Fig. 1140.—External Genitalia of Embryos. (After Spaulding.) A, embryo of 16.8 mm. (indeterminate stage). B, embryo of 45 mm., male. C, embryo of 49 mm., female.

Epispadias in the female is a rare anomaly and is the equivalent of the same condition found in the male. Associated with the condition is found a bifid clitoris and prepuce, and a deep groove separating the two halves. The urethral orifice may be in the region of the clitoris or at the level of the symphysis.

A *persistent Gartner's duct* (fig. 1141) occasionally gives rise to a cyst in the vaginal wall. The duct is the remains of the lower end of the Wolffian duct which terminates in the posterolateral edge of the hymen. *Hypertrophy of the clitoris* is an anomaly in which this organ is larger than normal and in this respect more nearly resembles the penis.

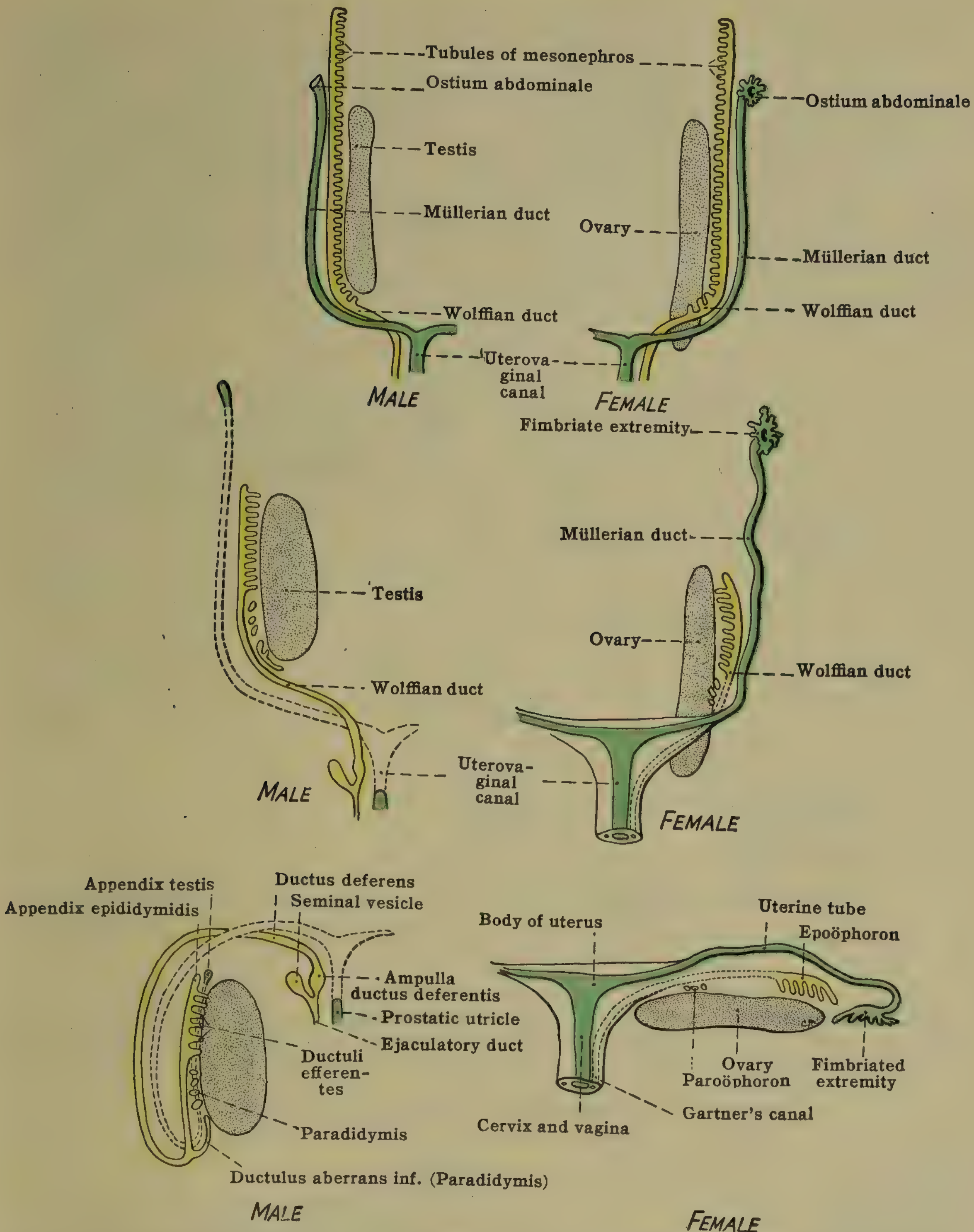


FIG. 1141.—DIAGRAM SHOWING HOMOLOGIES OF MALE AND FEMALE REPRODUCTIVE ORGANS (Modified after Felix.)

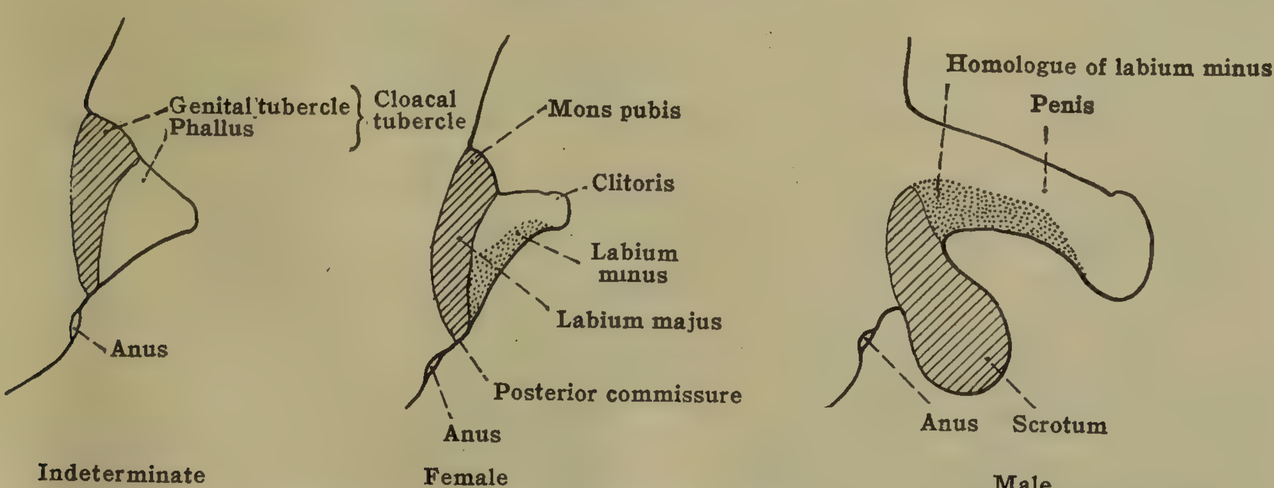


FIG. 1142.—HOMOLOGIES OF THE EXTERNAL GENITALIA. (Modified after Felix.)

Hermaphroditism.—True *hermaphroditism* depends not upon the form of the external genitalia but upon the presence of both ovary and testis in the same individual. The various possibilities are (1) *bilateral,* one ovary and one testis on each side, four gonads in all; (2) *unilateral,* a testis and an ovary on one side with either testis or ovary on the other, three gonads; (3) *lateral,* an ovary on one side and a testis on the other; (4) an *ovotestis,* a gonad including the elements of both testis and ovary on either one or both sides. No definitely authenticated cases of human bilateral or unilateral hermaphroditism have been described but there have been a few of the lateral and ovotestis types recorded in the literature. The case described by Young showed external genitalia of the male with hypospadias, the urethral opening being in the sulcus between a completely bifid scrotum. The right testis was descended but the left scrotal sac was empty. At operation the left gonad was found in the left inguinal canal and proved at operation to be an ovary with a typical uterine tube and a rudimentary uterus. Microscopic sections confirmed the testicular nature of the gonad in the right side of the scrotum and that of an ovary with typical Graafian follicles on the left side.

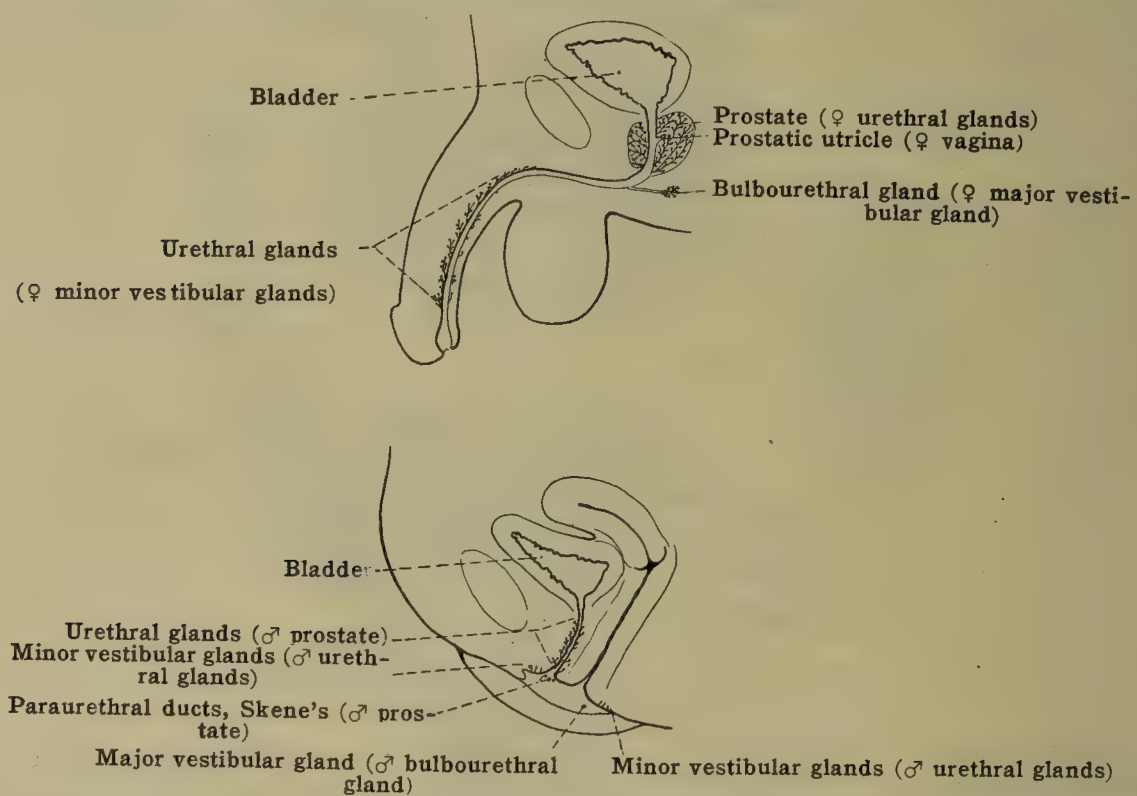


FIG. 1143.—DIAGRAM SHOWING HOMOLOGOUS GLANDS OF MALE AND FEMALE UROGENITAL TRACTS. ♂, male; ♀, female. (After Johnson.)

Pseudohermaphrodites may be either feminine or masculine. In the former ovaries are present but the clitoris is hypertrophied and the secondary body characteristics are of the masculine type. In the masculine type the individual is a male with a marked degree of hypospadias, bifid scrotum, etc., while the secondary characteristics are those of the female.

HOMOLOGIES OF THE SEXUAL ORGANS IN THE TWO SEXES

MALE	FEMALE
Testis	Ovary
Mesorchium	Mesovarium
Appendix testis	Ostium abdominale of uterine tube
No homolog	Remainder of uterine tube
No homolog	Uterus
No homolog	Vagina (upper portion)
Prostatic utricle	Vagina (lower porton)
Gubernaculum	Round and ovarian ligaments and part of fundus uteri
No homolog	Broad ligament
Appendix epididymis (ductulus aberrans superior)	Longitudinal duct of epoöphoron, distal portion
Ductuli efferentes	Transverse ducts of epoöphoron
Paradidymis (tubuli)	Paroöphoron
Paradidymis (collecting duct or ductulus aberrans inferior)	No homolog
Ductus epididymidis (proximal portion)	Remaining portion, longitudinal duct of epoöphoron
Ductus epididymidis (distal portion)	No homolog
Ductus deferens (proximal portion)	No homolog
Ductus deferens (distal portion)	Canal of Gartner
Seminal vesicle	No homolog
Urethra (portion above prostatic utricle)	Urethra
Urethra (portion below prostatic utricle)	Vestibule
Colliculus seminalis	Hymen
Scrotum	Labia majora

MALE	FEMALE
Processus vaginalis	Canal of Nuck
Penis	Clitoris
Urethral surface of penis	Labia minora
Prostatic tubules (Prostate)	Urethral glands including paraurethral ducts
Bulbourethral glands (Cowper)	Major vestibular glands (Bartholin)
Urethral glands (Littré)	Minor vestibular glands
Corpus cavernosum urethræ	Bulbi vestibuli
Corpus cavernosum penis	Corpus cavernosum clitoridis

References for the urogenital system.—(*General histology*) v. Möllendorff, Handbuch d. mikr. Anatomie. A. **Urinary tract.** (*General, incl. literature*) Keibel and Mall, Human Embryology; Kelly and Burnham, Diseases of the kidneys, ureter and bladder, 1914; Disse, in von Bardeleben's Handbuch; Hart, Jour. Anat. and Physiol., vol. 35; Lewis, Anat. Rec., vol. 9; (*Anomalies*) Johnson, in Practice of Urology, Young and Davis, 1926; (*Renal blood-vessels*) Brödel, Proc. Ass'n. Amer. Anatomists, 1901; Oppenheim, Frankf. Zeitschr. f. Path., Bd. 21; Hon-Jensen, Ztschr. f. Anat. u. Entw., Bd. 91, 1929; Hinman and Morrison, Jour. Urol., vol. 11, 1924; (*Renal tubules*) Huber, Amer. Jour. Anat., vol. 4; Peter, Die Nierenkanälchen, etc., Jena, 1909; (*Topography of female ureter*) Tandler u. Halban, Monatschr. Geburtsh. u. Gynäk., Bd. 15; (*Development of urethra*) Johnson, Jour. Urol., vols. 4, 8. B. **Male reproductive tract.** (*General, incl. literature to* 1903) Eberth, in von Bardeleben's Handbuch; (*Histology and development*) von Lichtenberg, Anat. Hefte, Bd. 31; Hill, Amer. Jour. Anat., vol. 9; (*Prostate*) Bruhns (*lymphatics*) Arch. f. Anat. u. Entw., 1904; (*Seminal vesicles*) Belfield and Rolnick, Jour. Urol., 1926; Thompson (*topography*) Jour. Anat. and Physiol., vol. 47; (*External genitals*) Forster, Zeitschr. f. Morph. u. Anthrop., Bd. 6; Henneberg, Anat. Hefte, Bd. 50, 55; Thompson, Jour. Anat. and Physiol., vol. 53; C. **Female reproductive tract.** (*General, incl. literature to* 1896) Nagel, in von Bardeleben's Handbuch; Waldeyer, Das Becken, Bonn, 1899; (*Lymphatics*) Bruhns, Arch. f. Anat. u. Entw., 1898; Polano (*ovary*) Monatschr. Geburtsh. u. Gynäk., Bd. 17; (*Nerves*) Roith, Arch. f. Gynäk., Bd. 81; (*Histology, ovary*) von Winiwarter, Anat. Anz., Bd. 33; (*Development, uterus*) Hegar, Beitr. z, Geburtsh. u. Gynäk., Bd. 13; Stratz, Zeitschr. Geburtsh. u. Gynäk, Bd. 72; (*Lig. teres*) Sellheim Beitr. z. Geburtsh. u. Gynäk., Bd., 4, 1901; *Hymen*, Kustner, Zeitschr. f. Geb. u. Gynäk., Bd. 81; (*Anomalies*) Graves' Gynecology, 1917; (*Perineal fasciae*) Wesson, Jour. A. M. A., vol. 81, 1923.

SECTION XIII

THE GLANDS OF INTERNAL SECRETION

By J. F. GUDERNATSCH, Ph.D.

FORMERLY PROFESSOR OF ANATOMY, CORNELL UNIVERSITY MEDICAL COLLEGE, NEW YORK CITY; VISITING PROFESSOR, NEW YORK UNIVERSITY, GRADUATE SCHOOL, WASHINGTON SQUARE COLLEGE, NEW YORK CITY

THE glands of internal secretion, endocrine or ductless glands, constitute a group of small units which do not represent a well defined anatomical system. In their microscopic anatomy, however, they have some distinctive features in common; and physiologically, it is indeed well to consider them as a group of closely related organs, though on account of their peculiar mode of origin the individual units are located in widely scattered regions of the body. Every germ-layer contributes to the group one or more endocrine glands, a developmental feature which, in itself, is an anatomical anomaly. The glands arise in connection with various organ-systems so that their grouping in a separate chapter cannot be justified from any morphological, but only from a functional, standpoint. Although there is no gross structural connection between the glands and each one separately fulfills its specific function, their *method* of functioning is much the same. Some, if not all, of the glands stand in definite chemical relationship to each other and in this manner make up a system of physiologically interdependent units. The chemical interdependence of the endocrine glands is noticeable to a striking degree during the processes of growth and differentiation; for the vertebrate organism can reach the final stages only when there exists a well regulated interaction of these glands.

In their finer structure, the glands of internal secretion show many similar and very characteristic features so that, on this basis too, we feel compelled to consider them as units of one group. The structural features that characterize the group are as follows:

1. Being glandular organs, they take their origin from some epithelium. Therefore, their physiologically active stratum, the secreting cells proper, are of an epithelioid, if not actually of an epithelial nature. The thyroid is the only gland which possesses a definite, uniform arrangement of its epithelial cells. In the others, we find merely an irregular distribution of epithelioid cells in the form of cords, trabeculæ, clusters, etc. Phylogenetically, the thyroid seems to be the oldest gland of internal secretion, which fact may explain its more advanced structural make-up. Even this gland, however, cannot strictly be called a well-defined organ in the lower vertebrates where it is represented by loosely distributed follicles without the presence of a limiting capsule.

2. The glandular cells lie in very close approximation to the endothelial cells of the blood- and lymph-channels, thus facilitating the direct passage of the secretory product, the *hormone*, from the parenchyma into the circulation. Although the glands are of small size, their vascular supply is extremely abundant, the vessels forming dense sinusoidal plexuses around and between the epithelial structures.

3. They are *ductless glands* (closed glands, BNA glandulæ clausæ), i.e. they have no excretory ducts. The secretion is poured directly into the vascular channels and it is for this reason that these organs are called glands of *internal* secretion. The absence of a duct is a feature which, phylogenetically, is of more recent appearance than the gland itself. During the ontogeny of most of these glands we still see the anlagen of definite excretory ducts which, however, normally retrogress, though occasionally rudiments remain. We have very good reasons

to believe that in the extinct lower vertebrates the ductless glands did possess excretory canals and, thus, were glands of *external* secretion originally.

From the **functional** standpoint, there are three groups of ductless glands (and of hormones), namely:

(a) the *morphogenetic* glands (or hormones) which exert their regulatory influence upon the chemical processes of growth and differentiation of the immature organism, (e.g., the influence of the anterior hypophysis on skeletal growth);

(b) the *metabolic* glands (or hormones) which exert their regulatory influence upon some nutritional and other specific chemical processes of the organism, immature and mature, (e.g., the influence of the pancreatic islands on carbohydrate metabolism);

(c) the *excitatory* glands (or hormones) which influence the physical behavior of certain tissues of the organism, immature or mature, (e.g., the influence of the posterior hypophysis and of the suprarenal medulla on smooth muscle).

Groups (a) and (b) seem to act directly on the tissues. Group (c) in all probability first acts on the sympathetic nerve-supply of the responding tissue. As the organism passes through the period of differentiation into that of adolescence and maturity, the morphogenetic glands either (1) exert their *strongest* influence at some specific period of the life-cycle (e.g., anterior hypophysis early, gonad later), (2) change their main function or (3) assume an additional function, usually one connected with metabolism (e.g., thyroid). Most glands, therefore, serve several of the purposes mentioned under (a), (b) and (c) either simultaneously or at successive periods. It is undecided whether the several simultaneous or successive functions of a gland are due to the elaboration of several hormones of individual chemical structures, or of a unitary, polyphasal hormone which acts differently on tissues of different chemical composition (so-called 'tissue responsiveness').

Group (a) is of more than morphological interest to the anatomist. It is this group which is chiefly concerned with the processes of growth and differentiation, thus being responsible to a considerable extent for the structural details of the mature organism. Yet, it must be kept in mind (1) that growth and differentiation are fundamental characteristics of protoplasm, (2) that these processes occur in a vast group of organisms devoid of internal secretions (invertebrates, plants) and (3) that even the vertebrate non-mammalian organism, while embryonic, grows and differentiates extensively without the aid of internal secretion. Hormonal factors, then, gain a directing influence on these biological processes only in the later stages. Without this influence, no vertebrate organism can reach that stage of perfection which is characteristic for its species.

Proper *correlation* is, therefore, necessary between the activities of the morphogenetic glands of group (a). In the other groups, too, *interaction* is distinctly noticeable, and strikingly so when the chemical processes do not proceed normally. For example, disturbances are shown in the functions, often also in the structure, of the hypophysis, of the thyroid, or of the pancreatic islands, when the sex gland, or the entire endocrine complex of the genital system, are under strain, as in pregnancy. The parathyroids seem to stand more aloof from the rest than any other of the ductless glands, although their coordinated influence in some metabolic processes, as in calcium regulation and thus, in skeletal differentiation, is obvious. The glands of group (c) act independently of the others and their stimulatory hormones are more of the type of definite pharmacodynamic agents, (e.g., suprarenin of the suprarenal medulla). On the other hand, suprarenal cortex, though belonging in group (b), seems to have some connection also with certain phases of differentiation (group a), primarily in the sex-sphere.

While the ductless glands to be discussed in this chapter are definite structural entities demonstrable in the dissecting room, other structures belonging to the same system of organs are recognizable in detail only under the microscope: the pancreatic islands, the gastric and intestinal mucosa, the interstitial cell-complex of the sex glands, the ovarian follicle, the corpus luteum. These structures are provided with the same physiological mechanism as the other glands of internal secretion but have no definite gross anatomical characteristics. In this connection must also be mentioned several other anatomically well-defined organs which may produce some form of internal secretion, while their chief functions serve other purposes (liver, placenta, sex-glands, mammary glands). All such structures are discussed under their respective anatomical systems.

THE THYROID GLAND

The **thyroid gland** [glandula thyreoidea] (fig. 1144) has approximately the form of a horse-shoe, the two lateral portions of which are usually more pronounced than the median connecting piece. These **lateral lobes** [lobus dexter et sinister] are somewhat asymmetrical in size and shape, while their connecting piece, the **isthmus**, varies considerably in size in different individuals. It may be entirely absent, or in other cases it may represent a considerable portion of the total mass of the organ. In the latter case, it may extend out into a strip which runs for a shorter or longer distance cephalad between the two lateral portions. When present, this short lobe of the thyroid gland usually has the shape of a pyramid, the broad base being represented by the isthmus, while it tapers toward the cephalic end. It is called the **pyramidal lobe** (fig. 1145). The main lateral lobes also resemble three-sided pyramids, their bases occupying the caudal end, merging there into the isthmus, while the somewhat rounded apices form the cephalic ends. The three surfaces of each lateral lobe (fig. 1146) are: (1) the *lateral* surface, by far the largest, which is somewhat convex and is covered by several

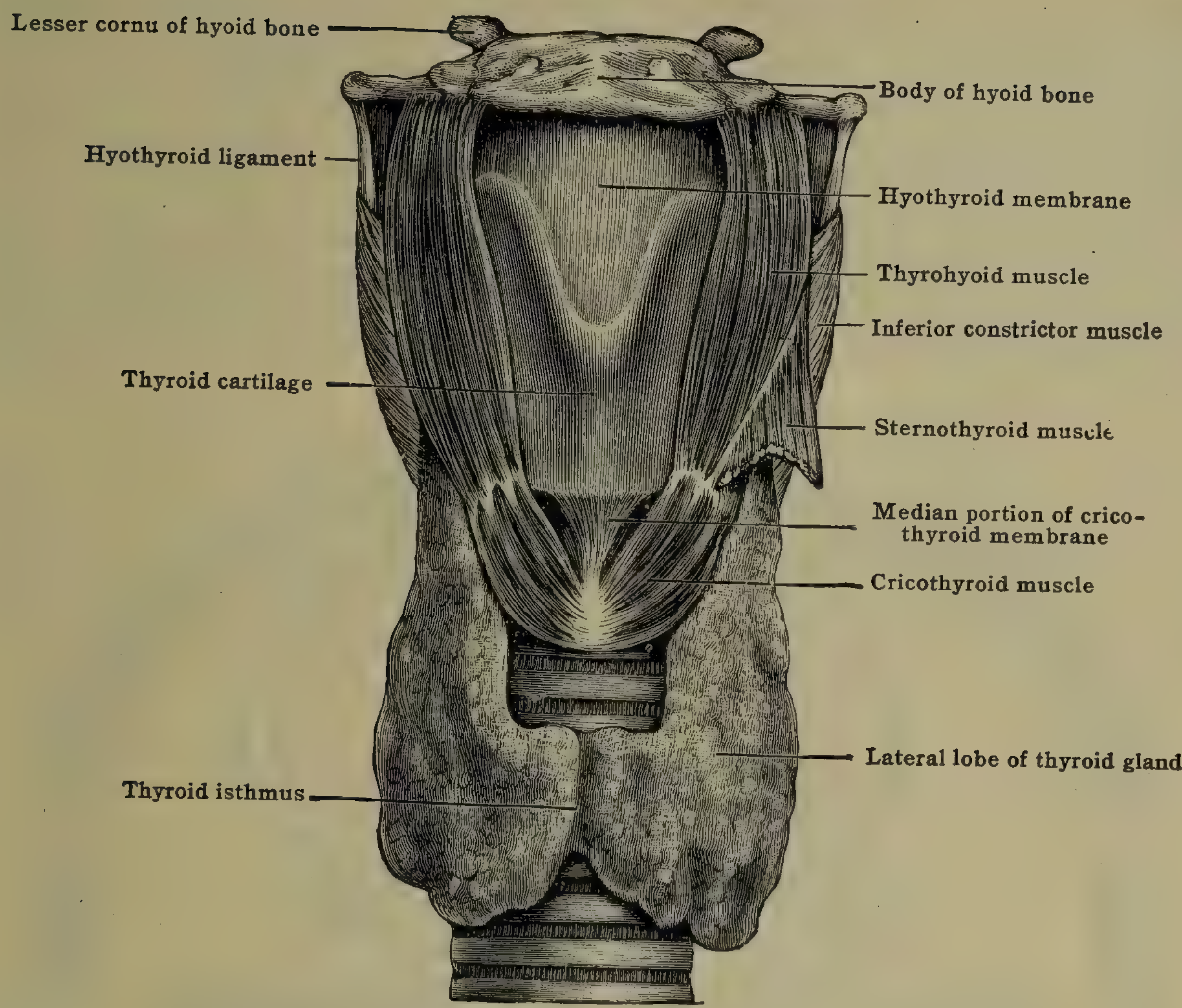


FIG. 1144.—VENTRAL VIEW OF THE THYROID GLAND.

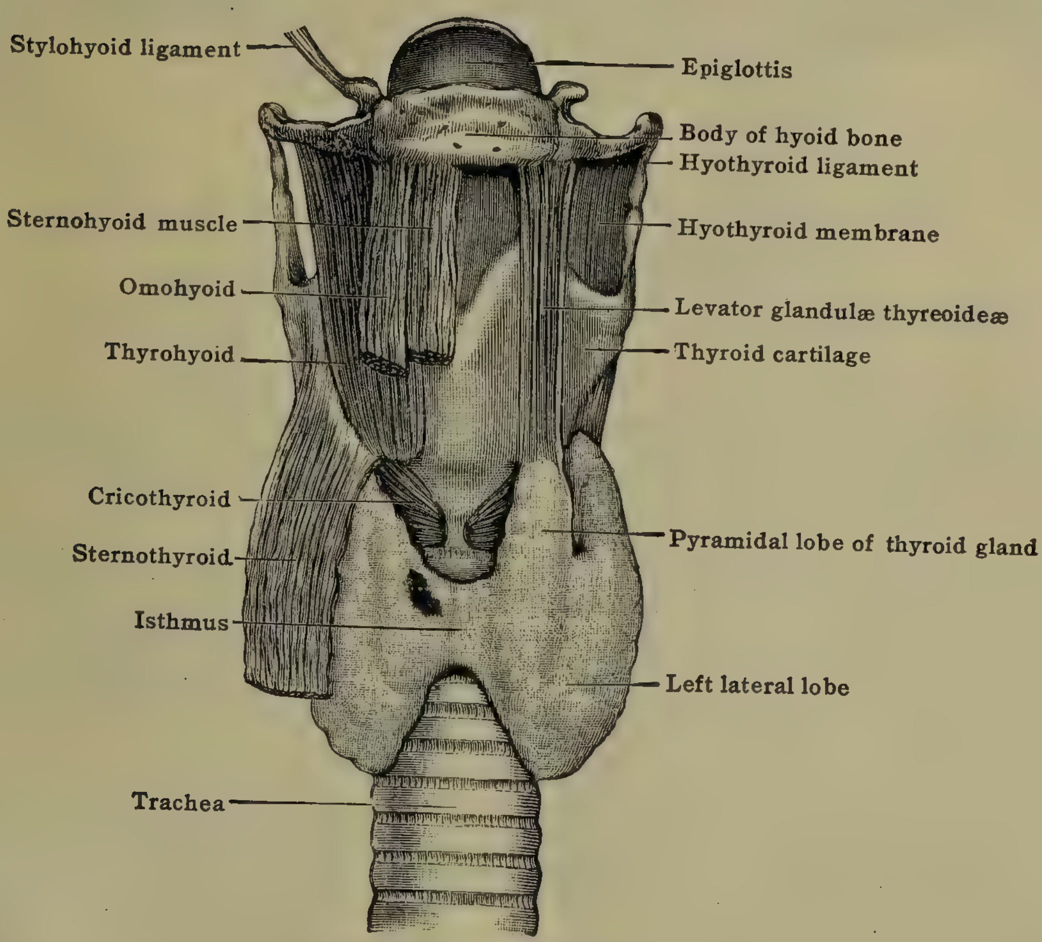


FIG. 1145.—THYROID GLAND, WITH PYRAMIDAL LOBE AND LEVATOR MUSCLE.

muscles (sternothyroid, sternohyoid, omohyoid), with the associated cervical fascia, the pretracheal lamina of which covers the anterior aspect of the gland; (2) the *medial* surface, rather concave since it is closely applied to the convex surfaces of the thyroid, cricoid, and tracheal cartilages; and (3) the *posterior* surface, the smallest one, rather flat, facing the great vessels of the neck, as shown in fig. 1146. The three borders of the lateral lobe are somewhat rounded off. The apex of the lobe lies more dorsally than the base.

The two lateral lobes (figs. 1144, 1145, 1147) are present in the greater number of individuals, although in some cases there may appear a decided asymmetry in the size and shape of these lobes. The median portion, the **isthmus**, however, is extremely variable in its extent. In some individuals it is rudimentary or

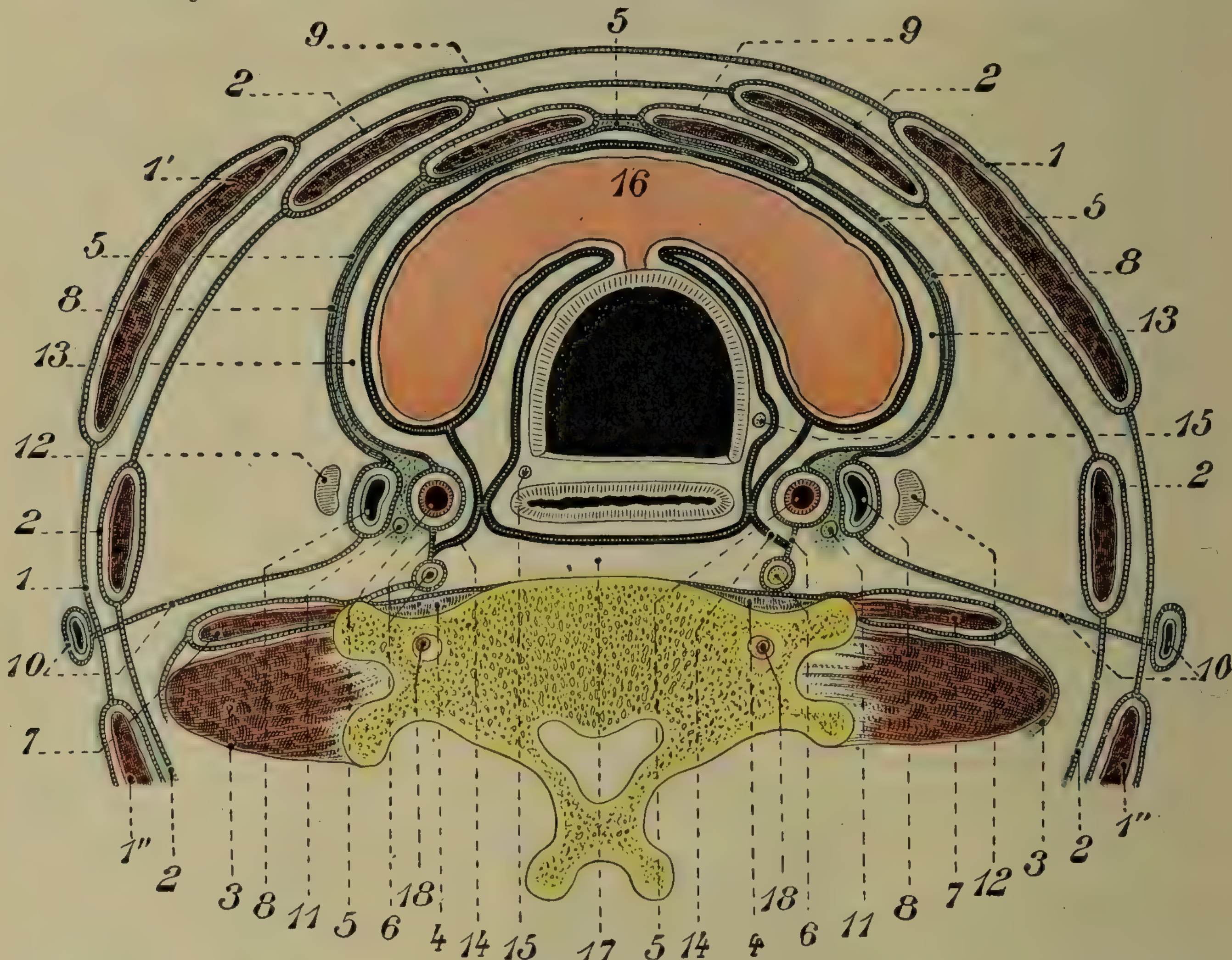


FIG. 1146.—DIAGRAMMATIC CROSS-SECTION OF NECK SHOWING RELATIONS OF THE THYROID GLAND. (After Truffert, from Testut and Latarjet, 'Human Anatomy.')

1, Deep cervical fascia, superficial layer; 1′, sternocleidomastoid; 1″, trapezius; 2, deep cervical fascia, middle layer; 3, 4, deep cervical fascia, deep or prevertebral layer; 5, carotid sheath, continued over sternothyroid (9); 6, sympathetic trunk; 7, scalenus anterior; 8, internal jugular; 10, external jugular; 11, vagus; 12, jugular lymph-node; 13, visceral space; 15, recurrent nerve; 16, thyroid gland (in red); 17, prevertebral space; 18, vertebral artery.

lacking entirely. When well developed (figs. 1144, 1145), it usually does not occupy an extreme caudal position, so that the shape of the entire organ is more that of an 'H' than of a horse-shoe, 'U.' Due to its relations the ventral surface of the isthmus is somewhat convex, while the dorsal one is distinctly concave. In some cases the isthmus is rather voluminous and it may then represent the greater portion of the gland (arrested morphogenesis, see below), while the lateral lobes are small, or one or the other is entirely absent.

The greatest degree of variation is shown in the size and extension of the so-called **pyramidal lobe** of the thyroid gland (pyramid of Lalouette, 1743). This pyramidal lobe (figs. 1145, 1147, 1148) usually has the shape of a rather narrow strip, broader at its basal end and tapering toward its cranial, apical end. It commonly arises from the isthmus, but may at times be attached to the caudal region of either of the lateral lobes. It may extend as far craniad as the hyoid bone, although more often it ends in the neighborhood of the thyroid cartilage and continues as a ligament or muscle (see below). It usually lies somewhat to the left of the midline and is present in about one-third of the cases.

Size.—The size and weight of the gland are subject to considerable variation. It is next to impossible to give exact measurements, since the line between normal, well developed and abnormal, hypertrophied glands is indefinite. In women, it enlarges at puberty and is espe-

cially liable to periodical changes, its size increasing somewhat during menstruation and considerably so during pregnancy. In older persons, the gland decreases in size, due to the partial replacement of the epithelial structures by connective tissue (fibrosis). Especially the pyramidal lobe seems to undergo gradual atrophy. It is more often found in children than in the adult. The length of the lateral lobes is variously given as ranging from 5 to 8 cm., the width 2 to 4 cm., the thickness 1 to 2.5 cm. The average weight of the gland is given as 34 g. with a range from 11 to 60 g. Racial and geographical differences are considerable. In women, the gland is always larger and heavier than in men, a difference not apparent in infants. The gland readily becomes hypertrophied, especially in women, and is apt to undergo pathological changes (goiter or struma). A congenital struma may be found in children of affected mothers, especially in regions where endemic goiter prevails, probably due to the lack of iodin in the soil.

The **color** of the thyroid gland is reddish or grayish brown, but may at times become rather bluish. The **consistency** is rather firm, but the gland is slightly compressible, the degree of rigidity depending on its physiological state. The surface of the gland is smooth or slightly uneven.

The thyroid gland is surrounded by a white fibrous connective tissue **sheath,** which is a part of, and in close connection with, the deep fascia of the neck. Near its insertion on the lateral vertebral processes, the deep fascia of the neck gives off a layer, the so-called transverse aponeurosis of the neck. As this approaches the area of the carotid artery, jugular vein and vagus nerve, it splits into two layers, surrounding these structures as the carotid sheath. Medially to the vessels, these two layers do not re-unite; the posterior one is continued

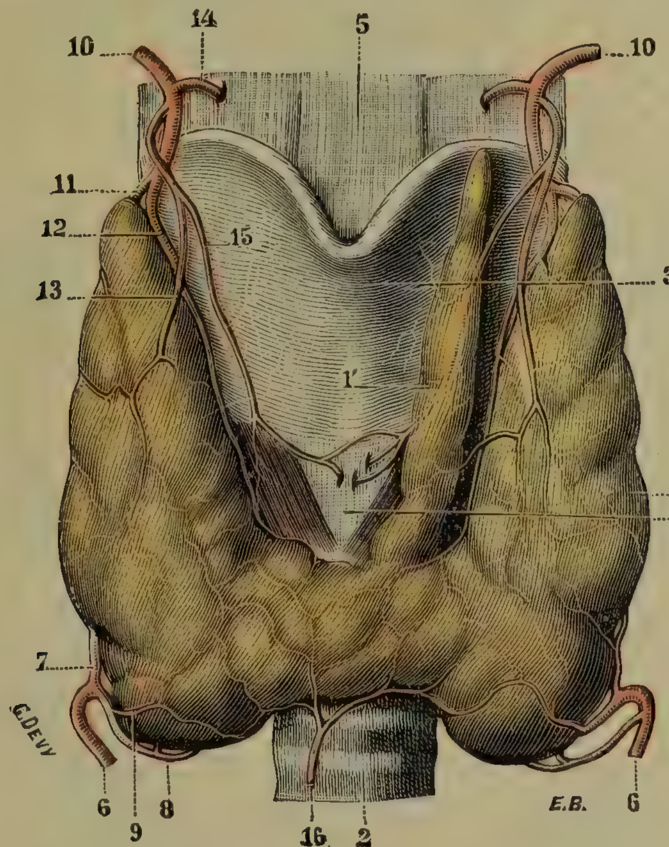


FIG. 1147.—ARTERIES OF THE THYROID GLAND, ANTERIOR VIEW. 1. Lateral lobe; 1′, pyramidal lobe; 2, trachea; 3, thyroid cartilage; 4, cricothyroid membrane; 5, hyothyroid membrane; 6, 7, 8, 9, inferior thyroid artery and branches; 10, 11, 12, 13, 14, 15, superior thyroid artery and branches; 16, thyroidea ima. (Testut and Jacob.)

behind the pharynx and fuses with the corresponding layer of the opposite side; the anterior, pretracheal layer forms the thyroid sheath. As it reaches the lateral margin of the gland, it splits into two secondary lamellæ, the anterior one being continued over the lateral and anterior surfaces of the gland, enclosing partly the inferior thyroid veins, while the posterior one is closely applied to the wall of the trachea. Thus the gland is completely surrounded by its sheath, which is more or less loosely attached to the surface, so that the gland may easily be shelled out. Finer fibrous trabeculæ connect the sheath with the surface of the organ. This sheath must not be mistaken for the fibrous capsule proper of the gland [capsula glandulæ thyreoideæ], which can be torn away only by force since its tough connective tissue is continued into the interior of the gland. There is an interval between the capsule and the sheath which is traversed by the arteries. The veins also form plexuses in this space (figs. 1147, 1148).

Three **suspensory ligaments** of the thyroid gland, attaching the dorsal surface of the fibrous sheath to the neighboring cartilages are described: a median, running from the ventral surface

of the thyroid cartilage to the dorsal aspect of the isthmus, and two lateral ligaments, attaching the basal portions of the lateral lobes to the tracheal and cricoid cartilages. There may be a fourth ligament, connecting the cranial tip of the pyramidal lobe to the thyroid cartilage or even to the hyoid bone. A muscular band [levator glandulæ thyreoideæ] may take the place of this ligament (fig. 1145). A number of other levator muscles have been described, which represent bundles split off from the neighboring muscles, thyrohyoid, sternohyoid, constrictor pharyngis inferior, etc.

Topography.—The thyroid gland lies ventrally to the upper part of the trachea in the mid-region of the neck. A well-developed pyramidal lobe may extend into the subhyoid or even hyoid region as far as the hyoid bone (fig. 1148). The isthmus and pyramidal lobe occupy a ventral, superficial position, while the lateral lobes extend back into a more dorsal, deeper area. The isthmus usually covers the second to the fourth tracheal ring. It may, however, reach as high as the cricoid cartilage and then cover the cricotracheal ligament, or as low as the eighth tracheal cartilage. In the midline, the isthmus and pyramidal lobe are covered by the skin and superficial and deep (pretracheal) layers of the fascia only. The lateral lobes lie in the main on the sides of the cricoid and thyroid cartilages and may extend to the fifth or sixth tracheal ring, about 2 cm. above the sternum. The cranial apices of these lobes may come in contact with the esophagus and pharynx. Their more dorsal position is due to the insertion on the thyroid cartilage of the sternothyroid muscle (fig. 1145). Their anterolateral surface is covered directly by this muscle; more superficially are the omohyoid, sternohyoid and also the sternocleidomastoid muscles. The medial surface is applied to the trachea and deeper in to the esophagus (fig. 1146). The attachment to the pharynx, esophagus and larynx is rather loose, while that to the trachea, especially laterally, is firmer.

Clinical aspects.—Persistent remnants of the thyroglossal duct may form cystic outgrowths in the midline of the neck, above, behind or (most commonly) below the hyoid bone. The position of the thyroid isthmus must be kept in mind in tracheotomy (see p. 1328). The posterior surface of the lateral lobe is in contact with the carotid sheath, which may be infiltrated in malignant disease of the thyroid. The gland may receive pulsations from the carotid artery. In ligating the inferior thyroid arteries, especial care must be taken to avoid the recurrent nerve, which passes upward behind the lateral lobe.

In short-necked people the thyroid is relatively lower in relation to the sternum, and enlargements of the gland are apt to become mainly intrathoracic. The presence of an intrathoracic or retrosternal goiter may be determined by X-ray examination. An enlargement of the thyroid is liable to give trouble by pressure on (1) the trachea, which is compressed laterally between the lateral lobes; (2) the esophagus; (3) the internal jugular vein and carotid artery; (4) the recurrent laryngeal or cervical sympathetic nerves.

Blood-vessels.—The blood-supply of the thyroid gland is extremely abundant. There are usually four arteries (fig. 1147) present: the two superior thyroid arteries, branches of the external carotid artery, and two inferior thyroid arteries, branches of the subclavian artery, or more often of the thyrocervical trunk. Not uncommonly, a fifth unpaired artery is present, the *thyroidea ima* artery.

The **superior thyroid artery** (figs. 527, 1147) usually divides into three branches, one coursing over the anterolateral surface, one running along the anterior border to the isthmus and there anastomosing with its mate of the opposite side, and one spreading over the upper part of the medial surface. The pyramidal lobe is supplied from the second branch, usually from that of the left artery. The **inferior thyroid artery** (figs. 527, 1147, 1148) usually has two branches, one running along the inferior border of the lateral lobe to the dorsal aspect of the isthmus and there anastomosing with its partner from the opposite side, the other one supplying the lower region of the dorsal and medial surfaces of the lateral lobes. A third one may establish an anastomosis with the superior branches. In the region of the isthmus there is usually found an anastomosis of all four or five thyroid arteries. The unpaired **thyroidea ima** artery arises from the aortic arch or the innominate artery, ascends ventrally to the trachea somewhat on the right side, until it reaches the isthmus, where it anastomoses with the others (figs. 584, 1147). These arteries send their branches directly into the substance of the gland, the primary ones running in the connective tissue septa which extend from the capsule into the interior.

The **veins** emerging from the gland form on the anterolateral surface a veritable plexus (fig. 1148) from which arise: the **superior thyroid veins,** tributaries to the internal jugular or more often to the common facial vein; the **middle thyroid veins,** tributaries to the internal jugular vein; the **inferior thyroid veins,** draining lower down into the jugular or innominate vein; and occasionally, the unpaired **thyroidea ima vein,** draining into the left innominate vein or the venous angle.

Lymphatics.—Of great importance is the lymph-circulation of the thyroid gland, corresponding to the inferior and superior blood-supply. There is a superior and an inferior area of lymphatic drainage, each area supplying medial and lateral channels. The medial superior channels drain the cranial border of the isthmus and the medial surfaces, the lateral superior channels drain the ventral and dorsal surfaces. Both groups run into the deep cervical lymph-

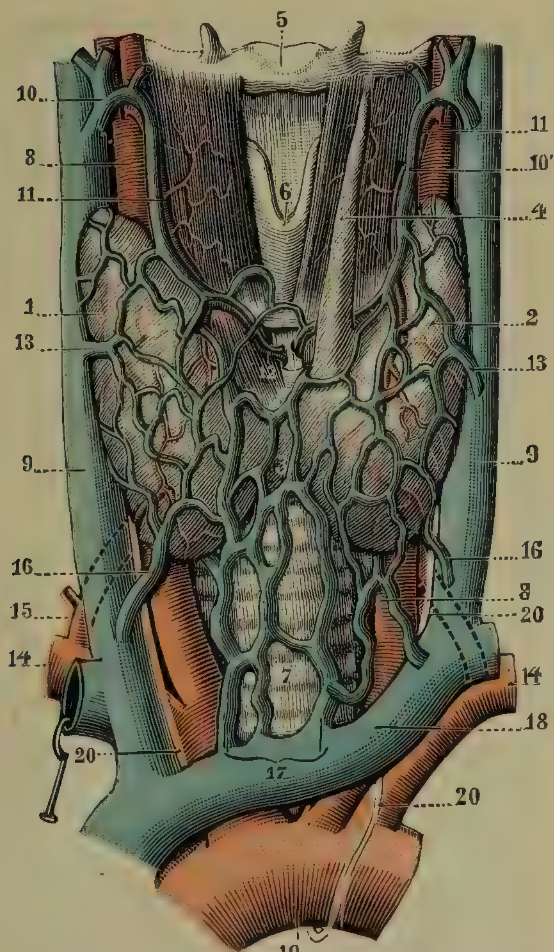


Fig. 1148.—Vessels of the Thyroid Gland, Anterior View. 1, 2, 3, Lateral lobes and isthmus; 4, pyramidal lobe; 5, hyoid bone; 6, thyroid cartilage; 7, trachea; 8, common carotid; 9, internal jugular; 10, thyro-linguo-facial vein; 11, superior thyroid artery; 12, anastomosing vessels; 13, middle thyroid vein; 14, subclavian artery; 15, inferior thyroid artery; 16, inferior lateral thyroid veins; 17, inferior medial thyroid veins; 18, left innominate vein; 19, aortic arch; 20, vagus and left recurrent nerves. (Testut.)

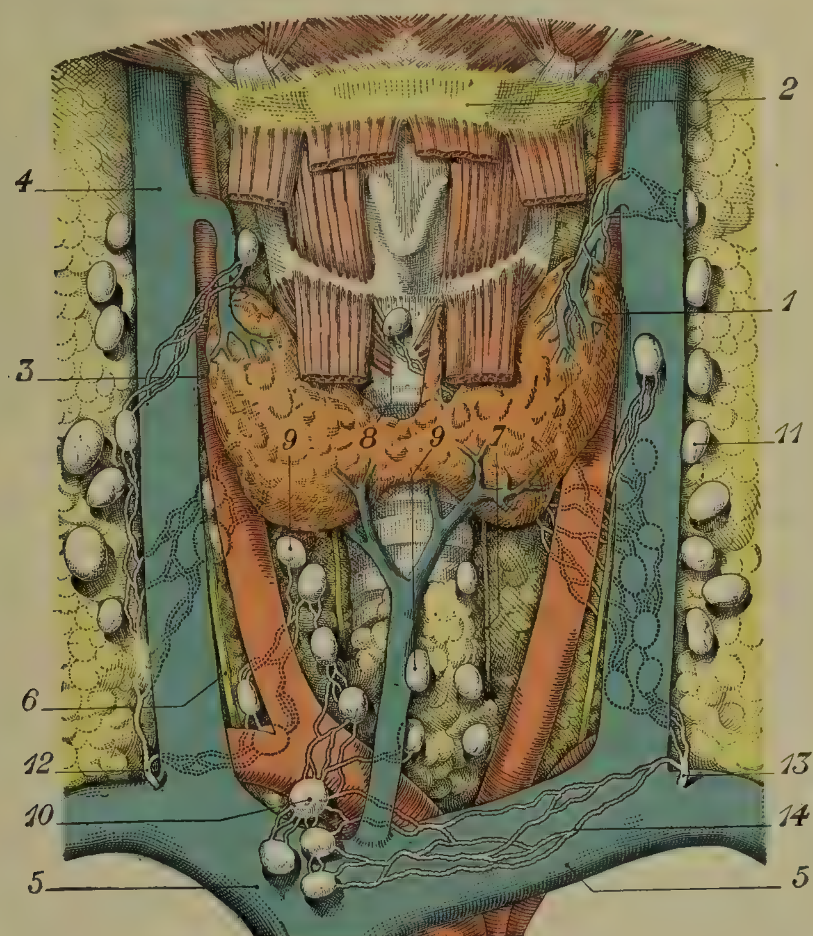


Fig. 1149.—Lymph-vessels and Nodes in the Region of the Thyroid. (Testut and Latarjet, 'Human Anatomy.')

1, Thyroid gland; 2, hyoid bone; 3, common carotid artery; 4, internal jugular vein; 5, right and left innominate veins; 6, vagus nerve; 7, recurrent nerve; 8, 9, laryngeal and paratracheal lymph nodes; 10, sternal (retrosternal) lymph nodes; 11, deep cervical (jugular) chain; 12, 13, right and left jugular lymphatic trunks; 14, connecting lymph vessels.

nodes. The medial inferior channels drain the isthmus and medial portions of the lateral lobes and run into the pretracheal and paratracheal nodes; the lateral inferior vessels drain the lateral inferior portions and run into the supraclavicular nodes. The lymph-nodes of the thyroid gland, which are surgically important, are, therefore: the deep cervical nodes (superior, as well as supraclavicular), the prelaryngeal, the pretracheal and paratracheal, sometimes also the upper mediastinal nodes. (See fig. 1149.)

Nerves.—The nerve-supply of the thyroid gland comes mainly from the middle and inferior cervical ganglia of the sympathetic system. The fibers follow the arteries and form a *superior* and an *inferior thyroid plexus.* Fibers have also been described coming from the recurrent, superior and inferior laryngeal, the glossopharyngeal, vagus and hypoglossal nerves.

Development.—The thyroid gland arises (see p. 59) as a ventral median diverticulum of the pharynx (figs., 42 A, 46), cranial to the second branchial arches. Grosser has shown that the thyroid anlage is unpaired and that all previous reports as to the paired, lateral origin of the gland have to be discarded. The epithelial diverticulum is first seen in human embryos of about 1.4 mm. length, with 5 or 6 somites. It is usually a hollow diverticulum which soon shows a slight terminal swelling. In embryos of 2.5 mm. (23 somites), this bud begins to lose its connection with the pharyngeal tube. The duct, *thyroglossal duct,* retrogresses, while the terminal vesicle transforms into a solid mass, which lengthens out in a transverse direction and forms a strip of epithelial tissue running across the midline and showing a distinct swelling at either end, the beginning of the lateral lobes. The point of origin of the epithelial duct moves somewhat caudad, until it comes to lie between the second gill-bars. In the development of the tongue, this region is taken up into the root of the latter, so that, ultimately, a slight depression, *foramen cecum,* on the back of the tongue marks the original opening of the thyroglossal duct, which may occasionally persist as the *ductus lingualis.* Normally the duct is transformed into a solid cord of cells running ventrally to the hyoid bone in the plane of the future lingual

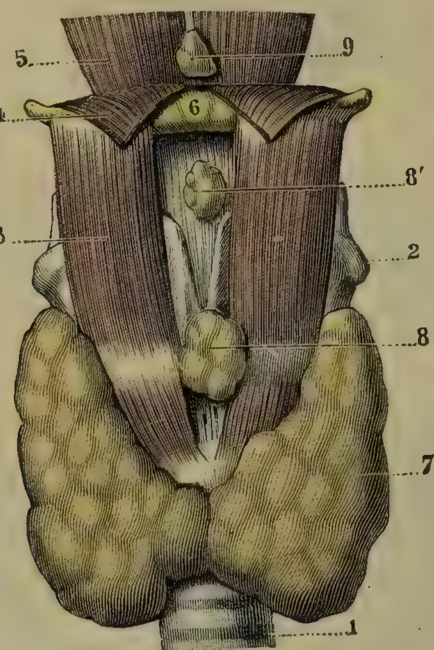


FIG. 1150.—ACCESSORY THYROID GLANDS. (Testut and Latarjet, 'Human Anatomy.')

1, Trachea; 2, thyroid cartilage; 3, thyrohyoid muscle; 4, mylohyoid muscle, retracted; 5, geniohyoid muscle; 6, hyoid bone; 7, thyroid gland; 8, 8′, infrahyoid accessory glands; 9, suprahyoid accessory gland.

septum. Its original course explains the occasional attachment of a well-developed pyramidal lobe to the ventral surface of the hyoid bone. As the thyroid mass increases it moves more caudad and during the lengthening of the branchial region is carried into its final position, caudal to the larynx. In extreme cases it may even extend into the mediastinum, and findings have been reported of hernias of the thyroid gland into the thoracic cavity. In older persons, there may be a physiological thyroptosis; as the larynx gradually assumes a more caudal position, the thyroid is pushed toward the thoracic aperture. In the early embryo the thyroglossal duct thins out, until finally it breaks up into small epithelial nodules which normally disappear. The lateral lobes expand further, numerous capillaries approach the surface of the epithelial tissue, penetrate into the interior and later break it up into numerous smaller groups and clusters of cells. These epithelial nodules finally hollow out, many of them not until after birth, and form closed follicles, in the lumen of which colloid begins to appear as early as the fourth month of fetal life. Iodin is usually present at the sixth month. The mass of the lateral lobes is slightly increased by the addition of epithelial cell groups, coming from the ventral portions of the fifth branchial clefts. These *ultimobranchial bodies* are taken into the area of the thyroid tissue, where they gradually disintegrate. Therefore, they do *not* form any part of the thyroid gland (Grosser). The capsule of the gland is formed rather late in fetal life, so that tissues, foreign to the thyroid, may easily become enclosed within its area. This sometimes happens with the parathyroids IV; muscle, ganglion cells and thymus tissue also have been found therein.

Variations.—All variations and abnormalities in the shape and size of the thyroid gland and the distribution of accessory thyroid nodules can easily be explained on an embryological and phylogenetic basis. The greatest range of variation is found in the pyramidal lobe and isthmus. Apparently, it is the phylogenetic tendency of the organ to lose its connection with the pharynx, push as far caudad as possible and then to spread out transversely, so as to form two distinct

lateral lobes. Two symmetrical lobes are normal in some amphibians and birds. The most extreme variations in man would be, on the one hand, a well-developed, unpaired, pyramidal lobe, attached to the lingual septum or hyoid bone, with a well-formed isthmus (selachian and reptilian type); on the other hand, two lateral lobes entirely separated or connected by a very thin isthmus, which may consist of connective tissue only. Between these two extremes all degrees of variations have been described. Sometimes one lobe may be very small, while the other is large. Remnants of the thyroglossal duct, sometimes *cranially* to the hyoid bone (27 per cent. of cases), may lead to the formation of small accessory thyroid nodules or, at least, epithelial cysts, lying between the fibers of the geniohyoid muscle. Such rudiments, in later life, may undergo a renewed development. Accessory thyroid glands, sometimes five or more, are more often broken-off parts of the pyramidal lobe (fig. 1150). All such nodules lie cranially to the gland proper. More distal portions of the gland may become cut off and then lie caudally to the larynx. A possible extension into the mediastinum and thorax has been mentioned above. The main gland may be absent entirely, while a number of smaller nodules assume its function. (In cyclostomes and teleosts we find scattered follicular units in place of a single encapsulated gland.) The connection with the foramen cecum may persist, or the latter may extend into a deep, branching canal with mucous glands present in its epithelium.

THE PARATHYROID GLANDS

The **parathyroid glands** [glandulæ parathyreoideæ] are small structures, usually two on each side, lying in the neighborhood of, or closely attached to, the dorsal surface of the thyroid gland. Not uncommonly, one may find one or the other

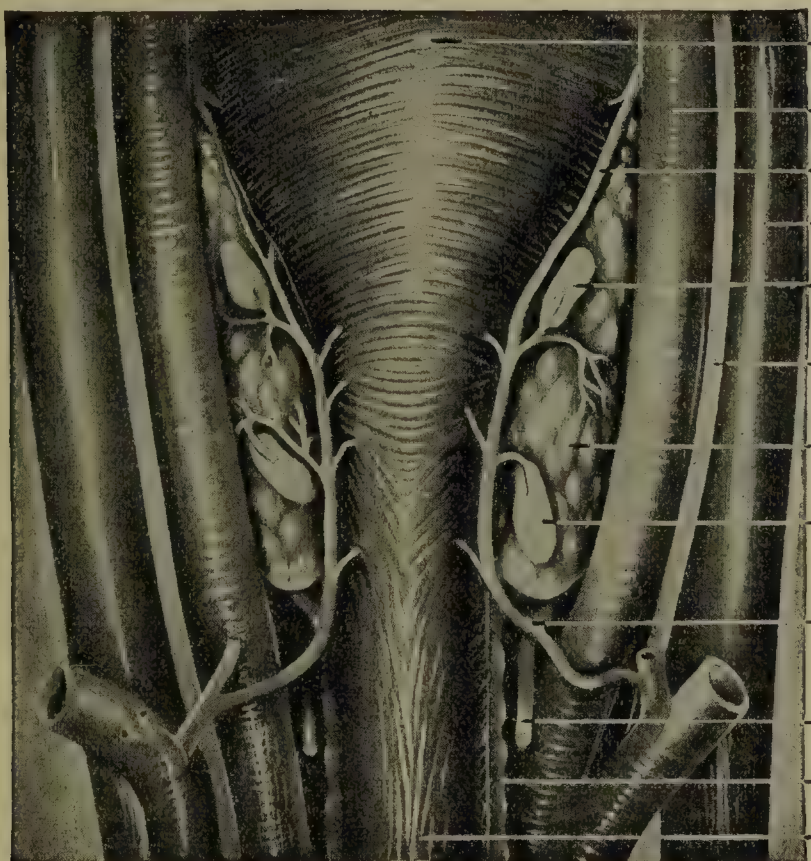


Fig. 1151.—Parathyroid Glands, Viewed From Behind (Natural Size).

nodule embedded in the thyroid tissue. Their structure is entirely different from that of the thyroid, as is also their physiology. Therefore they must *not* be grouped with the *accessory* thyroid glands, of which there may be several present. In spite of their minute size, the parathyroids are of extreme physiological importance, the removal of all of them leading to tetany and death.

The parathyroids are spherical or ovoid bodies, usually somewhat flattened (fig. 1151). Their *size* varies from 2 to 8 mm. in length. In old age they atrophy to some extent. Their *consistency* is firmer than that of the thyroid. Their *color* changes from a light pink in the young to a yellowish-gray in the old. They are easily mistaken for small lymph-nodules, or *vice versa.* Usually, they are situated on the dorsal surface of the lobes of the thyroid, sometimes near the medial border. Their position is rather variable; some may be found within the thyroid, or more caudally toward the sternum, attached to or enclosed in the thymus. The superior pair (parathyroids IV) lie on the finer branches of the inferior thyroid artery, usually dorsal to the recurrent nerve. They may be found as high up as the apices of the lateral lobes of the thyroid. The inferior pair (parathyroids III) lie near the base of the lateral lobes or still further caudad (see development). The average number of parathyroids is four. It varies, however, from one to

twelve. A reduced number means either a fusion of two or more anlagen, misplacement of one or the other bud, or a retrogression (retarded differentiation and ultimate absorption) of some rudiments. Such a process is normal in some mammals. A number higher than four, as found occasionally, indicates a splitting of some of the rudiments into secondary nodules.

The **blood-supply** of the parathyroids (fig. 1151) goes through branches of the inferior (sometimes superior) thyroid arteries and veins, each nodule receiving its artery, which enters at the hilus, a slight depression of the connective tissue capsule. The **lymph-vessels,** in all probability, also belong to the thyroid system. Independent parathyroid lymph-vessels have not been demonstrated. The very rich **nerve-supply** likewise comes from the thyroid branches.

Development.—The parathyroids develop from the epithelium of the dorsal, cranial areas of the most lateral extremities of the third and fourth gill clefts (fig. 46). They are entirely of entodermal origin. These epithelial bodies are soon approached by blood-vessels, which break up the cellular mass into a system of irregularly arranged clusters and cords of cells, between which the vessels form a complicated system of sinusoidal channels. The epithelial *anlagen* soon lose connection with the branchial epithelium and begin their migration in a caudal direction. The pair coming from the third clefts differs somewhat in this respect from that coming from the fourth. The parathyroids IV usually form the upper pair of glands, while the parathyroids III travel farther toward the sternal region. The glands IV usually become attached to, sometimes (rarely in man) embedded within, the thyroid. This variation, of course, depends on the time of formation of the capsule of the thyroid gland, and also on the lateral extension of the thyroid band (see development of thyroid), while the latter travels toward the cricoid region. The glands III, on the other hand, may retain their connection with the thymus-anlagen, and may then travel as far as the mediastinum, remaining attached to, or more often embedded within the thymus. When present, the connecting piece is a very short strip of branchial epithelium and can often be seen even in older embryos, the thymus buds, as it were, pulling along the parathyroids III. Should this connection be broken very early, the parathyroids III may fail to migrate at all and may then be found in a rather cranial location, even more so than the thyroid.

THE THYMUS GLAND

The **thymus** gland is distinctly a double organ, so it would be more correct to speak of the right and left thymus instead of its right and left lobes. The medial surfaces of the two lobes, however, are so closely attached to each other by connective tissue—they are rarely connected by a true isthmus—that usually the thymus has been described as a single, unpaired organ. Its development and the distinct separation into two bodies at the cranial end speak for its duplex anatomical structure.

The shape of the thymus is hard to define, since the gland on account of its very soft consistency easily molds itself to the surrounding structures. Each lobe might be described as a pyramid, the broader base occupying the thoracal end, while the apex is represented by the thinned-out, cervical portion. X-ray examination shows that the dorsoventral diameter is greater than appears in the dissecting room, where the gland often is found to be rather flat. The right lobe usually overlaps the left one.

Size.—The thymus is relatively largest in the child (figs. 1152, 1153) and reaches its absolute maximum of development in the adolescent. Soon after puberty it undergoes retrogression or involution, the thymic parenchyma gradually being replaced by fat, so that in the dissecting room one rarely finds a true glandular body, but in its stead a mass consisting chiefly of adipose tissue. The shape of the epithelial organ, previous to involution, may approximately be retained, and its replacement by fat proceeds by no means as fast and to such an extent as is commonly believed. Even in older individuals, thymus parenchymal tissue is still present. The considerably reduced organ lies then in the retrosternal fatty tissue of the superior mediastinum.

The *length* of the organ in the newborn is variously given from 4 to 6 cm., the width from 1.2 to 4 cm., the thickness from 0.8 to 1.4 cm. More instructive are the *weight* measurements (after Hammar): newborn, 13.26 g.; 11–15 years, 37.52 g.; 16–20 years, 25.28 g.; 46–55 years, 12.85 g. The greatest weight is, therefore, reached during the adolescent period. In the female, the gland is somewhat lighter than in the male. Still more interesting is the weight of the parenchyma, calculated by Hammar after the exclusion of the adipose and connective tissue: newborn, 12.33 g.; 11–15 years, 25.18 g.; 16–20 years, 12.71 g.; 46–55 years, 1.48 g. Thus the amount of thymic glandular tissue is also greatest at puberty. In disease or in malnutrition the thymus readily retrogresses (premature involution).

The **color** of the thymus changes from a pink or reddish tint in the fetus to a pale reddish-gray in the growing child. Later it assumes the yellowish color of fat. It is surrounded by a fine, but firm, connective tissue **capsule,** sending trabeculæ into the body and dividing the latter into numerous small lobules [lobuli thymi] the outlines of which can be seen and felt on the surface. By looser connective tissue the capsule is attached to the neighboring structures, more so on its dorsal than on its ventral aspect.

Topography.—The greater portion of the thymus lies in the upper anterior mediastinal space (thoracic portion); the cranial extremities of the two lobes,

when well developed, extend into the cervical region (cervical portion) (figs. 1152, 1153).

The *cervical portion* of the thymus lies ventral to the trachea, in the thoracal aperture and lower cervical region, starting at about the sixth cervical vertebra. It is covered by the superficial and deep layers of the cervical fascia and the sternothyroid and sternohyoid muscles. It is usually surrounded by some adipose tissue of the suprasternal region. It may be connected to the thyroid on each side by a ligament or strand of fibrous connective tissue (figs. 1152, 1153).

The *thoracic portion* lies in the upper, anterior mediastinal space between the two mediastinal laminæ of the pleura. The median portion of its somewhat convex, ventral surface rests against the dorsal aspects of the sternum and neigh-

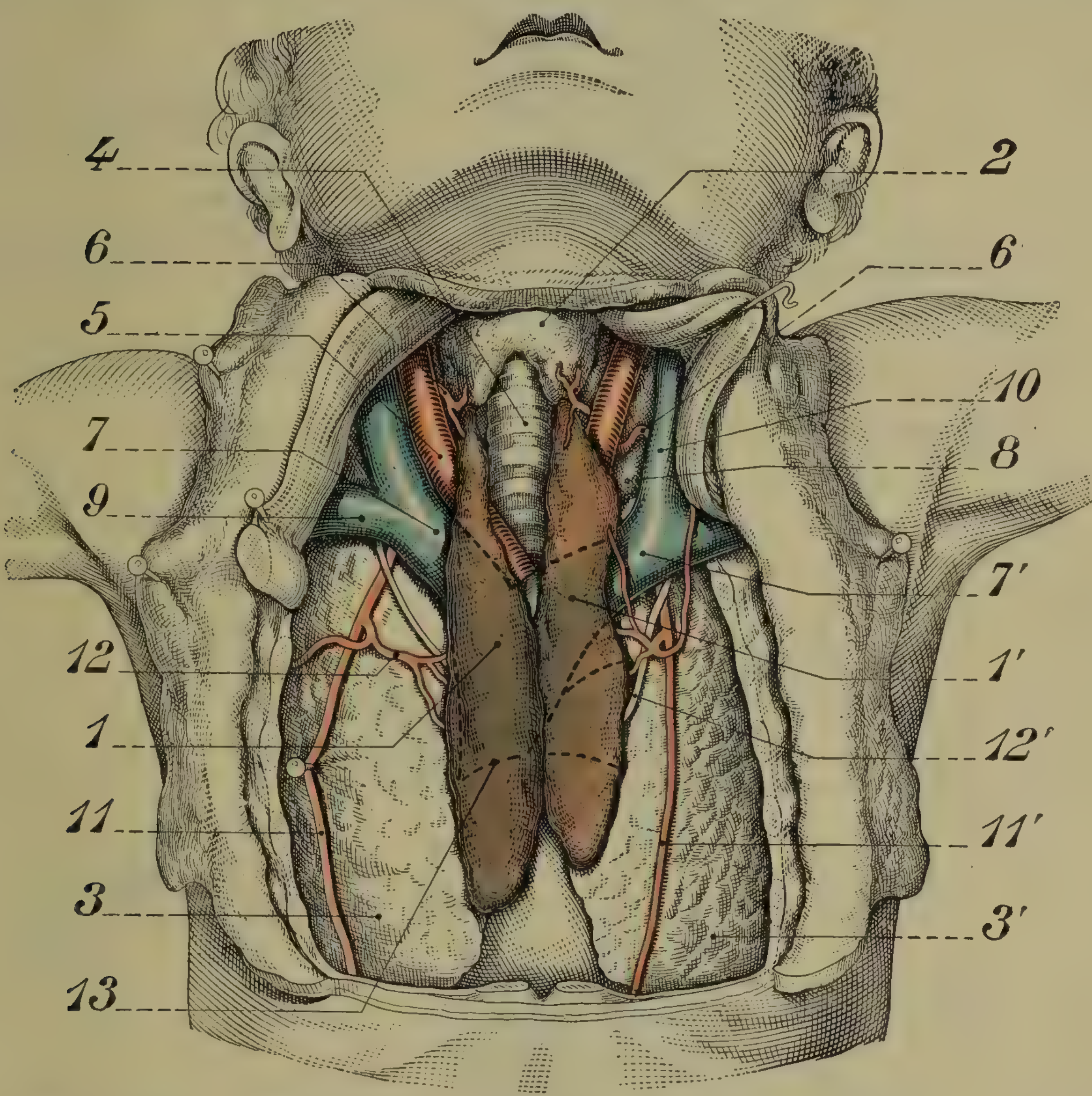


FIG. 1152.—VENTRAL VIEW OF THYMUS AND ITS RELATIONS IN THE NEWBORN. (Testut and Latarjet, 'Human Anatomy.')

1, 1′, Right and left thymus lobes; 2, thyroid gland; 3, 3′, right and left lung; 4, trachea; 5, right common carotid; 6, 6′, inferior thyroid arteries; 7, 7′, right and left innominate veins. (Their junction with the superior vena cava is shown in purple color between dotted lines. On the left, dotted outline of aorta.) 8, left subclavian artery; 9, right subclavian vein; 10, left internal jugular vein; 11, 11′, right and left internal mammary arteries; 12, 12′, right and left thymic arteries; 13, upper limit of pericardium.

boring costal cartilages (as far as the fourth). An excessively large thymus may reach to the diaphragm. In the more cranial region of the manubrium, the sternohyoid and sternothyroid muscles intervene between the sternum and the thymus. The more caudal portion of the concave, dorsal surface of the gland is closely applied to the convex pericardium. The cranial portion of the dorsal surface rests against the large vessels, aortic arch, innominate artery and veins, common carotids, etc. Occasionally, the left innominate vein may lie on the ventral side. As the individual grows, the thymus is withdrawn more and more from the prepericardial mediastinal space and finally occupies only its upper region.

Blood-vessels.—The **arteries** of the thymus are branches of the subclavian, or of the internal mammary artery, either arising directly or springing from the anterior mediastinal branches.

The cranial portions may be supplied by branches of the inferior or median thyroid [thyreoidea ima] arteries. The numerous **veins** of the thymus drain into the left innominate vein (fig. 1152), some into the internal mammary veins and their tributaries or into the inferior thyroid veins.

Lymph-vessels.—Three groups of lymph-vessels have been recognized: superior, anterior and posterior, draining the respective portions of the gland. Distinct lymph channels can be found within the parenchyma following the connective tissue trabeculæ. The larger channels lead into the anterior mediastinal lymph nodes.

Nerves.—Little is known about the nerves of the thymus and their endings. Fine, non-medullated nerve-fibers have been demonstrated within the gland, forming networks around the vessels and in the trabeculæ. These, no doubt, belong to the sympathetic system. Fibers from the vagus have also been observed. A branch of the left phrenic nerve extends to the left lobe. It has not been traced further than the capsule.

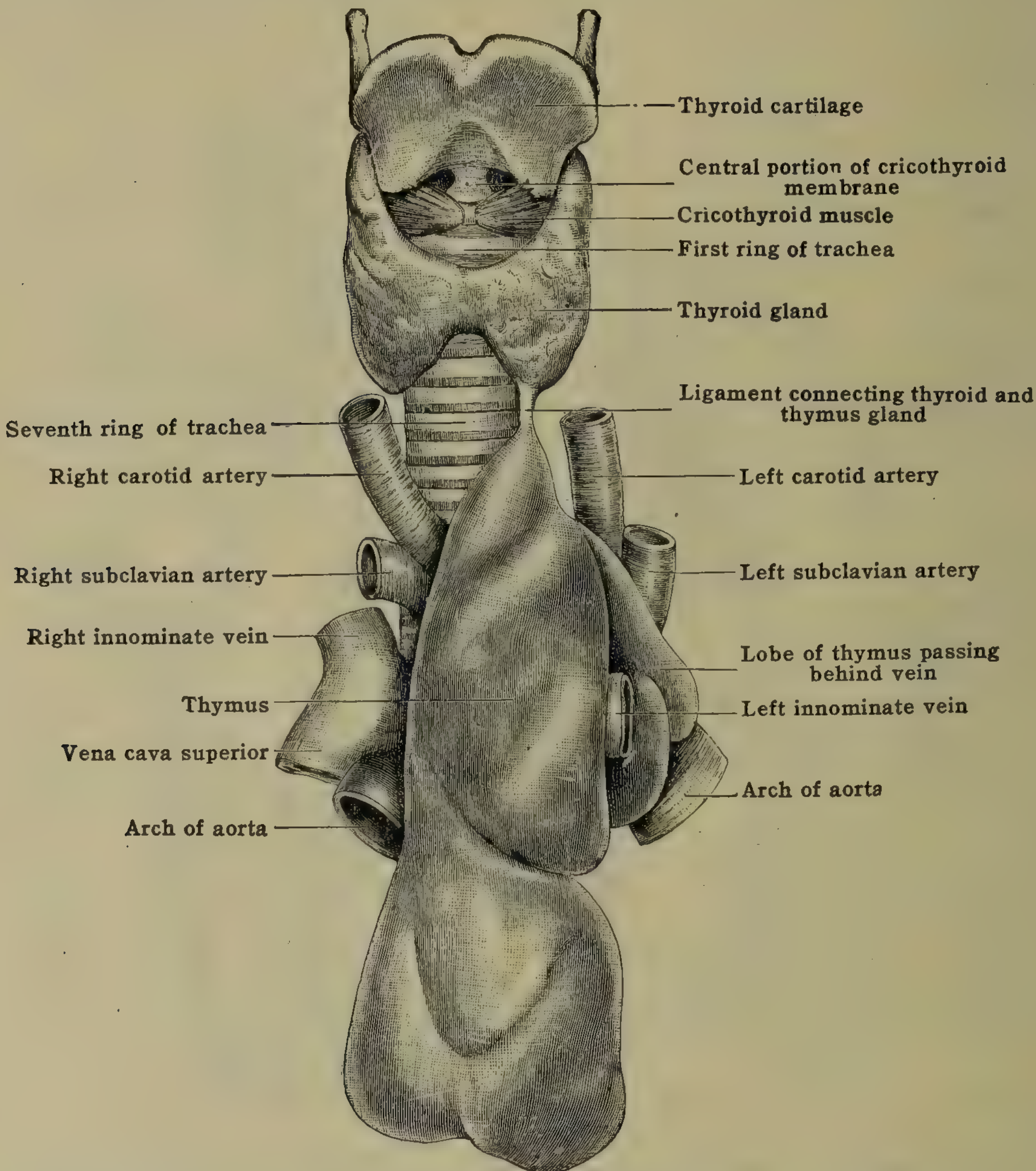


Fig. 1153.—Thymus and Thyroid Gland in a Child of Two Years.

Development.—The thymus bodies arise (see p. 59) during the fourth week of fetal life (5–7 mm. embryos) from the ventral region of the most lateral extremities of the third, sometimes also of the fourth, gill clefts (fig. 46). In man, the thymus is entirely of endodermal origin. The thymus diverticulum, sometimes distinctly hollow, grows in a ventral and caudal direction and lengthens out into a solid mass of epithelial cells, which loses its connection with the pharyngeal epithelium (in embryos of about 12 mm.). Blood-vessels very soon approach its surface and penetrate into the interior. No connection is established with the lobe of the other side. Later, in the 15 mm. embryo, when the two portions move still farther caudad into the sternothoracal space and after a connective tissue capsule has been formed, the two glands lie close against each other, the right one usually in a more ventral position and overlapping the left. If separate epithelial buds are formed from the ventral side of the fourth gill clefts, they may undergo independent development. Usually they are taken up into the main thymic tissue and there retrogress; or they may form an additional lobe. The parathyroids, which develop from the same gill clefts as the thymus anlagen III and IV, may be attached to, or enclosed in, the thymus-tissue. As the epithelial thymus mass moves caudad, its cranial portion (stalk) disintegrates. The glandular tissue then sprouts out in the form of small lobules. For some time a distinct central tract or even a hollow canal is noticeable.

Variations.—Variations from the anatomical norm are usually due to some irregularity in development. Like the thyroid, the thymus seems to have a phylogenetic tendency to move toward the thoracic region. A failure to do so or a failure to reduce the stalk will give a large

cervical thymus (reptilian or avian type), sometimes bordering on the thyroid. At times, the cervical portion is represented merely by a strand of connective tissue. Accessory thymus glands may be broken-off portions of the stalk, left behind in the caudal migration of the tissue, or may come directly (in rare cases) from the epithelium of the clefts. In lower forms, several (2–5) branchial clefts assist in the formation of the organ. Absence of the thymus has been reported, usually in combination with other abnormalities. An abnormally long persisting thymus is found in the pathological condition of *status lymphaticus* or status thymicus. In cases of sudden death in children (thymic death) a large thymus is often found, but it is doubtful whether this is the cause of death.

It is definitely established that (1) the thymus is a gland of the infantile period (group *a*, see p. 1414); (2) the normal physiology of the thymus is upset during an abnormal progress of growth and differentiation (e.g., precocious involution, delayed involution); (3) the thymus most readily responds to stimuli exerted by any of the other glands of group *a*, yet it is by no means certain whether the thymus is able to act as a *primary, causal* factor in this physiological ring of developmental glands (group *a*), or is simply *secondarily* influenced and controlled by the other members. In other words, a primary and controlling internal secretion of the thymus might be questioned. Anatomically, we must admit that the morphological basis for a secretory function is lacking, although the gland develops as a typical epithelioid organ. On the other hand, some physiological correlation seems to exist between the state of differentiation of the organism and the condition of the thymus.

THE CHROMAFFIN SYSTEM

To the **chromaffin system** (fig. 1154) belong a number of organs, some minute in size, which are serially arranged along both sides of the dorsal aorta, most of

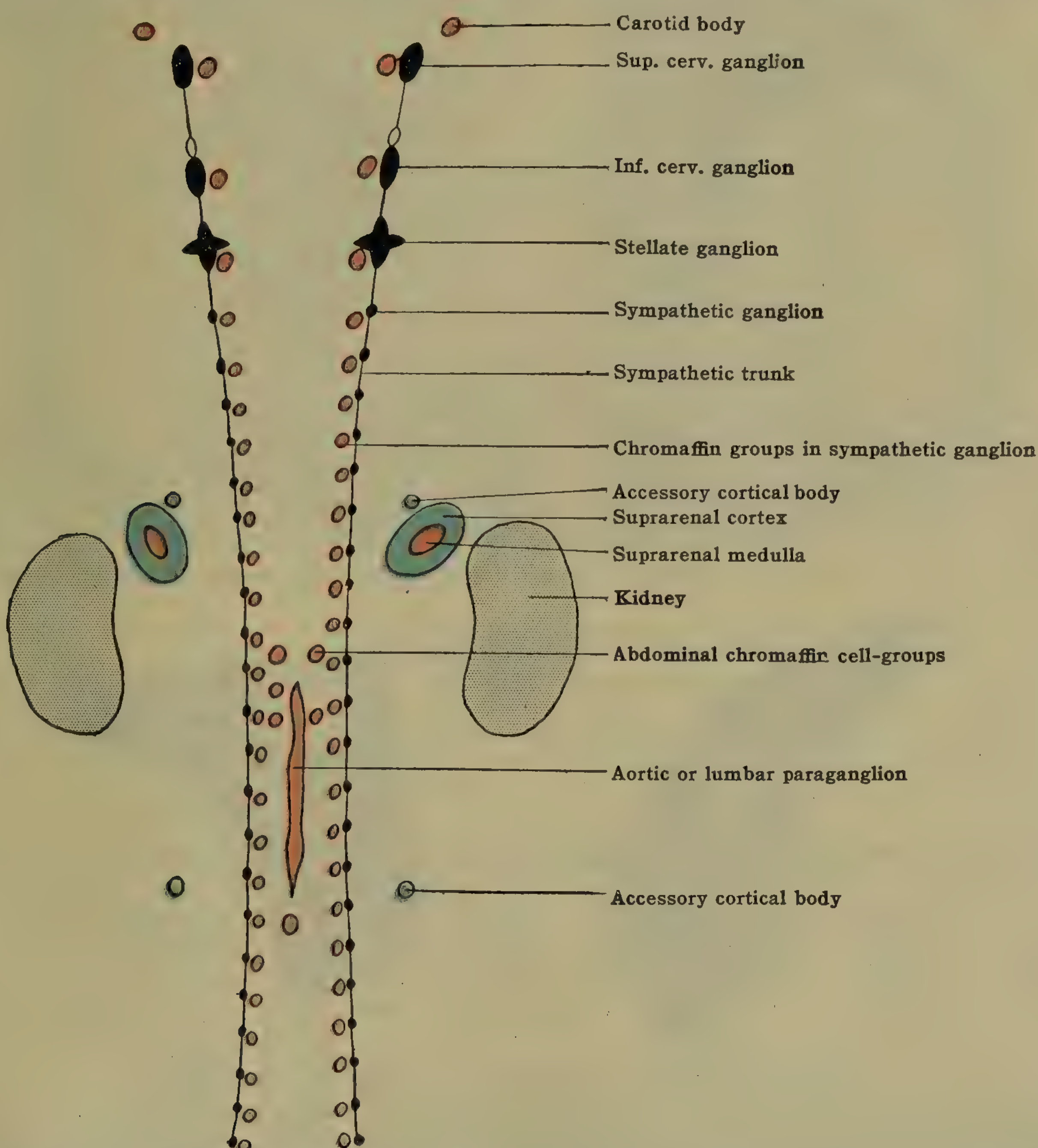


Fig. 1154.—Diagram showing the Constituents of the Chromaffin System in Mammals. Chromaffin structures in red; cortical in blue. (Swale Vincent, 'Internal Secretion and the Ductless Glands.')

them in close proximity to the sympathetic ganglia. They are made up mainly of chromaffin cells, the term 'chromaffin' designating a special chemical affinity

of these cells for salts of chromic acid. The cells are derived from cell groups, the greater portion of which is used up in the formation of the sympathetic ganglia. Originally, the sympatho-chromaffin cells are a part of the ganglionic crest, which is constricted off to form the spinal and sympathetic ganglia shortly after closure of the neural canal. The chromaffin cells are, therefore, ectodermal (neural plate) cells, which have traveled, by way of the ganglionic bodies, a further distance to form the chromaffin or paraganglionic bodies. Due to their place of origin, it is not unusual to find true ganglionic cells in these nodules. To the chain of these paraganglionic bodies belong: the **carotid bodies;** the **paraganglia proper**; the **aortic bodies**; and, in part, the **suprarenal glands,** the medulla of the latter being a pair of larger and further developed paraganglia. The chromaffin cells are *not* specialized sympathetic ganglion cells, but present a separate type of cell, which can be recognized as such rather early in development.

THE SUPRARENAL GLANDS

The **suprarenal gland** [glandula suprarenalis] (adrenal gland) [corpus suprarenale NK] lies between the vertebral column and the cranial pole of the kidney,

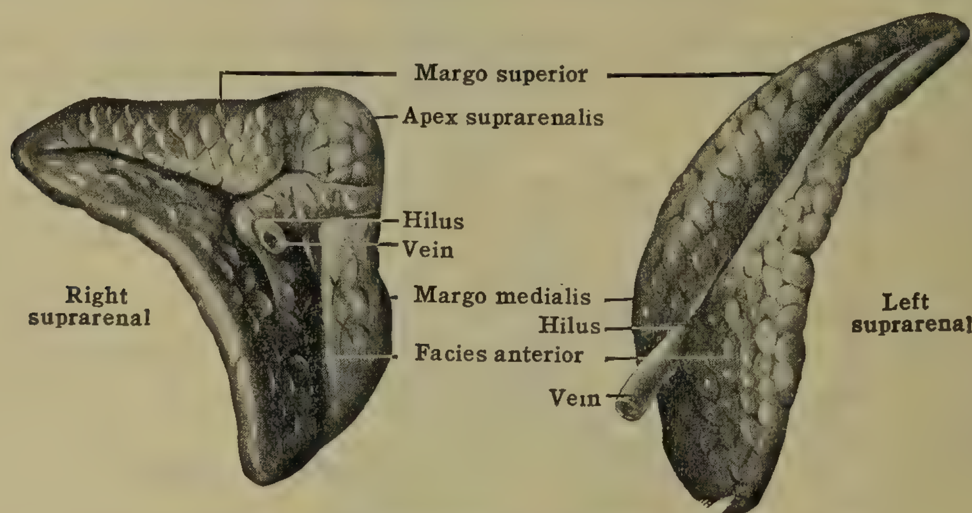


FIG. 1155.—THE SUPRARENAL GLANDS, VENTRAL VIEW.

close to that body, so that the convex upper extremity of the kidney causes a concave impression on the suprarenal (fig. 1157). The left gland lies more along the anteromedial border of the kidney, reaching at times as far down as the hilus and touching the renal vessels. Considering the concave surface as the *base,* the suprarenal gland might be described as a very low pyramid, the basal surface resting against the kidney, the distinct *apex* of the right gland

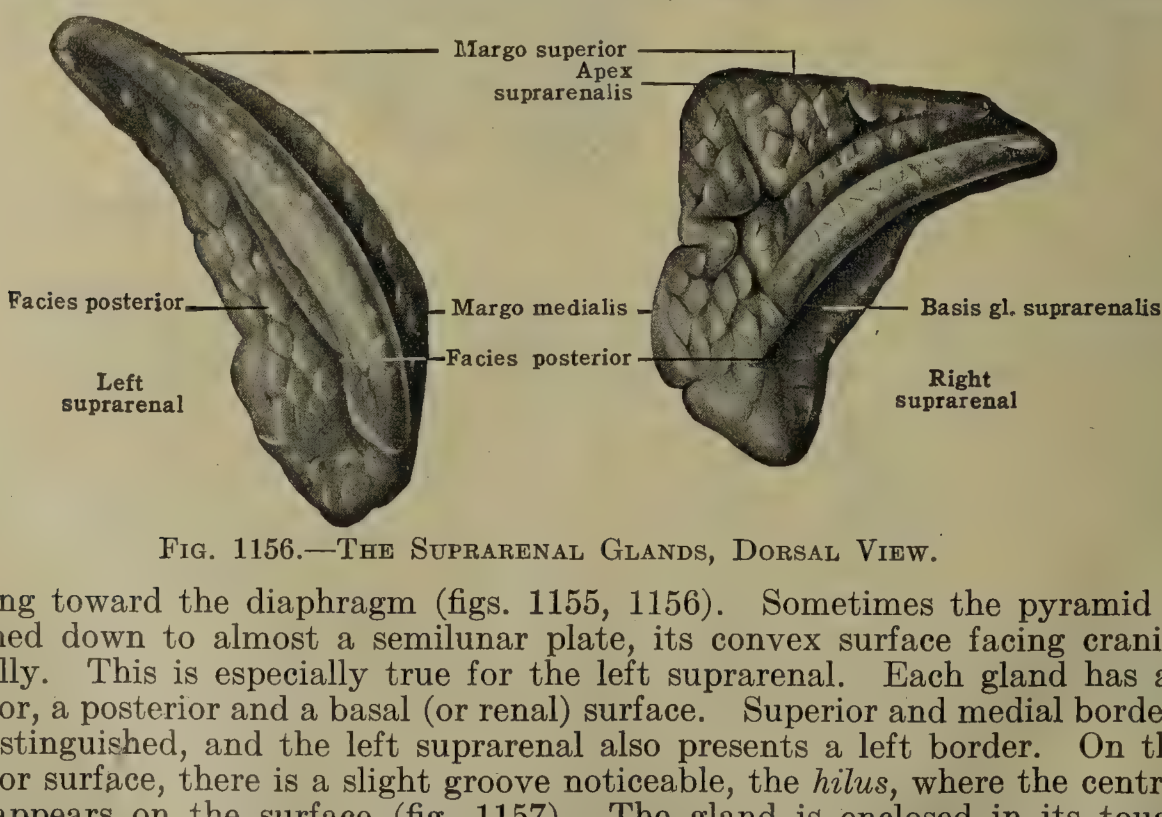


FIG. 1156.—THE SUPRARENAL GLANDS, DORSAL VIEW.

pointing toward the diaphragm (figs. 1155, 1156). Sometimes the pyramid is flattened down to almost a semilunar plate, its convex surface facing craniomedially. This is especially true for the left suprarenal. Each gland has an anterior, a posterior and a basal (or renal) surface. Superior and medial borders are distinguished, and the left suprarenal also presents a left border. On the anterior surface, there is a slight groove noticeable, the *hilus,* where the central vein appears on the surface (fig. 1157). The gland is enclosed in its tough

connective tissue *capsule*, and is embedded in adipose tissue. It is surrounded by the renal fascia (fig. 1090) and is more firmly attached to the latter than to the kidney.

The **weight** of the glands is given from 4 to 18 grams and is liable to considerable physiological variation. The measurements vary from 40 to 60 mm. in length and 20 to 30 mm. in width. The gland is relatively large in the fetus and in the young. In malformations (for instance, anencephalic monsters), it is considerably enlarged. Its **color** is of a yellowish or brownish tint. Its texture is rather firm.

Topography.—The suprarenal glands lie in the epigastric region (figs. 1032, 1087, 1157), at about the level of the eleventh thoracic vertebra. The posterior

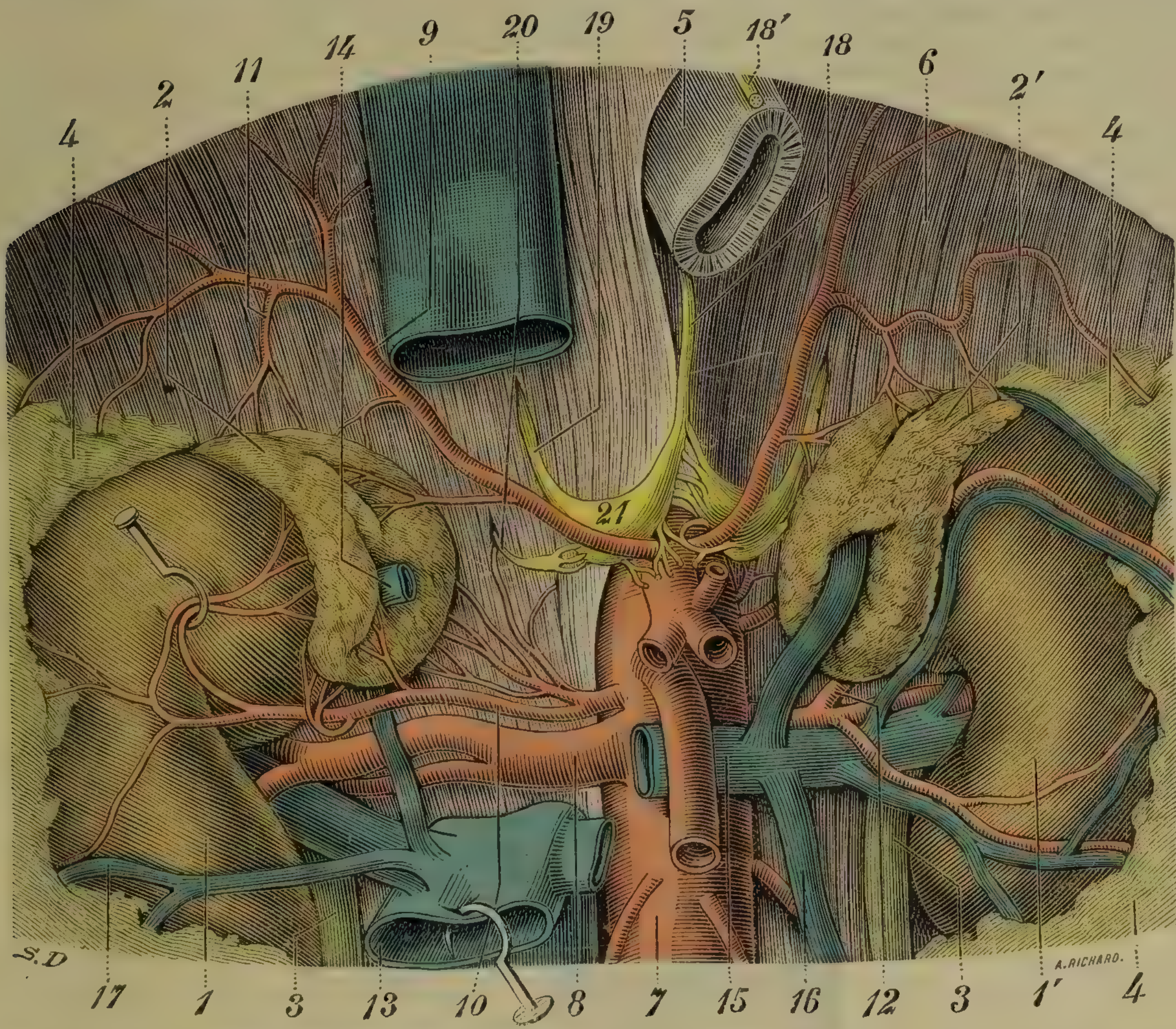


FIG. 1157.—TOPOGRAPHY OF THE SUPRARENAL GLANDS. VENTRAL VIEW, SEMIDIAGRAMMATIC. (Testut and Latarjet, 'Human Anatomy.')

1, 1′, Right and left kidneys; 2, 2′, right and left suprarenals; 3, ureter; 4, fat; 5, esophagus; 6, diaphragm; 7, abdominal aorta; 8, renal artery; 9, inferior phrenic artery; 10, middle suprarenal artery; 11, superior suprarenal artery; 12, inferior suprarenal artery; 13, inferior vena cava (cut); 14, central (suprarenal) vein; 15, renal vein; 16, spermatic vein; 17, vein from renal adipose capsule; 18, 18′, right and left vagi; 19, great splanchnic nerve; 20, lesser splanchnic nerve; 21, right celiac ganglion.

surface rests against the lumbar area of the diaphragm. The anterior surface of the right gland touches the inferior vena cava medially, the liver laterally and (sometimes) the duodenum below. The left gland lies somewhat more cranially and nearer the aorta, behind the lesser omental sac. Anteriorly it is in relation above with the posterior surface of the stomach, below with the posterior surface of the pancreas and the splenic vessels, and laterally, in many cases, with the renal surface of the spleen.

Peritoneal relations.—The extent of the peritoneal covering over the gland varies considerably. On the right side, the peritoneum may not reach the gland at all or only the lower half of the anterior surface. When the right gland touches the duodenum, the peritoneum may cover only the mid-region. On the left side, the omental bursa usually covers the upper half of the anterior surface, and when the pancreas and the splenic vessels lie further caudally, the entire anterior surface.

The suprarenal glands are attached more firmly to the diaphragm than to the kidneys. Hence they do not accompany 'wandering kidneys,' and are not removed in nephrectomy.

Structure.—From the fibrous capsule are given off numerous trabeculæ which pervade the gland and form septa between the groups and rows of cells. Within the capsule, the suprarenal

is composed of two distinct portions, an external firmer, yellowish layer, the *cortex* [substantia corticalis], and an internal, softer layer, the *medulla* [substantia medullaris], which usually appears dark reddish-brown in color, on account of its large blood content. These two portions, the cortex and medulla, really represent *two* distinct *glands* which are different both physiologically and morphologically (see further under Development and Variations).

Blood-supply.—The blood-supply of the suprarenal gland is unusually abundant and richer than that of any other organ. Three arteries, the **superior**, the **middle** and the **inferior suprarenal artery**, approach the capsule at various points and penetrate into the interior along the connective tissue trabeculæ which extend inward from the heavy fibrous capsule. They are branches of the inferior phrenic artery, aorta and renal artery respectively. All veins collect into one large **central vein**, lying in the medulla of the organ and passing out at the hilus as the **suprarenal vein**, which, on the right side, drains into the inferior vena cava, on the left side into the renal vein. Some arterial twigs form a network in the capsule, and special veins drain the peripheral area as tributaries to the inferior phrenic veins, or veins of the adipose and fibrous capsule of the kidney. (See fig. 1157.)

The **lymph-vessels** of the suprarenal form a plexus directly under the capsule and a second one in the medulla. The peripheral plexus drains into vessels leaving the capsule; the central one into those following the central and suprarenal veins. On the right side, the lymph-channels connect ventrally with 2 or 3 lymphatic nodules near the aorta; and dorsally with a node near the crus of the diaphragm. On the left, they drain ventrally into a node situated at the point of origin of the renal artery, and dorsally also into a node between the aorta and the crus of the diaphragm, or, following the splanchnic nerve through the diaphragm, into a mediastinal node lying between the aorta and the ninth thoracic vertebra. Some lymph-channels also drain into the subperitoneal network of the kidneys.

The very abundant **nerves** of the suprarenal gland, forming the **suprarenal plexus**, connect with the renal and celiac plexuses and the celiac ganglia. The greater splanchnic nerve con-

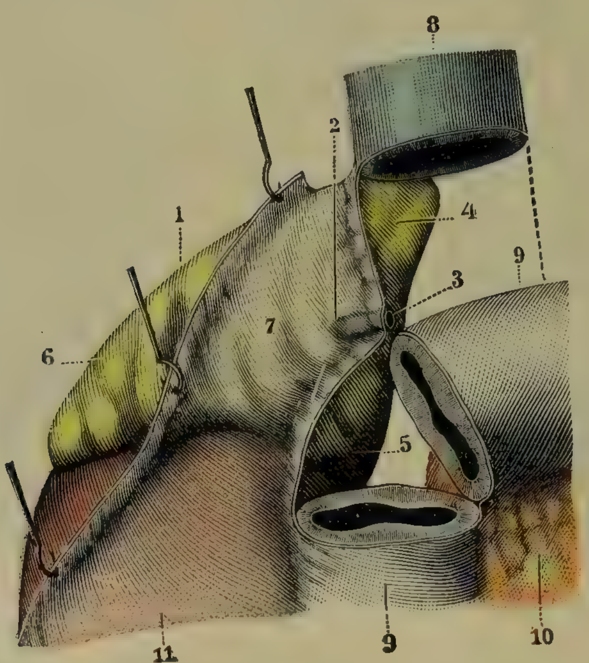


Fig. 1158.—Right Suprarenal Gland, Ventral Aspect. (Testut and Latarjet, 'Human Anatomy.')

1, Suprarenal gland; 2, hilus; 3, central vein; 4, surface covered by inferior vena cava (8); 5, surface covered by duodenum (9); 6, surface in direct contact with liver; 7, surface covered by peritoneum and liver; 10, pancreas; 11, right kidney.

tributes numerous medullated fibers to the suprarenal plexus; some fibers come from the vagus and phrenic nerves. Within the gland the nerves are non-medullated. Small ganglia are present.

Development.—In the discussion of the development of the suprarenal gland, the two portions of the gland, cortex and medulla, have to be considered separately. It is the medullary portion which is derived from the ectodermal cells of the ganglionic crest, and which alone contains chromaffin (phæochrom) cells. Very early, such cells are split off from the nodules containing the sympathetic ganglion-cells, and migrate further ventrad, so as to lie latero-ventrally to the aorta (paraganglia). Several such nodules, near the cranial end of the gonad, combine into a larger mass of cells, lying between the dorsal aorta and the dorsomedial border of the mesonephros. They come into close approximation to the group of mesoderm cells derived (at least the greater part) from that narrow strip of mesothelium of the body cavity between the dorsal mesentery and the genital ridge. There is, in human embryos of 6 mm., an actual budding of mesothelial cells into the underlying mesenchyma, sometimes in tubular form, as occurs in pig embryos. The tubular budding process is a phylogenetic remnant of an older 'duct-gland.' The rapidly multiplying cells which arise in numerous places in the suprarenal ridge soon lose their connection with the mesothelium and form a complete layer of mesoderm around the ectoderm cells, derived from the sympathetic ganglia. In this way, the mass of the chromaffin cells, the medulla, is finally enclosed within the outer cortical layer. Comparatively large twigs of the dorsal aorta (mesonephric vessels) are seen to approach this mass

very early (in 9–10 mm. embryos). The fibrous capsule is formed rather late. For further details on the growth of the suprarenal glands, see DEVELOPMENTAL ANATOMY, p. 60.

Variations.—In lower forms, most of the anamnia, the two portions of the suprarenal glands are still separate as *interrenals* (cortical substance) and *adrenals* (medullary substance). In reptiles, the partial union of the two structures begins to appear. Therefore, it is not at all unusual, even in man, to find, in addition to the suprarenal glands proper, some accessory structures made up of one or the other, or of both components. Only such nodules, which consist of cortex *and* medulla, are properly called **accessory suprarenal glands.** They are usually found near the cranial region of the kidneys, sometimes embedded in the cortex of the kidney or in the suprarenal itself. More often, one finds nodules made up of cortical tissue only. Such *accessory cortical* bodies have been found in more caudal regions of the abdominal cavity, and since, during development, the cortical (mesothelial) tissue is situated close to the germinal epithelium, these bodies may, with the descent of the gonad, be carried into the pelvis or even the scrotum. Such nodules, lying in the adventitia or the ligaments of the genital glands, the spermatic cord or the broad ligament of the uterus, at times have been the cause of a wrong diagnosis of true hermaphroditism, since they were mistaken for rudiments of the genital glands of the opposite sex. Still more often one finds, even in the pelvic region, scattered masses of the medullary substance, which are misplaced paraganglia (*not* accessory suprarenals). A complete absence of the suprarenal glands is rare and only occurs in cases of severe malformations. A hypoplastic condition is often found in connection with hypoplasia of the genital glands and hyperplasia of the thymus and lymphatic structures (*status thymolymphaticus*). A hyperplasia of the suprarenal is usually associated with hirsutism, large genital organs and precocious puberty, particularly in the female.

THE CAROTID BODY

The **carotid body** [glomus caroticum] is a small, ovoid nodule, from 2 to 7 mm. in size, consisting of paraganglionic (chromaffin) tissue and usually lying on

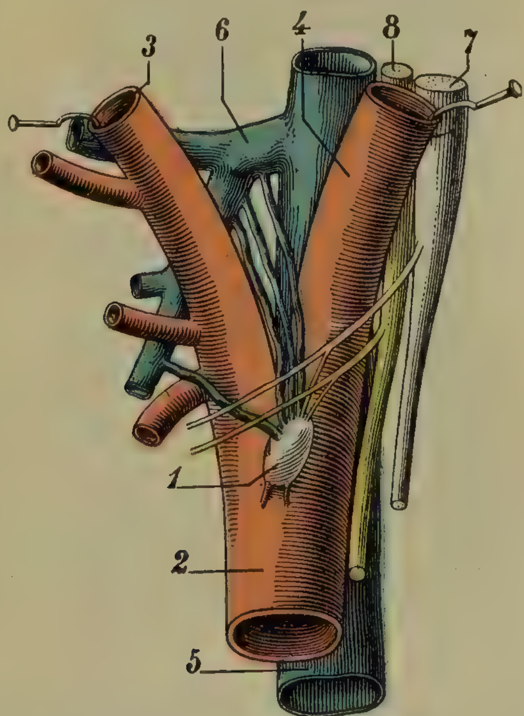


FIG. 1159.—THE GLOMUS CAROTICUM (CAROTID BODY). (From Testut, after Princeteau.) 1, Carotid body; 2, 3, 4, common, external and internal carotids; 5 and 6, int. jugular and tributaries; 7, inf. cervical sympathetic ganglion; 8, vagus.

the medial side of the common carotid artery, at or in the neighborhood of the branching of this vessel into the external and internal carotids (fig. 1159). It is brownish-red in color. The connective tissue of the adventitia of the vessels takes part in the formation of the capsule from which fibrous elements penetrate into the interior of the nodule. Thus, the carotid body is rather closely attached to, and sometimes even partially embedded in, the tunica externa of the arteries. Occasionally, the carotid body is represented by several additional nodules lying in the neighboring adipose tissue. A separate *cardiac paraganglion* has been observed near the origin of the left coronary artery.

The carotid bodies are richly supplied with fine *blood-vessels* which form dense sinuses within the glands. The arteries arise from the carotid, and the venules drain into the internal jugular vein or its tributaries. Large lymph-vessels are present. The *nerve-supply* is mainly sympathetic, coming from the inferior cervical ganglia. Branches have been described from the vagus and laryngeal nerves. Most fibers are non-medullated. Many ganglion cells are present. Nerves and veins enter and leave at the upper pole.

THE AORTIC PARAGANGLIA

The **paraganglia** proper are minute accumulations of chromaffin cells, lying within or attached to the capsule of the ganglia of the sympathetic chain.

Their size is not more than 2 or 3 mm. and usually only one paraganglion belongs to a sympathetic ganglion. Several, sometimes numerous, paraganglia are attached to, or imbedded in, the abdominal sympathetic plexuses. Some usually are attached to one or more of the genitourinary organs, kidney, ureter, ovary, epididymis, prostate.

The **aortic** or **lumbar paraganglia** (paraganglia lumbalia) represent a special group of chromaffin bodies, which likewise develop from the sympathetic nodules. While the rest of the chromaffin bodies are very small, the carotid bodies being the largest of them, the right and left aortic, or abdominal paraganglia, attain a larger size. They may represent a fusion of several large chromaffin bodies into

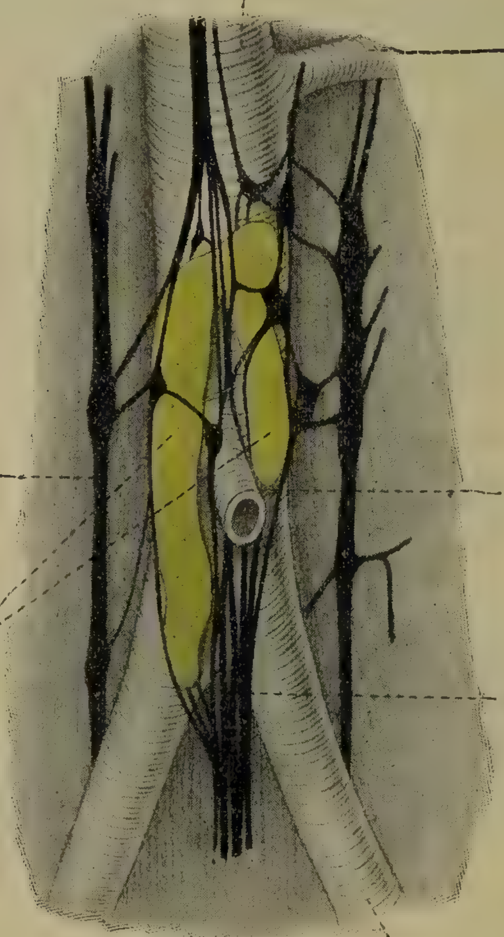


FIG. 1160.—AORTIC PARAGANGLIA. (Zuckerkandl.)

elongated, cylindrical masses, over 1 cm. in length in the young, lying behind the peritoneum, ventrolaterally to the dorsal aorta, at about the level of the origin of the inferior mesenteric artery (fig. 1160). Their size and extension is extremely variable. They may consist of a number of smaller nodules (as many as 70 have been counted). Often the right and left bodies are connected with each other. They are said to undergo partial retrogression after puberty.

The *vascular supply* of the paraganglia is very abundant. The arteries come from the aorta and inferior mesenteric artery; the veins lead into the inferior vena cava, on the right, and into the spermatic or ovarian vein, on the left. Paraganglia attached to other viscera are supplied by branches of the respective vessels, renal, ureteral, spermatic, ovarian, middle colic, lowest lumbar, etc. Nothing is known about the lymph-vessels. The sympathetic *nerve-supply* comes from the abdominal aortic plexus.

THE HYPOPHYSIS

The **hypophysis cerebri** (pituitary gland) is an ovoid, somewhat flattened mass attached to the end of the infundibulum. The latter is an attenuated, funnel-shaped process of the tuber cinereum (see p. 924) which extends downward and

forward (fig. 1161). The cavity of the infundibulum (infundibular recess) is a continuation of the cavity of the tuber cinereum and a part of the third ventricle; it may extend almost into the hypophysis (fig. 1161).

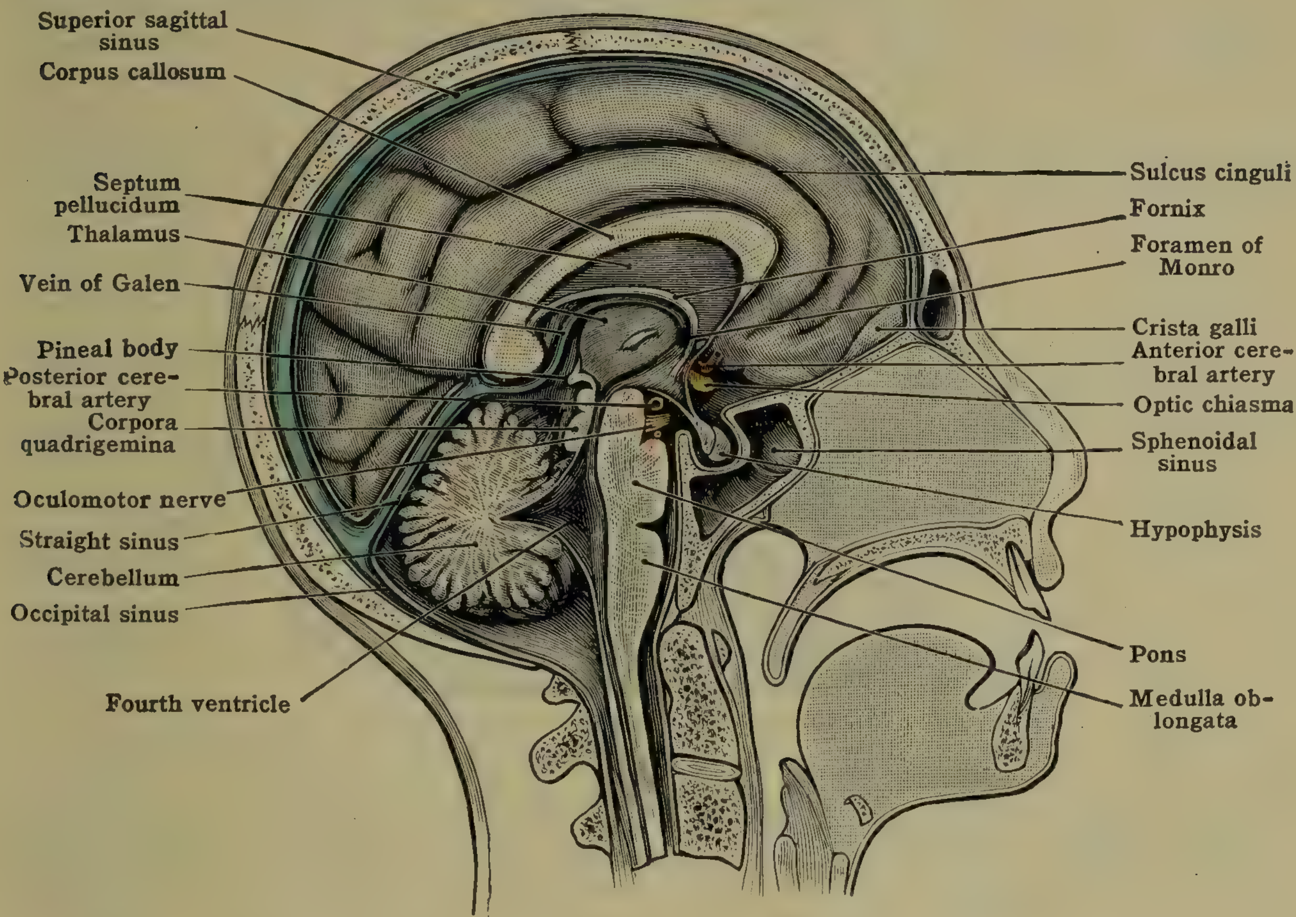


FIG. 1161.—MIDSAGITTAL SECTION OF THE HEAD, SHOWING TOPOGRAPHY OF THE HYPOPHYSIS.

The hypophysis is lodged behind the optic chiasma and in front of the mammillary bodies in the sella turcica of the sphenoid bone (fig. 1164), where it is held down and roofed in by a fold of the inner layer of the dura mater, the *dia-*

FIG. 1162.—TOPOGRAPHY OF HYPOPHYSIS, SHOWN IN HORIZONTAL SECTION. The plane is slightly oblique, passing somewhat lower on the left than on the right. (Testut and Latarjet, 'Human Anatomy.')

1, Hypophysis (showing anterior and posterior lobes); 2, process of sphenoid; 3, sphenoidal sinus; 4, nasal fossæ; 5, ethmoidal sinuses; 6, orbit; 7, basilar artery; 8, cavernous sinus; 9, internal carotid; 10, optic nerve; 11, trigeminal nerve; 12, ophthalmic nerve; 13, oculomotor nerve, inferior group; 14, trochlear nerve; 15, oculomotor nerve, superior group; 16, pons; 17, cerebral hemisphere; 18, cerebellum; 19, middle cranial fossa; 20, superior cerebellar artery.

phragma sellæ. Next to the dura mater on either side runs the sinus cavernosus. The gland is surrounded by a dense, fibrous capsule and consists of two lobes, the larger *anterior*, glandular or buccal lobe (lobus oralis NK), possessing a

concave posterior surface; and the smaller *posterior* or neural lobe (lobus cerebralis NK), which is the terminal swelling of the infundibulum. Usually, the neural portion fits into the posterior concavity of the glandular portion (hypophysis proper) as a ball into the hollow of the hand. The transverse diameter of the gland measures about 15 mm., the antero-posterior about 10 mm., the vertical about 6 mm. The weight is approximately 0.6 gram.

The *blood-supply* of the anterior lobe is very rich, several small arteries leading into it from the neighboring circulus arteriosus, the veins draining into the venous circle and basilar plexus. Posterior hypophyseal branches of the internal carotid arteries supply the far less vascular

FIG. 1163.—HYPOPHYSIS AND RELATIONS. Inferior view.

posterior lobe, with veins leading into the sinus. Little is known about the lymphatic circulation. *Nerves* are supplied along the arteries from the carotid plexus and the infundibulum.

Clinical aspects.—Apart from the general skeletal and nutritional changes (acromegaly and Frœhlich's syndrome), which are caused by alteration in the function of the gland, pressure-effects upon neighboring structures, especially upon the optic nerve and adjacent bones, are noted as the gland enlarges. The anterior lobe as it enlarges is apt to erode and expand the

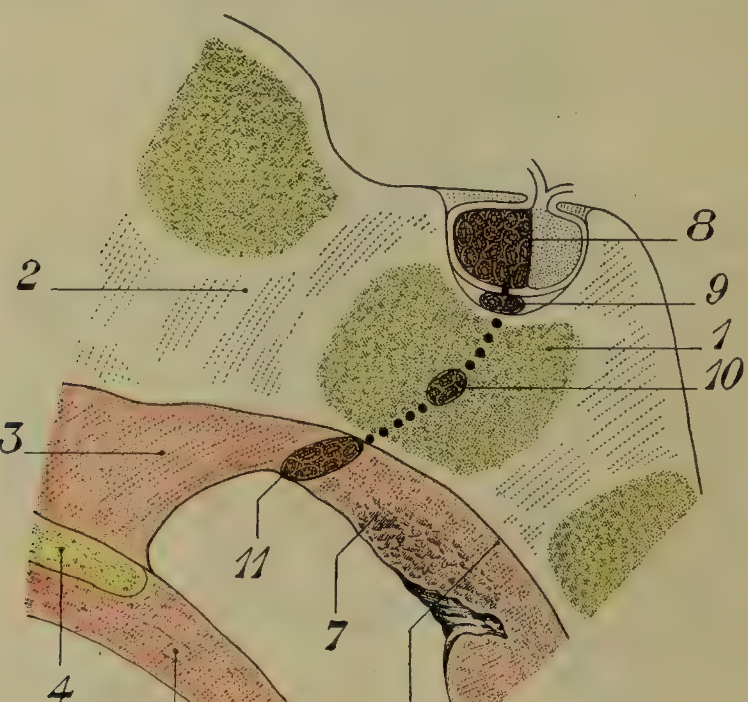


FIG. 1164.—DIAGRAM SHOWING THE RELATIONS OF THE HYPOPHYSIS AND ACCESSORY HYPOPHYSES IN SAGITTAL SECTION. (Testut.)

1, 2, sphenoid bone; 3, nasal septum; 4, palate bone; 5, soft palate (uvula); 6, vault of nasal pharynx; 7, pharyngeal tonsil; 8, hypophysis, showing anterior and posterior lobes; 9, intracranial accessory hypophysis; 10, intraosseous accessory hypophysis; 11, pharyngeal hypophysis. The dotted line indicates the original position of the embryonic hypophyseal outgrowth (Rathke's pouch) from the primitive mouth.

floor of the sella pushing toward the sphenoidal sinus. Interpeduncular tumors on the other hand widen the entrance to the sella, causing destruction of the clinoid processes. The enlargements may be detected by lateral radiograms.

There are three surgical approaches to the *hypophysis*. In one, employed by Cushing, Kanavel and Halsted, a sublabial incision is made in the vestibule of the mouth and through it

the mucosa is separated from each side of the nasal septum back to the sphenoidal sinus. A submucous resection of the septum is then made, the floor of the sphenoidal sinus is removed, the hypophyseal fossa is opened and part of the gland removed. The frontal approach to the hypophysis (McArthur and Frazier) is used by many because of the lessened risk of infection. In this operation a plastic operation is performed upon the frontal bone, the optic foramen is located and the dura incised at this level to permit of exposure of the hypophysis. In Heuer's operation a large flap is turned down on the side and front of the skull and an intradural approach is employed. Text-books upon operative surgery or special articles dealing with these should be consulted for details.

Development.—The entire body is of ectodermal origin, the anterior lobe arising from the ectoderm of the primitive oral cavity (3 mm. embryo), the posterior from the ectoderm of the neural tube. The posterior lobe develops as a ventral diverticulum of the diencephalon (see p. 59). Through the infundibulum, it retains its connection with the tuber cinereum. The anterior lobe develops as a dorsal diverticulum from the roof of the stomodæum (Rathke's pouch) and very soon (second month) loses its connection with the oral ectoderm. It then forms a closed vesicle. Remnants of its duct through the tissue which later forms the sphenoid bone can be seen for some time and may give rise to accessory glandular nodules, or cysts and tumors, lodged in the sphenoid bone. At least one accessory nodule is often found forming the *pharyngeal hypophysis.* A persistent canal is occasionally found in the sphenoid bone (fig. 1164). In myxinoids and sharks, the duct into the oral cavity remains patent. Even in the human adult, the anterior lobe possesses a cavity which represents the extension from the embryonic buccal cavity.

The structure of the anterior lobe of the gland is that of a typical organ of internal secretion. Its influence upon growth and differentiation is well established. In cases of excessive growth of the skeleton and connective tissue (gigantism, acromegaly) and late epiphyseal ossification as well as in hypoplasia of the sex-glands, the anterior lobe of the hypophysis is found to be enlarged or diseased. After removal of the thyroid gland, a vicarious hypertrophy of the glandular lobe, with attempt at colloid-formation, may set in. During menstruation, and still more so during pregnancy, a transient hyperplasia of this lobe occurs, sometimes to such an extent, that pressure may be exerted on the neighboring optic chiasma and temporary blindness may follow. It is well known that the neural portion plays an important rôle in metabolism (urinary excretion, sugar, etc.) and also is capable of stimulating smooth muscle fibers. Anatomically, however, no basis for any secretion can be detected in the posterior lobe, except in the so-called *intermediate portion,* attached to the glandular lobe, lying between it and the neural lobe proper.

THE PINEAL BODY

The **pineal body** [corpus pineale] or **epiphysis,** a part of the epithalamus, is a small nodular ovoidal structure, lying in the transverse cerebral fissure, below

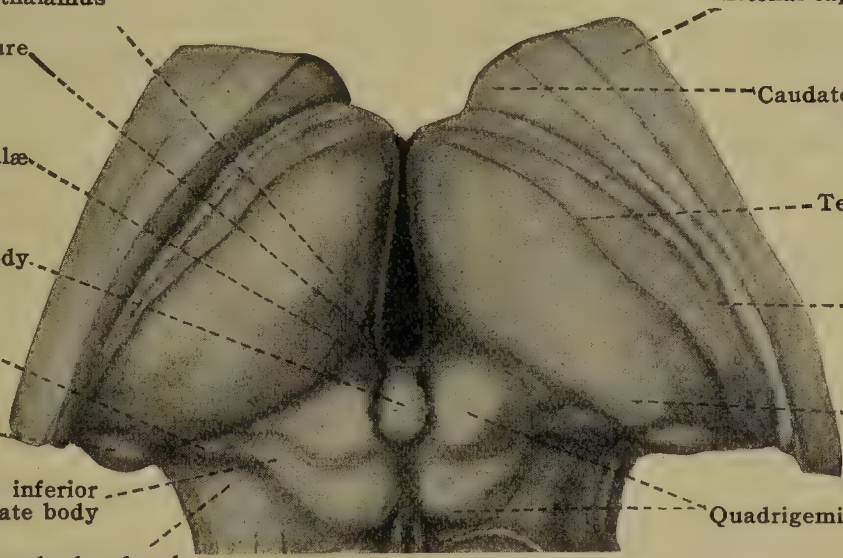


FIG. 1165.—PINEAL BODY AND RELATIONS. Superior view.

the splenium corporis callosi, and extending over the quadrigeminal lamina in a caudal direction from the roof of the posterior extremity of the third ventricle (figs. 714, 744, 1165). It is connected to the medial surfaces of the optic thalami by two attenuated strips, the habenulæ. Its stem is attached just above the posterior commissure of the cerebrum, and its body rests in the groove between the superior quadrigeminate bodies (fig. 1165). The pineal recess of the third ventricle extends into the cavity of the pineal stem. Overlying it is another recess, the suprapineal recess, likewise an evagination from the third ventricle. The pineal body and the suprapineal recess are covered by pia mater and arachnoid and are involved in a continuation of the tela choroidea of the third ventricle. The pineal body is surrounded by a dense capsule of fibrous tissue and consists of groups of epithelioid cells derived from the ependymal layer of the ventricle.

Between these cells are frequently found accretions (brain-sand), surrounding organic particles and consisting of phosphates of calcium, magnesium and ammonium, and of calcium carbonate. Blood-vessels are supplied from the pia mater.

Development.—During the second month of fetal life, several, at least three, dorsal diverticula (epiphyses) develop from the roof of the diencephalon close to the mesencephalon. They are entirely rudimentary in man. The *epiphysis proper* is the most posterior one and is the only one, which, in man, differentiates to any extent (cf. p. 59). The other two are the *paraphysis* and the *parietal eye*, a rudimentary sense-organ of some reptiles. The epiphysis proper is a structure different from the parietal eye.

In different individuals the gland is found in various stages of phylogenetic degeneration. As can be seen in organs of subjects of all ages, the degree of degeneration as well as the amount of accretions do not coincide with the age of the individual. There is no doubt that normally the pineal body is *not* an organ of internal secretion. It is, however, possible that in a diseased, hyperplastic, tumor-forming epiphysis the excessive amount of epithelial tissue *may* give rise to certain secretory products, although no definite facts in this direction have been proved as yet. An enlarged and diseased epiphysis is usually found in precocious sexual development, particularly of the male.

THE COCCYGEAL BODY

Ventral to the tip of the coccyx, between the tendons of the anterior sacrococcygeal muscles, along the median sacral artery are one or more small, varicose nodules (usually there are several accessory nodules), called the **coccygeal body**

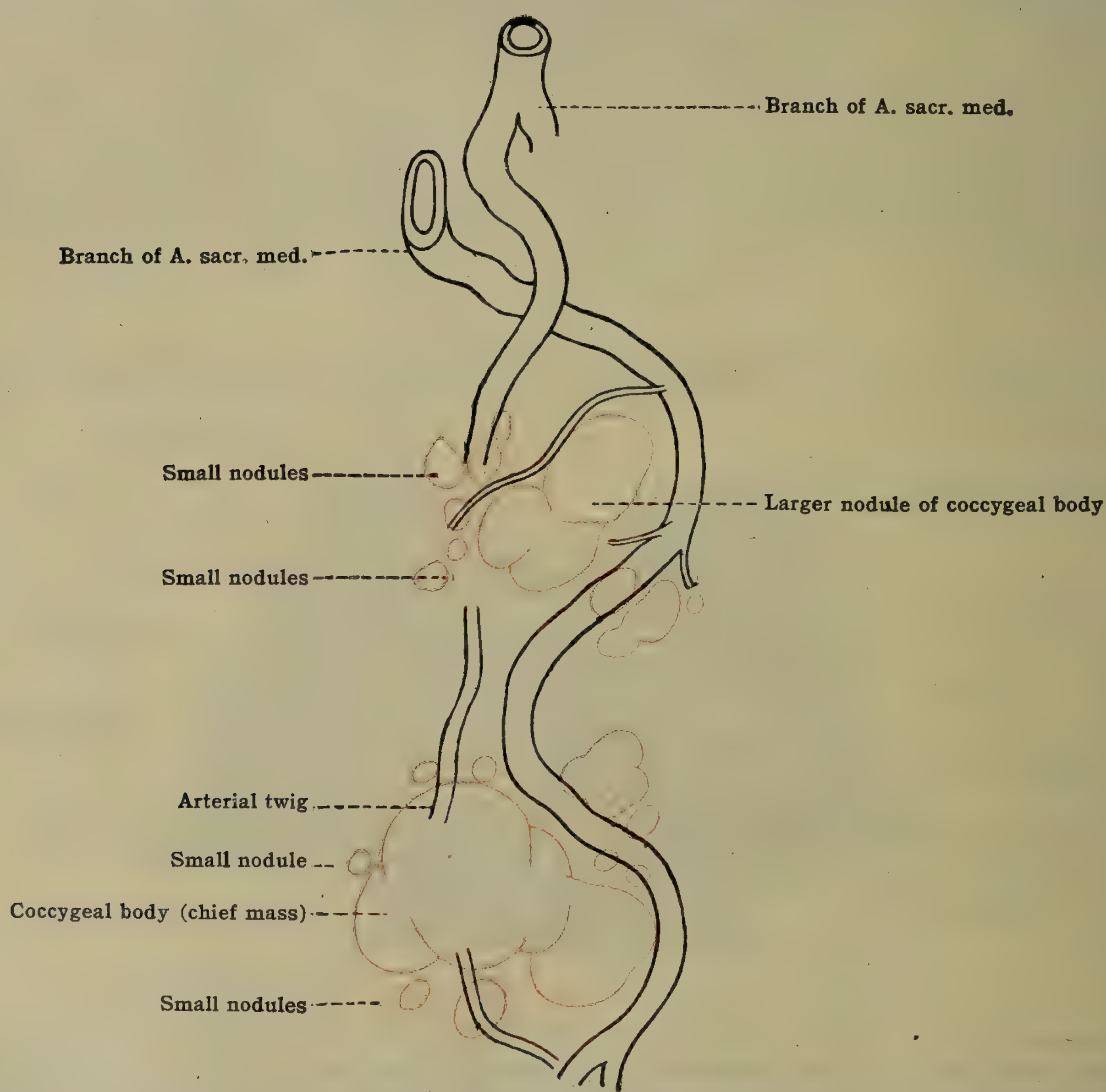


FIG. 1166.—DIAGRAM SHOWING RELATIONS OF THE COCCYGEAL BODY AND ACCESSORY NODULES TO THE MIDDLE SACRAL ARTERY. (J. W. Thomson Walker.)

[glomus coccygeum] (fig. 1166). This group of organs apparently is not glandular and has nothing to do with the chromaffin system. Its nature is entirely doubtful. The vascular supply of these nodules is abundant. The afferent artery forms a skein of anastomosing vessels, which drain into the median sacral vein. Nerves are supplied from the pelvic branches of the sympathetic. Several layers of spheroidal cells, presenting the appearance of epithelioid cells, surround the thin-walled vessels. They are considered to be modified muscle-cells. Between

these epithelioid cells are found connective tissue strands and true smooth muscle-fibers. The coccygeal body, when single, marks the termination of the median sacral artery, and thus takes the place of the rudimentary caudal vessel.

References For The Glands of Internal Secretion

Barker, L. F. (and 96 contributors): Endocrinology and metabolism. Vols. I–V. Appleton & Co., New York, 1922.

Biedl, A.: Innere Sekretion, 2nd–4th ed. 1913–1925. (Complete bibliography.)

Copper, E. R. A.: The histology of the more important human endocrine organs at various ages. Oxford University Press, 1925.

De Beer, G. R.: The comparative anatomy, histology and development of the pituitary body. Oliver & Boyd, Edinburgh, London, 1926.

Dodds, E. C. and Dickens, F.: The chemical and physiological properties of the internal secretions. Oxford Medical Publications, 1925.

Gley, E.: Les grands problèmes de l'endocrinologie. Paris, 1926.

Hirsch, M. (and 60 contributors): Handbuch der inneren Sekretion. Vols. I–III. C. Kabitzsch, Leipzig, 1928–1931. (Complete bibliography.)

Hogben, L. T.: The comparative physiology of internal secretion. Cambridge University Press, 1927.

Sharpey-Schafer, E. A.: The endocrine organs; Part I, the thyroid, the parathyroids and the suprarenal capsules. Part II, the pituitary, the pineal, the alimentary canal, the pancreas, the sex glands. 2nd ed. Longmans, Green & Co., London, New York.

Vincent, S.: Internal secretion and the ductless glands. 3rd ed. London, 1924.

INDEX

In general, only nouns are indexed. Bones, Muscles, Nerves, etc. are grouped under the appropriate common headings. Boldface type indicates the more complete descriptions.

J

K

L

N

S